02
22

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The future of chassis validation

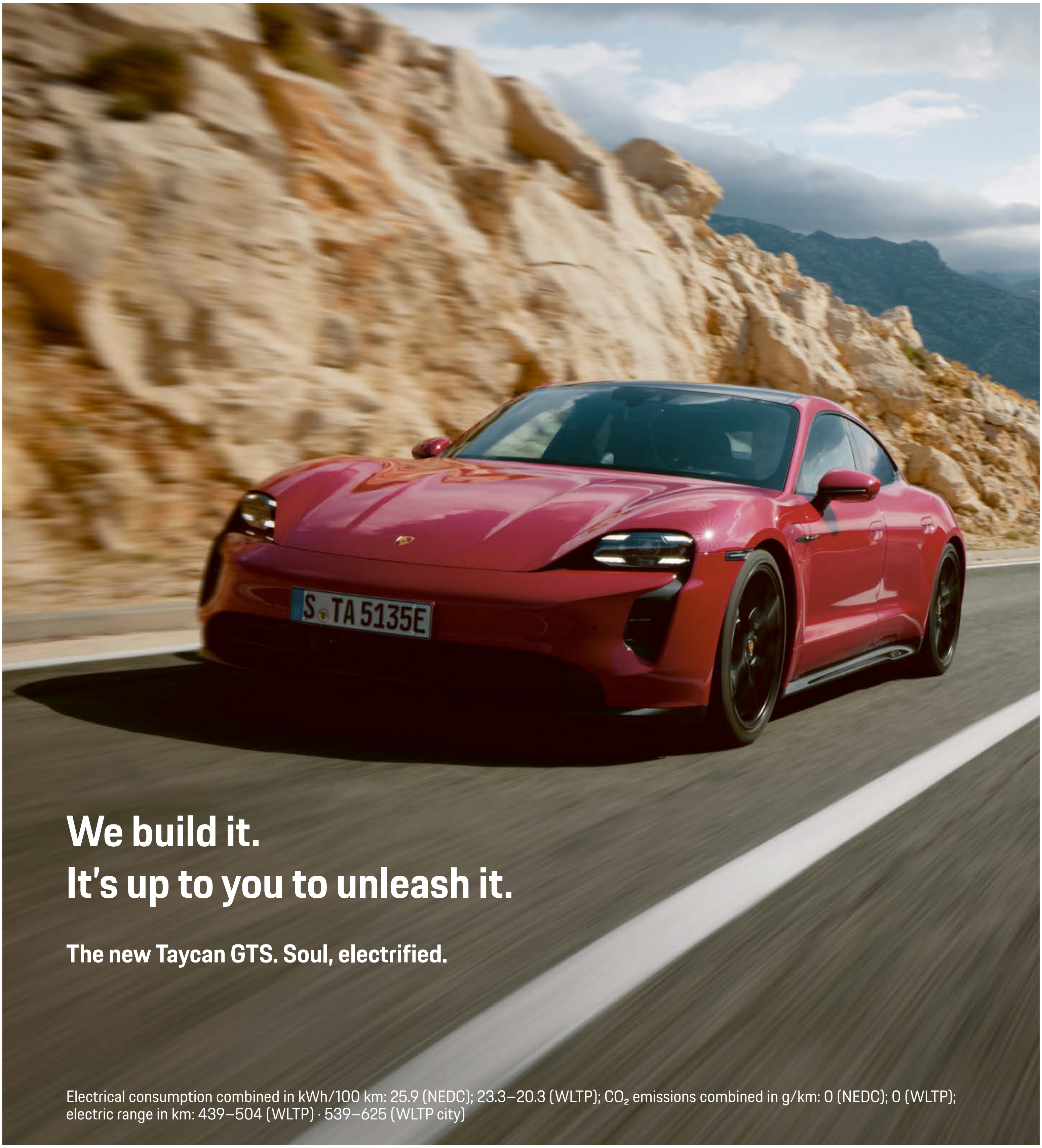
Developments in and for China

Sustainability at the Nardò Technical Center

Porsche Engineering Magazine

A NEW ERA

Engineering's journey into the future


S TA 5135E
We build it.
It's up to you to unleash it.
The new Taycan GTS. Soul, electrified.
Electrical consumption combined in kWh/100 km: 25.9 (NEDC); 23.3–20.3 (WLTP); CO_2 emissions combined in g/km: 0 (NEDC); 0 (WLTP); electric range in km: 439–504 (WLTP) · 539–625 (WLTP city)

Dr. Peter Schäfer
Managing Director of Porsche Engineering

Dear Reader,

As a doctoral student in the late 1980s, I was introduced to a new world of mechatronics and software. The new technologies, along with designing an HiL test bench for my dissertation, were extremely rewarding for me as a young mechanical engineer. The rapid developments in electronics were not just an important experience for me personally—they also brought about a major leap forward for the entire automotive industry.

Today we once again find ourselves on the cusp of a great leap driven by technologies such as the cloud, artificial intelligence and Big Data. To meet the moment, we must develop new capabilities and transform our processes. The cover story of this issue of the magazine highlights how we are adapting chassis development, to take one example, to meet the requirements of a new era. For measurement data analysis, too, we utilize the latest IT technologies to accelerate processes.

Alongside the technological leaps, China is also shaping the engineering of the future. With regard to digital innovations in particular, the country has built up an ecosystem of its own. Developments for China are ideally pursued in China itself; only there are the engineers close enough to the market and customers to develop 'China-specific functions'. We are very well positioned for this with our location in Shanghai.

Another trend is also shaping our work: Sustainability. In this issue, we report on how the Nardò Technical Center is doing its bit to contribute to sustainability, environmental protection and social responsibility.

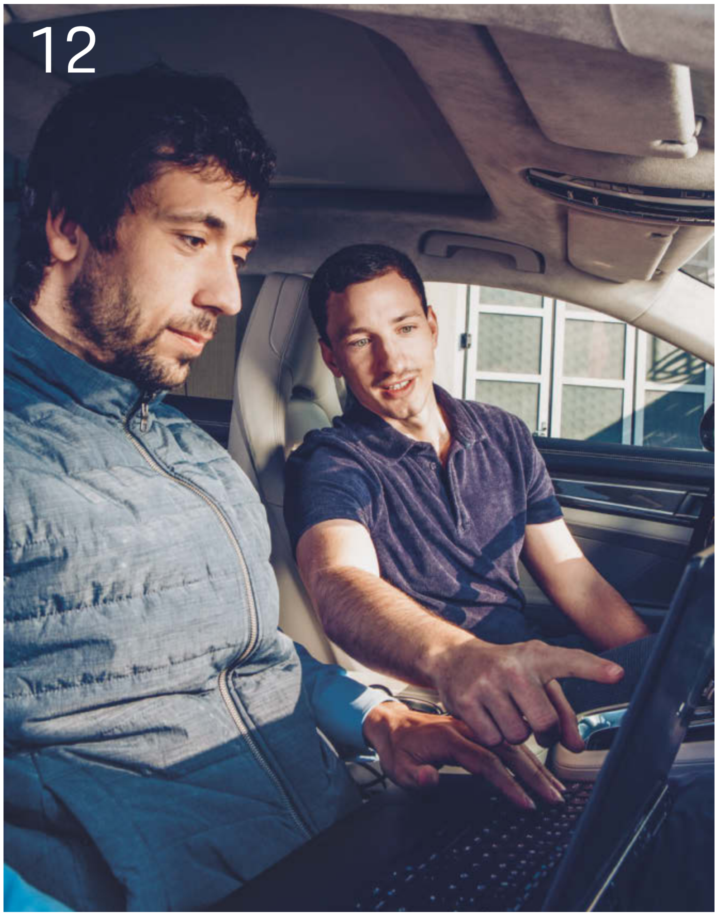
New technologies, climate change, industry-specific and geopolitical shifts: Major changes await us in the years to come. Despite the myriad uncertainties, as a technology partner for the development of the intelligent and connected vehicles of the future, we see great opportunities ahead—as long as we're well prepared, resolute in our approach, and ready to change course when needed. We need to establish a clever approach while maintaining operational flexibility. If we do so, this leap will bring rewards for us all.

Our magazine is changing as well. We've not only made a few changes to its appearance, but are now offering even more information about interesting topics related to technology and much more—with the same in-depth coverage as always, of course.

I hope you enjoy reading this issue of the magazine!

Peter Schäfer

→ **ABOUT PORSCHE ENGINEERING:** Porsche Engineering Group GmbH is an international technology partner to the automotive industry. The subsidiary of Dr. Ing. h.c. F. Porsche AG is developing the intelligent and connected vehicle for its customers—including functions and software. Some 1,500 engineers and software developers are dedicated to the latest technologies, for example in the fields of highly automated driving functions, e-mobility and high-voltage systems, connectivity, and artificial intelligence. They are carrying the tradition of Ferdinand Porsche's design office, founded in 1931, into the future and developing the digital vehicle technologies of tomorrow. In doing so, they combine in-depth vehicle expertise with digital and software expertise.



Intelligent technology: Fabian Pfitz (left) and Max Schäfer intend to use an automatic vehicle dynamics control system for chassis endurance testing.

Defying the wind: Vehicle manufacturers are continuously optimizing the aerodynamics of their models. E-mobility is helping them to do so.

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COVER STORY ENGINEERING'S JOURNEY INTO THE FUTURE

PERFORMANCE AND EXPERTISE

PORSCHE ENGINEERING DIGITAL

Focus on sustainability: The Nardò Technical Center is taking responsibility for the environment and the community.

Special challenge: Because of country-specific conditions, many vehicle functions have to be developed locally in China.

CONTRIBUTORS

Dan Matutina
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NEWS 02/2022

The Taycan Sport sedans

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As of 06/2022

Anniversary and upgrade to cell coverage in Nardò

NTC: 10 YEARS WITH PORSCHE AND LAUNCH OF ITS OWN 5G NETWORK

The Nardò Technical Center (NTC), owned by Porsche and operated by Porsche Engineering, is celebrating its tenth anniversary of the acquisition by the sports car manufacturer in 2012. Since then, it has been transformed from a proving ground with unique tracks and facilities into an integrated center for high-performance testing, validation and development of intelligent and connected vehicles. "Porsche's acquisition of the Nardò Technical Center in 2012 saw it gain an important asset for the entire Porsche Group," says Michael Steiner, Member of the Executive Board for Research and Development at Porsche AG and Chairman of the Shareholder's Committee of Porsche Engineering. Since 2012, new investments have been made in the modernization and technological advancement of the infrastructure in Nardò. High-power charging stations have been set up across the whole proving ground—thus further laying the ground for electric vehicles. In addition, the engineers in Nardò are integrated into the global innovation and development network of Porsche Engineering and enable a seamless transition between development, virtual simulation, and real testing.

The latest achievement at the NTC is a 5G mobile network of its own. The installation of eight antennas on the periphery of the high-speed circuit guarantee state-of-the-art 5G speeds as well as secure transmission of data between vehicles, infrastructure and digital devices. This will allow the NTC to broaden its services in the areas of networking, digitalization and next-generation testing. "The real-time capability enabled by 5G is an essential prerequisite for future testing of advanced autonomous driving functions," says NTC Managing Director Antonio Gratis. In a few years, 'Smart City Emulation' is expected to become part of the service package. This idea involves a city with movable buildings and traffic signs in which urban scenarios can be devised for testing advanced driver assistance systems.

The NTC in figures

The number of employees has increased by more than

50

percent over the past ten years. Today, there are more than 160.

The NTC covers an area of more than

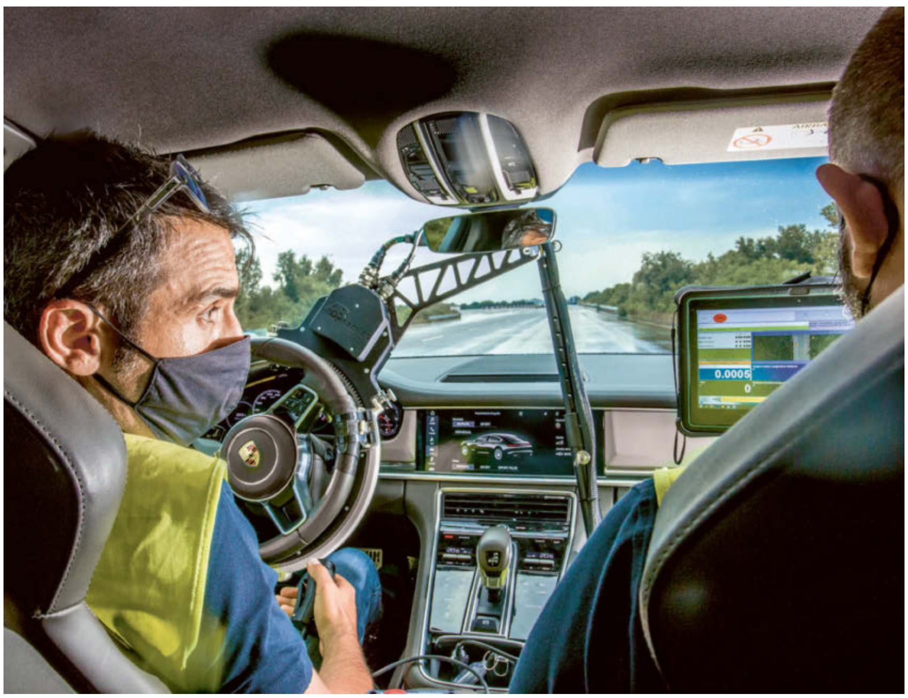
700

hectares.

More than

20

test tracks exist on the grounds.



Fully connected:
New tracks and additional infrastructure have been set up to test the intelligent and connected vehicle.

News from China

CHANGE OF MANAGEMENT AT PORSCHE ENGINEERING CHINA

Uwe Pichler-Necek will take over the position of Managing Director of Porsche Engineering China on July 1. He is succeeding Kurt Schwaiger, who has headed up the company's Chinese activities since 2015. "With his broad local management experience in new and traditional vehicle technologies, Uwe Pichler-Necek is ideally qualified for this challenging task," says Peter Schäfer, Managing Director of Porsche Engineering and Chairman of the Advisory Board of the Chinese subsidiary. Pichler-Necek was most recently responsible for development activities at FEV China as Executive Vice President for Engineering. Kurt Schwaiger is returning to Germany to retire after more than six years as Managing Director of Porsche Engineering in China. "He has successfully built up the Shanghai location, broadened its technological scope and expanded its reach," says Schäfer. Today, we have a first-class development team on site that knows the complex Chinese market in detail and develops China-specific solutions for Porsche and other OEMs."

Change in management: Uwe Pichler-Necek (large picture) will take over as the new Managing Director of Porsche Engineering China on July 1. He replaces Kurt Schwaiger, who is retiring.

“More than almost any other company, Porsche embodies the idea that dreams are achievable when you work at them consistently and meticulously enough.”

Sebastian Steudtner
Big wave surfer

The Taycan Sport sedans

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As of 06/2022

Big wave surfing

TAKING SURFING TO THE NEXT LEVEL

The reigning big wave surfing world champion Sebastian Steudtner and Porsche are entering into a long-term partnership. Steudtner is working with Porsche Engineering and others to elevate the sport of surfing to the next level. In collaboration with scientific institutes, the partners intend to transfer knowledge from automotive engineering to the development of more powerful surfboards. The latest simulation methods and wind tunnel validations, for example, will be used as a basis to optimize the behavior of the surfboard in the water and the aerodynamics of the board and surfer even further. “We are bringing together our experience in flow and structural optimization with the practical expertise of world-renowned surfer Sebastian Steudtner to create an optimized board for surfing particularly high waves,” says Marcus Schmelz, project manager at Porsche Engineering. Steudtner adds: “I am proud and delighted to have gained Porsche as a long-term partner. In addition to the technological expertise and the spirit of innovation that has established itself in the company, one thing in particular fascinates me: more than almost any other company, Porsche embodies the idea that dreams are achievable when you work at them consistently and meticulously enough.”

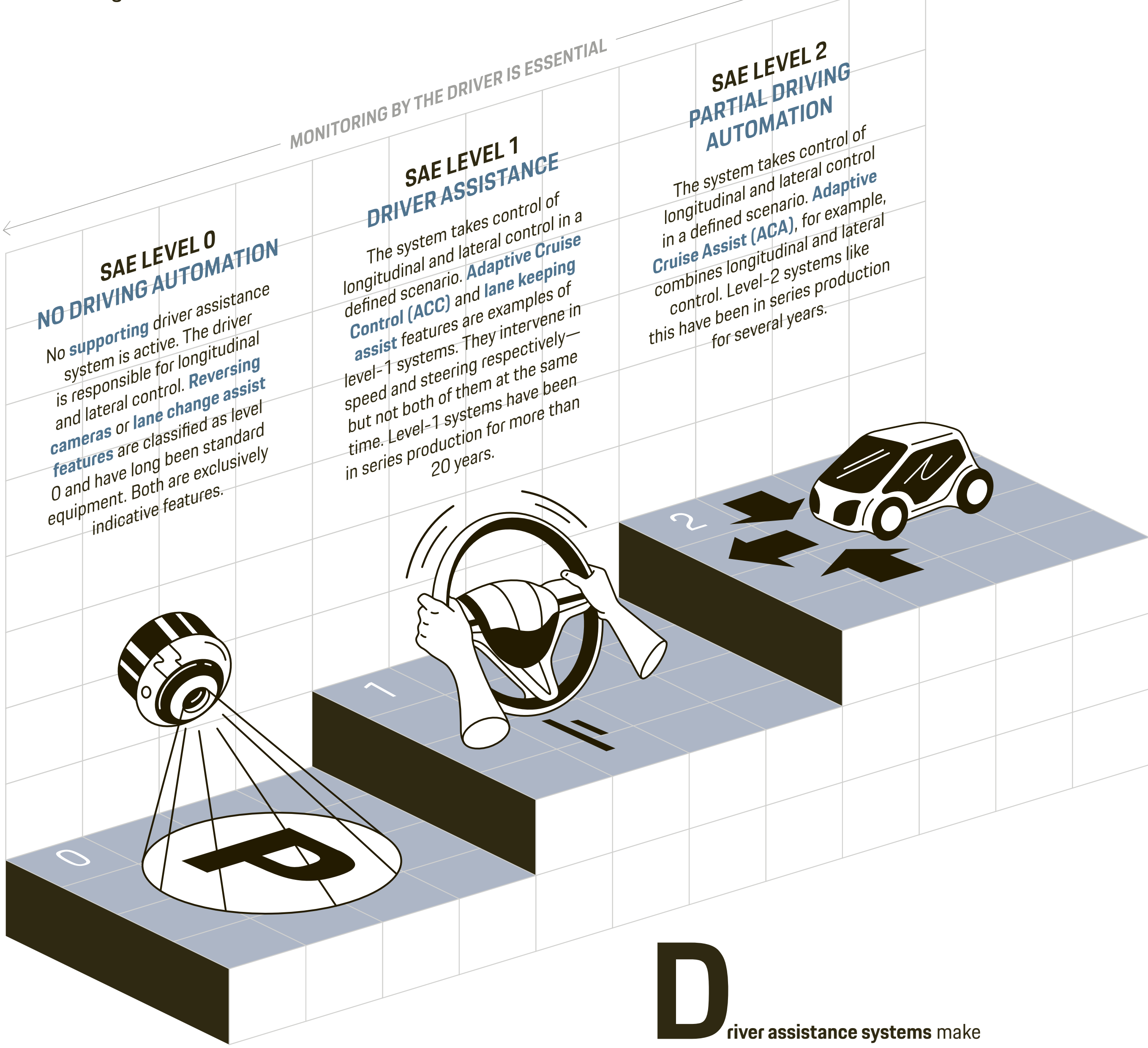
Porsche Engineering can look back on many years of experience in the development of high-performance sports equipment. The company developed a competition sled for luger Georg Hackl on which he was able to change the damping during the run and thereby achieve higher speeds in the corners. The result was a silver medal at the Winter Olympics in Salt Lake City in 2002.

TO THE POINT.

New technologies are driving development in the automotive industry. In this section, we get straight 'to the point' on the issues of the moment.

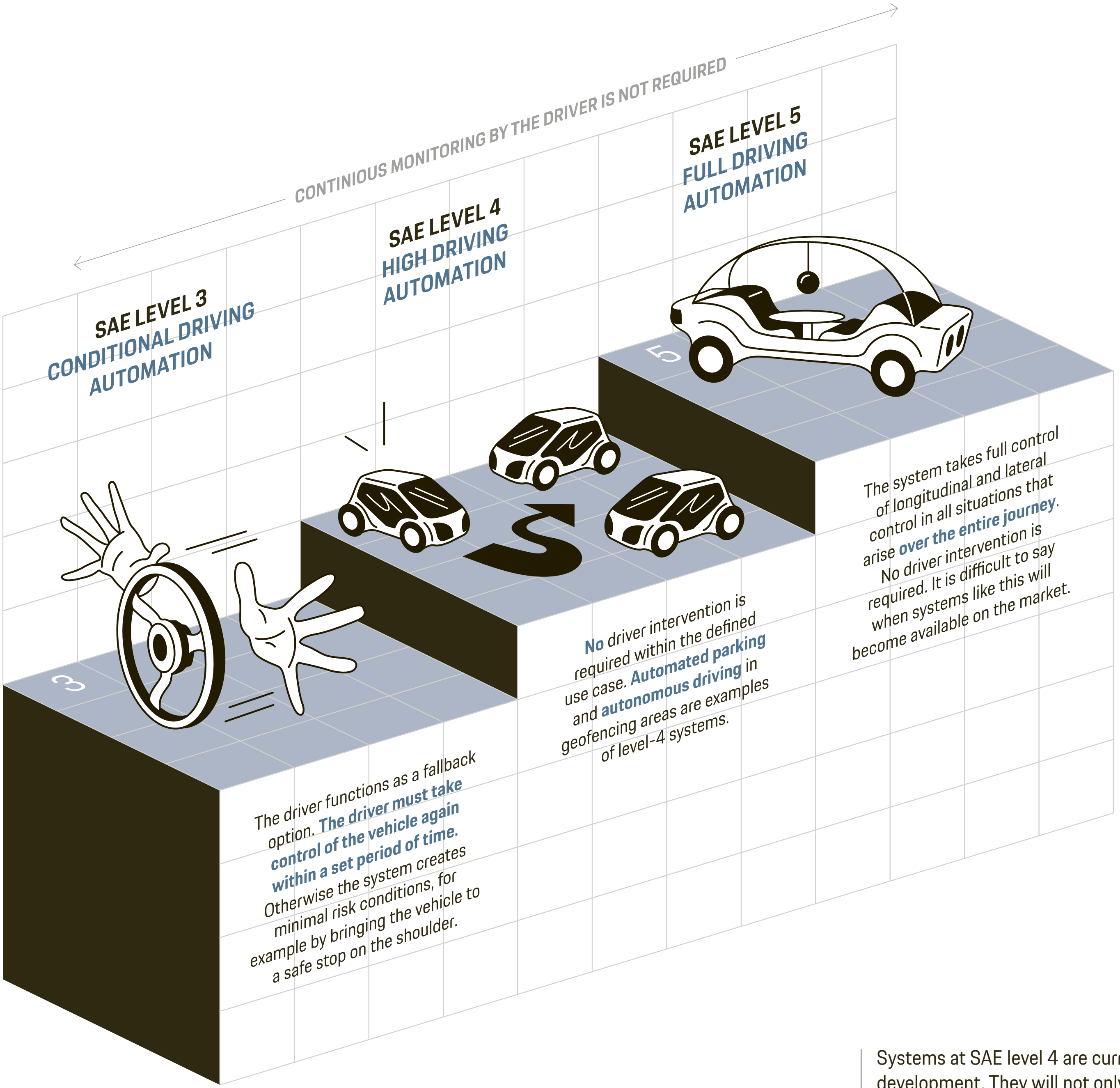
Hold the driver, please

The ongoing evolution of driver assistance systems is continuing apace and will soon open up new markets for autonomous transport solutions. We explain what all this has to do with the SAE levels of driving automation.



Driver assistance systems make traveling easier and development has progressed rapidly in recent years. Cruise control and lane keeping assistance systems are among the best-known examples. Over the next few years, new systems such as one for automatic parking in parking garages are likely to be added.

Text: Christian Buck
Illustration: Benedikt Rugar



The technology organization SAE has defined various levels ('SAE levels') to classify driver assistance systems according to their capabilities. SAE level 0 describes a car in which the driver is responsible for all aspects of driving and, at most, is supported by warnings that alert the driver. Intervention in longitudinal or lateral control by the technology starts at SAE level 1. Systems at SAE level 2 can intervene in both longitudinal and lateral control.

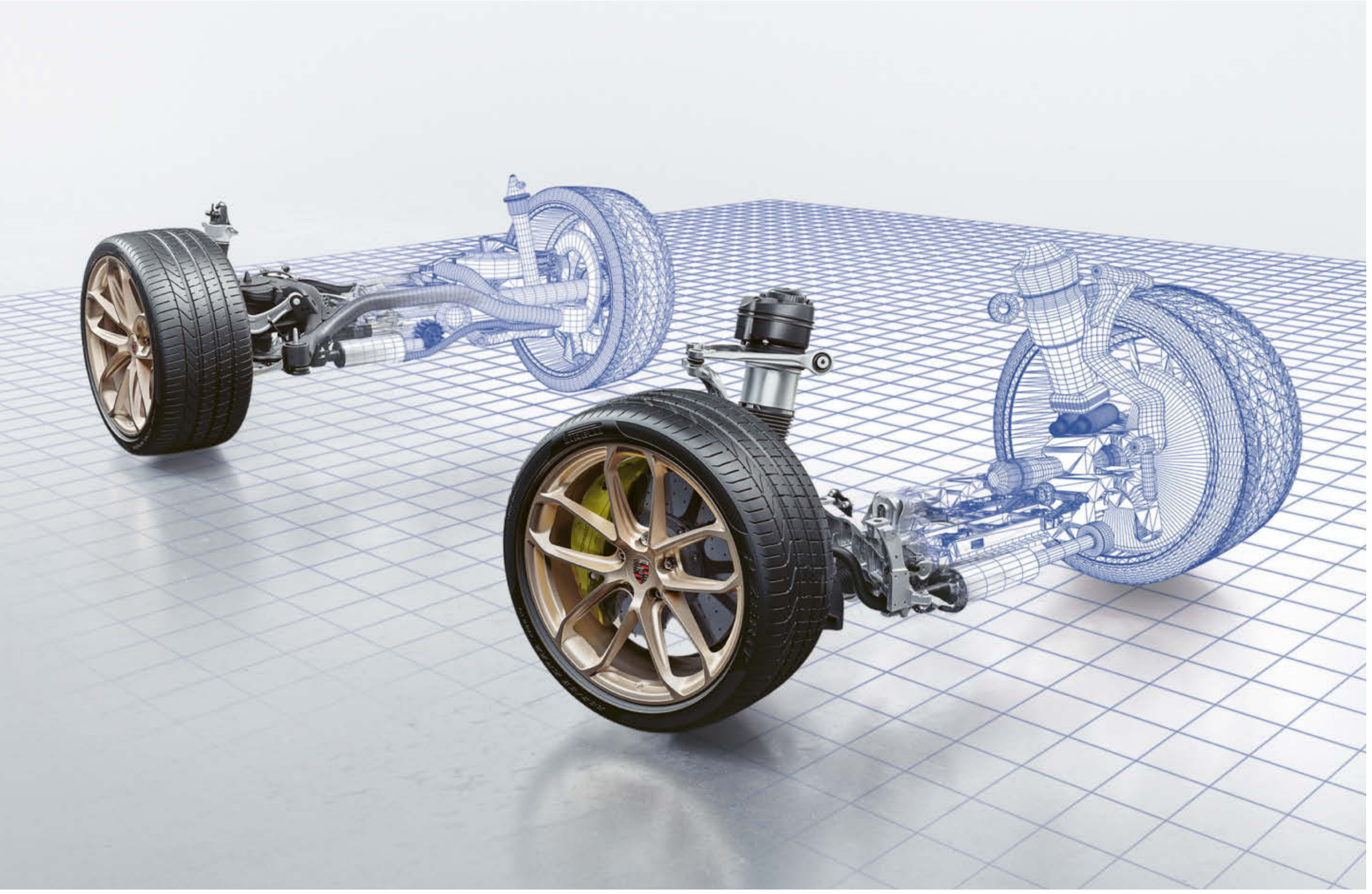
The progression from SAE level 2 to SAE level 3 marks an important turning point: While drivers at levels 0, 1 and 2 have to monitor the systems at all times, this is no longer necessary at levels 3, 4 and 5. As the levels progress, the systems are increasingly capable of taking the vehicle to its destination without human intervention.

In the context of driver assistance systems, a distinction is also made between 'automated' and 'autonomous'. When automated driving functions are used, the driver activates the system according to preference, and does not have to monitor it continuously. The driver is assisted and, in certain cases, prompted to take over all driving tasks within a limited time. This corresponds to SAE level 3. When autonomous, driverless driving systems are used, there is no need for a driver to monitor the system. Driving on a variety of routes is possible without driver intervention. This corresponds to SAE levels 4 and 5.

Systems at SAE level 4 are currently under development. They will not only simplify driving even further, but also open up new markets: At SAE level 4 and higher, innovative driverless services such as Mobility as a Service (MaaS) and Transport as a Service (TaaS) become possible. Autonomous vehicles will then be able to transport people and goods to their destinations. Robots or drones could complete the final-mile delivery of parcels, for example, to the front door or window.

This will require new apps and backend solutions in the cloud, however, as functions such as ordering or paying for services have to be processed by software, and fleets of intelligent and networked level-4 vehicles also have to be coordinated and directed to their customers. Porsche Engineering is working intensively on these issues and intends to offer its customers the development and validation of such systems in the future. — ●

Automation: Fabian Pfitz (left) and Max Schäfer use a model-based vehicle dynamics control system that follows a predefined trajectory.



Virtualization: Chassis development is increasingly shifting from real-life testing to the realm of digital data.

THE DIGITAL PATH TO THE PERFECT MIX

With more and more electronic control functions, new driver assistance systems and automated driving functions, along with continued advances in system connectivity, the work involved in calibration and validation continues to increase for the chassis as well. To be able to implement development projects with a high level of efficiency, Porsche Engineering is establishing new digital development methods.

Text: Richard Backhaus
Photos: Annette Cardinale

Teamwork: Tim Wright, Eva-Verena Ziegahn, Moritz Markofsky and Martin Reichenecker (from left to right) are using more and more advanced digital development methods.

Convenient and economical or agile and dynamic? This question doesn't even arise when designing today's chassis systems—current vehicles are expected to meet all of these requirements at once. Chassis developers therefore need to find the exact mix of settings to give the vehicle the required handling characteristics. Due to all the many different parameters and control variables, new vehicles sometimes have millions of test kilometers behind them before they reach series production.

Added to this are the ever-increasing number of electronic control functions, driver assistance systems and automated driving functions, as well as the ever-advancing connectivity between electronic systems in the vehicle. "They increase the effort involved in development even further, while at the same time there is less and less time available for calibration and validation," says Eva-Verena Ziegahn, Senior Manager Chassis Systems at Porsche Engineering. "Traditional work methods involve numerous development loops—and are increasingly reaching their practical limits in terms of both time and costs."

"There is less and less time available for calibration and validation."

Eva-Verena Ziegahn
Senior Manager
Chassis Systems
at Porsche Engineering

AUTOMATED TEST DRIVES

In order to continue to be able to implement the integration of new chassis functions with a high level of efficiency, Porsche Engineering is relying on advanced digital development methods. The first step involves automating the test drives using prototype vehicles on the test track. "In driving tests involving physical stress on the test drivers, a vehicle dynamics control system assumes control of the vehicle," explains Martin Reichenecker, Senior Manager Chassis Testing at Porsche Engineering. "To this end, we are working on a project to develop a model-based longitudinal and lateral dynamics control system for automated test drives."

To prepare for a series of tests, a driver drives the route first, recording vehicle data such as speed and acceleration along with GPS data. This reference trajectory then provides the path for the vehicle dynamics control system during subsequent test drives. "The system looks about a second into the future and uses the vehicle's current position, speed and orientation to predict how the steering, and the brake and gas pedals, need to be adjusted in order to remain on the specified trajectory," explains Fabian Pfitz, Development Engineer for Chassis Systems at Porsche Engineering. This is the key difference to conventional non-model-based driving dynamics control systems, which can only compensate for control errors and cannot calculate vehicle guidance predictively.

In the future, this should also make it possible to conduct demanding driving tests with high-level driving dynamics automatically. Mastering driving conditions like these is difficult, because there is very little reaction time for steering and braking commands. "We are currently optimizing the way the driving dynamics control system is programmed so that it can also perform these tasks. To do so, we use artificial intelligence methods to improve the predictive capability and with it the precision of the control system," says Pfitz.

The advantage of automated driving tests can be seen, for example, in endurance tests in which test drivers are continuously exposed to high physical stresses, for instance due to the specified driving profile on rough sections of road. "Work on model-based vehicle dynamics control systems for endurance tests has progressed to the point where it is likely to soon be able to be used for endurance testing in customer development projects," says Max Schäfer, a doctoral student at Porsche Engineering. In the future, the model-based vehicle dynamics control systems will be used, for example, on the test track at the Nardò Technical Center (NTC) to perform highly dynamic driving tests using automation.

"In driving tests involving physical stress on the test drivers, a vehicle dynamics control system assumes control of the vehicle."

Martin Reichenecker
Senior Manager Chassis Testing at Porsche Engineering

VIRTUAL COMPLETE VEHICLE IN THE SIMULATOR

Fundamental challenges faced in real-life driving tests —whether with test drivers or automated—include high costs, considerable demands on time and the general availability of test vehicles. In early phases of vehicle development in particular, there are often no or very few prototypes available. In a further digitalization step within chassis development, Porsche Engineering is therefore increasingly shifting vehicle tests from the road to test benches.

Individual assistance or driving dynamics control functions have been tested and calibrated on test benches for some time. However, isolated solutions like this do not factor in the interactions between the individual systems in the complete vehicle. "This can lead to mutual interference that only comes to light in the subsequent driving tests and can then only be rectified at great expense," explains Tim Wright, Development Engineer for Vehicle Dynamics Simulation at Porsche Engineering. "We have developed a test bench concept in which we integrate the functions and systems into a virtual complete vehicle and run them in a closed control loop. As in the real vehicle, the electronic control units communicate with each other by means of the data bus. This allows problems to be easily identified and remedied."

The special feature of Porsche Engineering's solution is the real-time rendering of actual road performance. For example, when the lane departure warning system intervenes in the steering during the test, the driver feels these forces directly on the steering wheel, as is the case in the vehicle. Another example is the effect of the stability program. In this case, the driver perceives dynamic changes by looking at the simulation screen. "This is what makes the test realistic, and it is the prerequisite for virtual calibration in which the functions are tailored to the driver," says Wright.

The test scenarios are either recorded in advance by a test vehicle equipped with a camera, or created on the computer. The virtual environment can be mapped out down to the last detail, so that the driver on the simulation test bench hardly notices any difference to reality. Since the virtual traffic situations can be configured to suit requirements, many different variants can be created, such as driving with and without oncoming traffic or driving during the day and at night. "The main advantage, however, is that we can generate potentially dangerous driving conditions aided by the computer, and reproduce them in the driving simulator without any safety risk for the test driver, such as evasive maneuvers on wet roads at very high vehicle speeds," says Wright.

"The system looks about a second into the future."

Fabian Pfitz
Development Engineer for Chassis Systems at Porsche Engineering

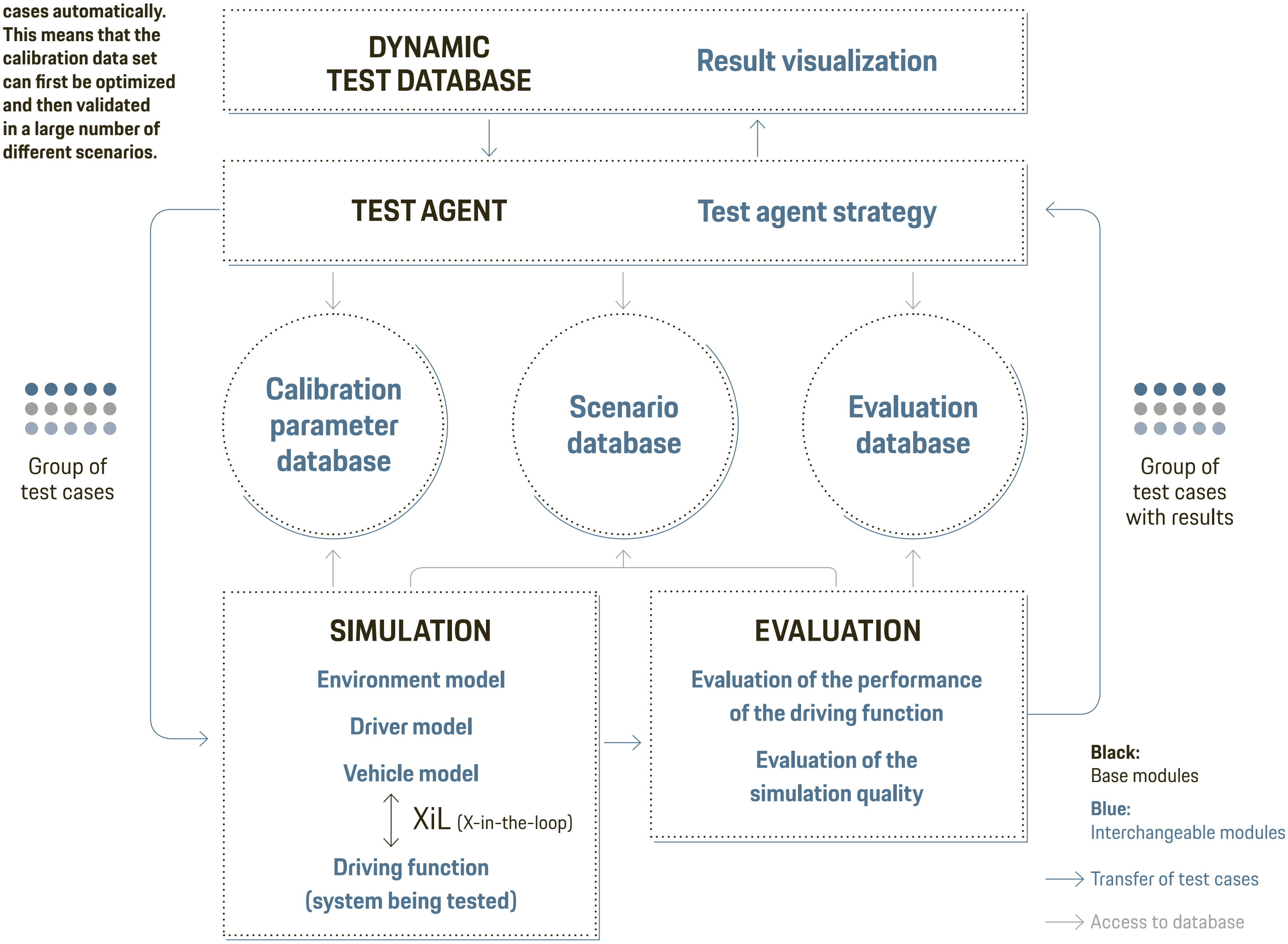
In the future, Porsche Engineering will use tests on the simulation test bench to evaluate the functional safety of electronic systems and functions in the vehicle. During these tests, faults are deliberately imposed on the vehicle's electronics. The driver on the test bench then evaluates the impact on the vehicle functions. The categorization is based on an internationally standardized classification according to Automotive Safety Integrity Levels (ASIL). "The more difficult the situation is to control, the more serious the consequences of the fault are and the more

"The main advantage is that we can generate potentially dangerous driving conditions aided by the computer, and reproduce them in the driving simulator without any safety risk."

Tim Wright
Development Engineer for Vehicle Dynamics Simulation at Porsche Engineering

INTEGRATION ARCHITECTURE
FOR VIRTUAL CALIBRATION AND VALIDATION OF DRIVER ASSISTANCE SYSTEMS AND HIGHLY AUTOMATED DRIVING FUNCTIONS

The integration architecture generates test cases automatically. This means that the calibration data set can first be optimized and then validated in a large number of different scenarios.



frequently it occurs, the higher the safety requirements become," says Wright. "Currently, we are successfully using a simulation test bench for complete vehicle calibration and validation at the Shanghai location," explains Wright. Further facilities are planned for the development departments in Mönsheim, in Cluj-Napoca, Romania, and in Prague.

VIRTUAL CALIBRATION AND VALIDATION

Porsche Engineering is taking a step toward a fully digital development chain by using a methodology in which calibration and validation are carried out by virtual means only. "In order to apply and validate highly automated driving functions holistically, all traffic scenarios that occur while driving would theoretically have to be recreated in countless variants and be tested with different calibration parameters. In the future, this will only be able to be done at a feasible cost if conventional methods are enhanced by approaches such as virtual integration," says Moritz Markofsky, a doctoral student at Porsche Engineering.

In a development project, he is therefore working on the design of a modular, virtual integration architecture for driver assistance systems and highly automated driving functions. Its basic framework consists of base modules—for test case creation, simulation and evaluation, for example—that are used independently of the driving function that will be tested. Depending on the development project, this basic framework is broadening using interchangeable modules to adapt the architecture to the system being tested. This gives the new methodology a high degree of flexibility to cover the breadth of developments on the one hand, while also catering to the requirements of the future on the other—before they can even be determined in any detail.

Another special feature of the new methodology is the high degree of automation when creating test cases and conducting them as virtual driving tests. The integration architecture generates test cases automatically based on parameters for the scenario, calibration and evaluation. In an Adaptive Cruise Control (ACC) system, for example, comfort and safety are evaluated in different scenarios that involve a vehicle cutting in. For example, the calibration data set can be optimized first and then validated in a large number of different scenarios—all fully automatically.

One challenge in developing the modular concept was defining and designing the interfaces between the software modules. "Our solution gives us all sorts of freedom when it comes to the selection and definition of modules. At Porsche Engineering, many of our colleagues are working on innovative methods for developing and validating highly automated driving functions. The modular approach allows us to integrate all of these efforts easily and efficiently," says Markofsky. One example is the central Porsche Engineering Virtual ADAS Testing Center (PEVATeC), which provides the simulation environment, virtual test scenarios, and route models.

Currently, the performance of the new development methodology is being intensively tested as part of a proof-of-concept study. But the developers also have their sights set on further optimization. In the future, the system could use artificial intelligence to systematically apply highly automated driving functions or search for critical test cases. "The use of artificial intelligence offers the opportunity to derive relevant test cases from the calibration and scenario parameters in an efficient way," says Markofsky.

"In the future, the calibration and validation of highly automated driving functions will only be able to be done at a feasible cost if conventional methods are enhanced by approaches such as virtual integration."

Moritz Markofsky
Doctoral student at Porsche Engineering

SUMMARY

Porsche Engineering is taking new approaches to chassis development to keep the development workload manageable in the future as well. Model-based control systems enable automated test runs, and simulations are increasingly replacing real driving tests. The virtual calibration and validation of driver assistance systems complements conventional integration methods and reduces the development workload.

Data evaluation and conversion

Once the right measurement has been found, its content must be examined and processed in detail for model optimization. When there are 100,000 signals, this is often a challenge.

Data storage

The measurement file prepared for model optimization is saved in a format compatible with the simulation tool, and is now ready for model optimization.

Data processing

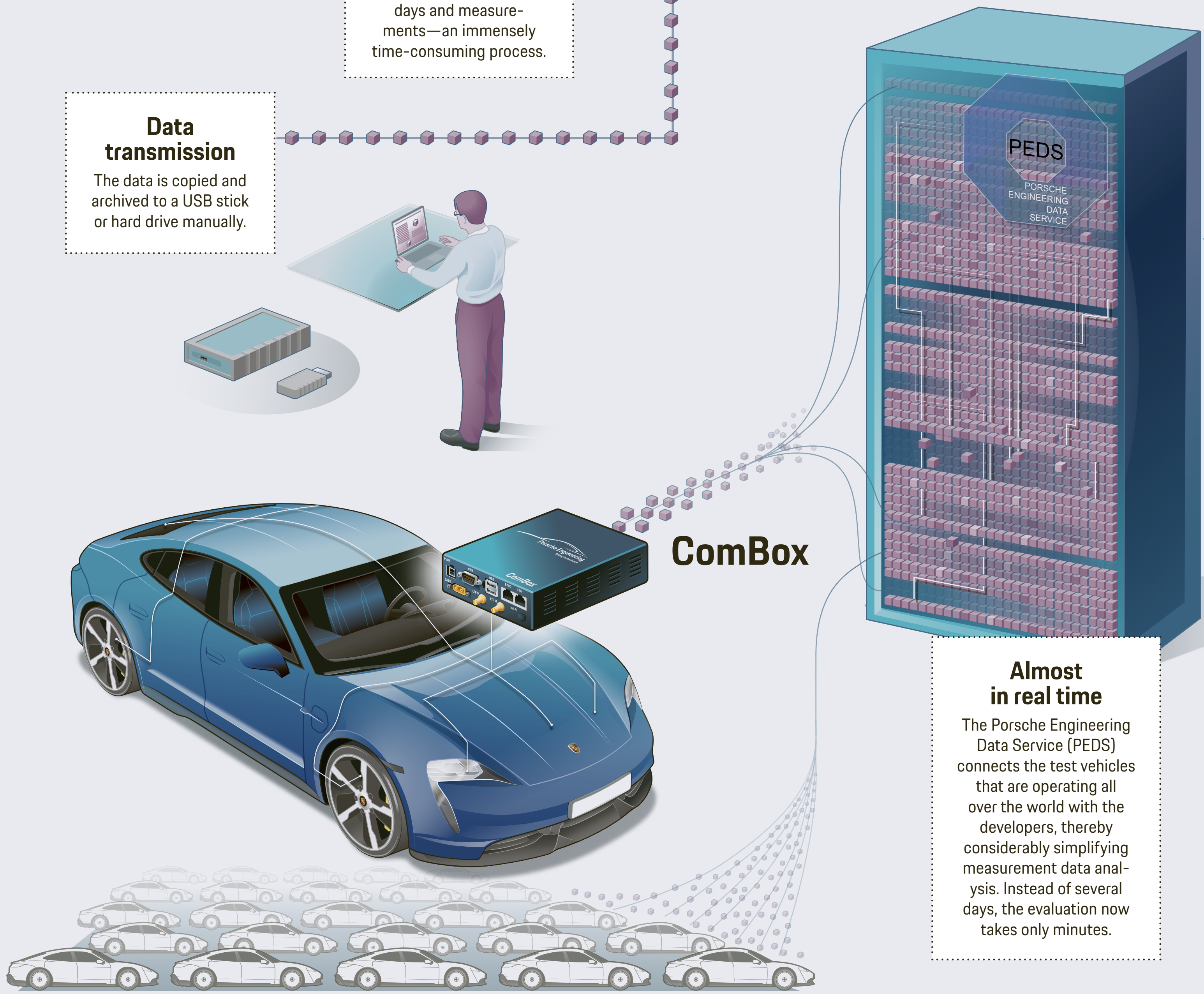
Partially automated and numerous iteration loops are used to optimize a large number of physical parameters. Even a small change in one parameter can affect all the others.

Measured data selection

The right data must be selected from a large number of measurement days and measurements—an immensely time-consuming process.

Data transmission

The data is copied and archived to a USB stick or hard drive manually.



Almost in real time

The Porsche Engineering Data Service (PEDS) connects the test vehicles that are operating all over the world with the developers, thereby considerably simplifying measurement data analysis. Instead of several days, the evaluation now takes only minutes.

The Taycan Sport sedans

Consumption data in the NEDC:
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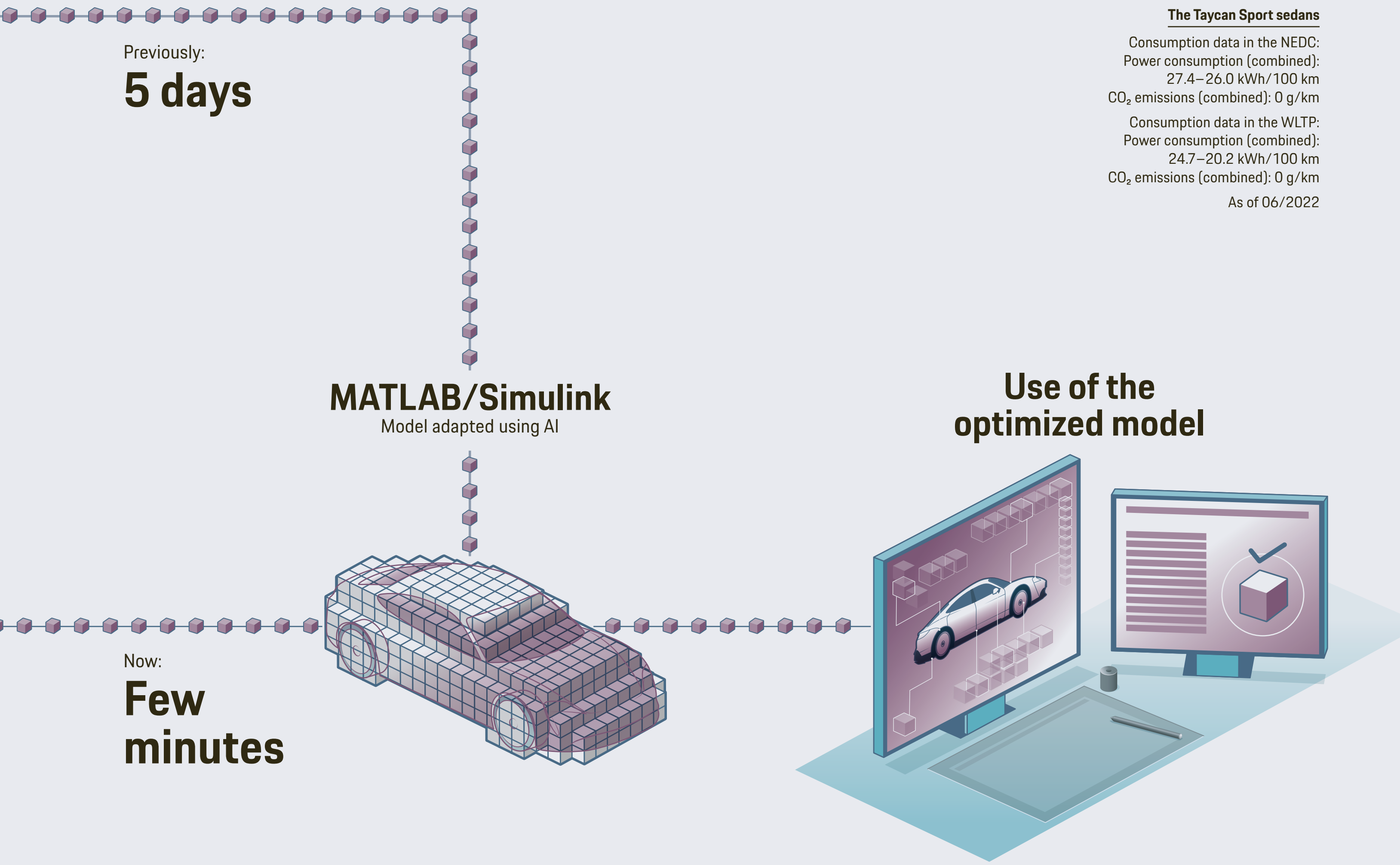

Out of the ComBox

The Porsche Engineering Data Service (PEDS) facilitates wireless provision of measurement data after a test drive, and allows it to be evaluated quickly. Analyses can be available just minutes after the drive—or indeed during it. And the share of measurement data evaluated live can be increased before any archiving occurs.

Text: Constantin Gillies
Illustrations: Andrew Timmins

The tradition at Porsche is for a new vehicle model to be tested not only by the development engineers, but also by many staff in the testing and quality departments. The testers can now provide their feedback even faster: Anyone who finds an optimization opportunity turns off the vehicle, taps their smartphone and records a voice memo. For example: “Seat heating in level 1 too warm.” A few moments later, the department responsible receives an e-mail with the comment, which has been automatically converted into text. The engineers can also access all the measurement data from the vehicle, as a mobile network is used to send it to a central server. This means that the feedback can be checked quickly and, if necessary, a software customization can be developed for the vehicle.

This live optimization is made possible by the Porsche Engineering Data Service (PEDS): This system connects the international test vehicles with the developers and thereby makes measurement data analysis considerably easier. To use the service, all that needs to be done in the test vehicle is to connect what is known as a ComBox (see the box on page 22) in addition to the measurement system or data logger, which can be done in just a few simple steps. The device forwards the data from the integrated measuring devices to a PEDS server using a mobile network (LTE/5G) or WiFi. There, the data is processed and automatically evaluated. “This is a plug-and-play digitization process,” explains Björn Pehnert, Manager Digitization and initiator of the PEDS project at Porsche Engineering.

DISPENSING WITH MANUAL PROCESSES

The ComBox eliminates the need for many manual processes during the testing phase, for example during transfer of the measured values that were collected: A data logger in the vehicle, for example, records a significant volume of data each and every minute, capturing camera images, pressure and temperature data as needed in addition to the communication between the control units. Previously, removable media were used to transfer the measurement data to stationary PCs (readout stations) automatically. “Data loggers provide raw data that can only be evaluated after conversion,” explains Stephan Gehrmann, Manager Automation Measurement Technology department at Porsche AG. In the final step, the developers selected the relevant data and analyzed it interactively. If testing was performed at a different location and a business trip was necessary, several days could pass before the first findings from a test drive were available.

↓

Roughly

150

test vehicles are already connected to the PEDS servers by a ComBox. By the end of 2022, that number is expected to have doubled.

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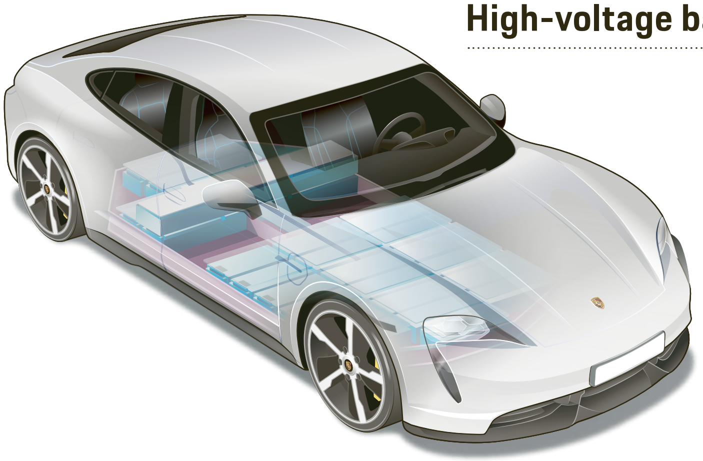
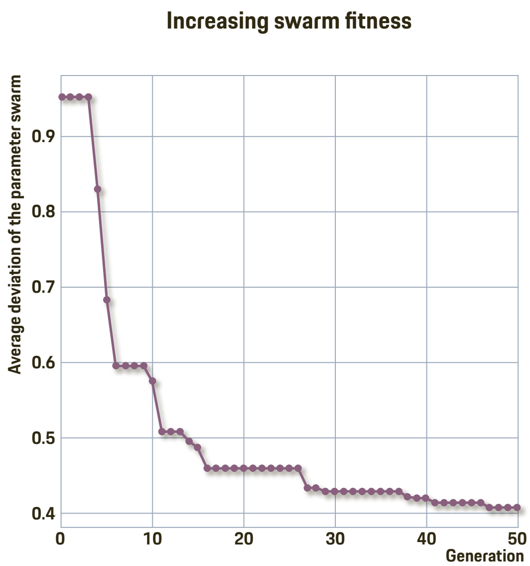
As of 06/2022

High-voltage battery optimized in seconds with PEDS



PEDS can be used to create and compare digital twins quickly. In this example, the model of a high-voltage battery was optimized on the basis of 37 parameters. Data from the test vehicle flowed into the mathematical simulation while the vehicle was still on the road, thereby continuously improving it. The diagram on the right shows how quickly the error rate decreases. The diagrams on the page opposite show a number of original parameters and the optimized ones. The fact that processes like this are now possible almost ‘live’ thanks to PEDS is a real breakthrough.



“We didn’t reinvent anything, but rather integrated the existing know-how into a digital process.”

Björn Pehnert
Manager Digitization at Porsche Engineering

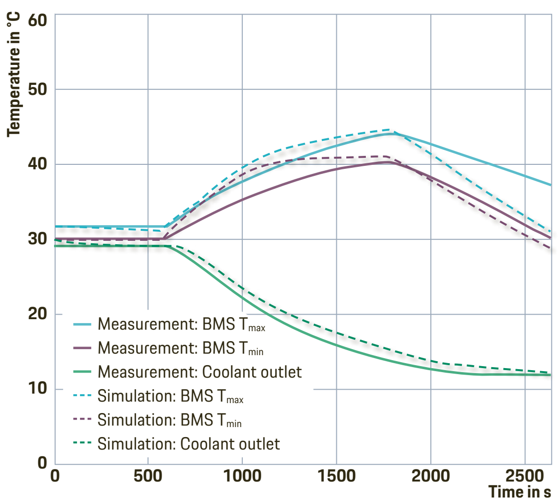
20

is the approximate number of seconds it takes to transfer small volumes of data from the ComBox to the server.

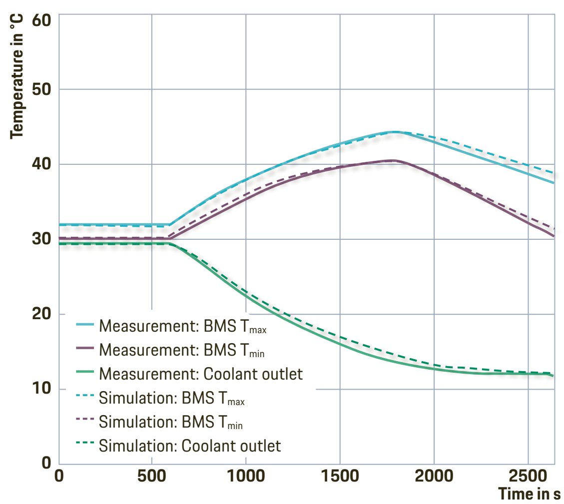
Thanks to PEDS, data transfer and analysis now takes only minutes. One factor that saves time is the fact that the ComBox transmits measurement data so swiftly: The delay only totals 15 to 20 seconds for small volumes of data. Another factor is that all subsequent work steps now proceed automatically: PEDS converts the raw data and filters out the data that is relevant to the department. For example, the interior climate plays no role in chassis optimization. Finally, automatic analysis is carried out. For this process, the tools already in use at the specialist departments are integrated into the overall solution. “We didn’t reinvent anything, but rather integrated the existing know-how into a digital process,” explains Pehnert. “For example, PEDS can automatically feed data into the existing simulation of a component.”

Automation not only ensures shorter response times, but also helps significantly build up the database at the same time, which is evaluated promptly and automatically. Around 150 test vehicles are already connected to the server by means of a ComBox, and by the end of the year around the same number again is expected to have been added. This means faster availability of data for developers—and this at all locations, since all the international measurement data flows into a common pool, for example into Porsche’s in-house measurement data and testing platform ‘Cluu’. Whereas each specialist department previously

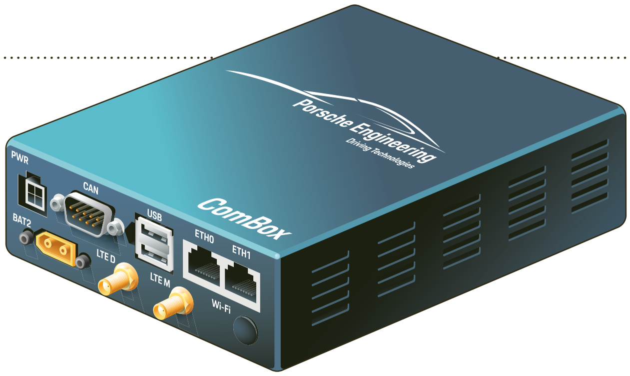
Start parameters without PEDS AI optimization



Parameters after PEDS AI optimization



AT A GLANCE: TECHNICAL DATA OF THE COMBOX



The ComBox uses a mobile network to transmit the measurement data from a test vehicle to a PEDS server. The device is quick and easy to install in the vehicle, requiring only two connectors for power and data. “The box is simple, inexpensive and can dock into a wide range of measurement systems,” explains Björn Pehnert. The unobtrusive black box is about the size of an internet router and is connected to the data loggers on board by ethernet. A cellular modem or WiFi module uploads the data. In addition to the technology, Porsche Engineering also makes the mobile data transmission available worldwide, allowing the ComBox to be used without any problems during test drives outside Germany as well.

The box is supplemented by the ‘Trigger App’ on a smartphone in the vehicle. It can be used to trigger a measurement data transmission by simply touching the display, with a voice memo able to be recorded at the same time. The memo is automatically converted into text and forwarded to the relevant specialist department. In addition, the Trigger App can display information when a sensor in the vehicle has exceeded a limit value.

The bidirectional connection of the ComBox is used to update the configuration of the measurement systems over-the-air (OTA). “This is important in development operations,” Stephan Gehrmann emphasizes. “Until now, new configurations could only be transferred to the data loggers using removable media. Thanks to the OTA updates, the configurations are now always up-to-date—this has resulted in a leap in data quality.”

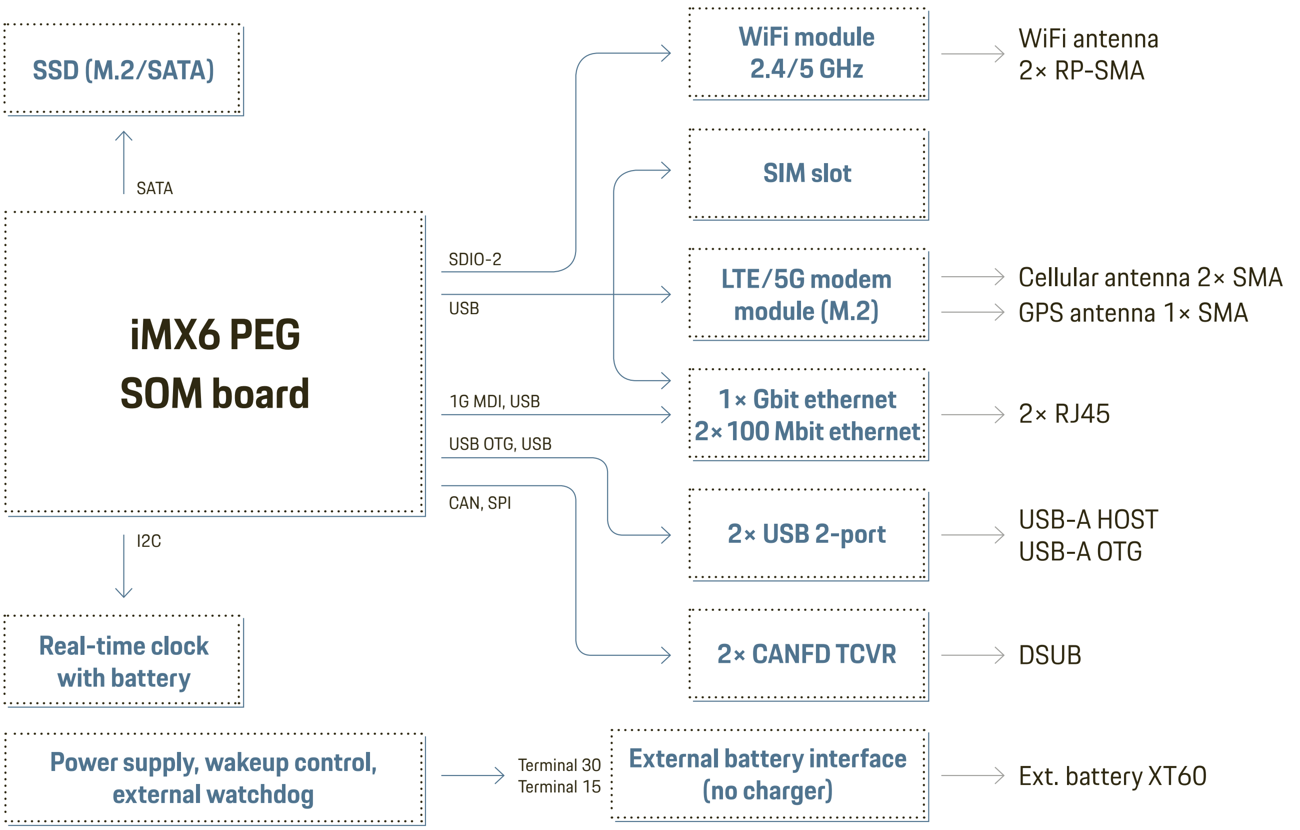
Dimensions:

W
108 Millimeter

H
40 Millimeter

D
141 Millimeter

Block diagram of the ComBox



“Thanks to the OTA updates, the configurations of the measurement technology systems are now always up-to-date—this has resulted in a leap in data quality.”

Stephan Gehrmann
Manager Measurement Technology Automation department at Porsche AG

had only a handful of test vehicles at its disposal, other teams can now systematically supply the engineers with relevant data. To do this, the developers only need to have the authorizations necessary to use the data. An engineer in Weissach, for example, is actively alerted to an anomaly in measurement data collected by colleagues in Anting, China. This makes it possible to test and implement new functions much faster.

PEDS also makes it easier to create and compare digital twins, these being simulations of components. The developers at Porsche Engineering have created one such model of the high-voltage battery of an electric vehicle, for example. Its thermal response is exactly the same as a real power storage unit. This model with 37 parameters was optimized with the help of PEDS: Data from the test vehicle flowed into the mathematical simulation while the vehicle was still on the road, allowing ongoing improvements to be made. The result: The error value—i.e. the deviation between the real and simulated behavior of the battery—was halved. “The fact that processes like this are now possible ‘live’ is a real breakthrough,” says Pehnert.

DIGITAL OPTIMIZATION LOOPS

Because the digital twin of a component operates so realistically, it can effectively supplement real experiments and in some cases actually replace them altogether. It can be used, for example, to optimize the design and arrangement of the cooling plates in the high-voltage battery. To actually build all the options in this case would be impossible. “Digitally, however, the optimization loops can be run in seconds,” Pehnert explains. “Even the response of the battery in a prototype that doesn’t even exist yet can be simulated and perfected.”

To optimize driving comfort, test vehicles are often equipped with accelerometers. In some cases, they are secured in places that can only be reached when the vehicle is disassembled. During the test drive, sensors may occasionally shift slightly. This is a tricky situation, because the sensor concerned usually doesn’t fail completely, but continues to provide data. While the data stills seems plausible, it’s no longer reliable. “Even an experienced engineer often fails to recognize this,” explains PEDS developer Jonas Brandstetter from Porsche Engineering. In the past, errors like this were only identified weeks after the drive, which meant that testing had to be repeated—requiring enormous efforts, particularly when testing in remote areas.

PEDS ensures this can no longer happen: The system checks the measurement data for anomalies while the vehicle is still on the road. This is done by using an AI algorithm on the server, which has learned from a few data sets what a correct sensor signal looks like, enabling it to detect erroneous measurements. If the algorithm fails, the test engineer receives a push message on the smartphone and can cancel the test run.

PEDS has already been successfully tested in 15 use cases across all disciplines—from chassis optimization to global defect analysis at quality stations. But the system’s potential is far from exhausted. “We are now looking at scaling it up,” reports Pehnert. Setting up a network integrating the Volkswagen Group’s measurement data management system is therefore currently on the agenda. PEDS is already connected to the ‘Cluu’ measurement data and test platform. Access to the measurement data from Porsche’s data loggers is already available here. There are also plans to further simplify the wireless transmission of measurement data. The idea is to use WiFi to transmit the data from the measuring devices to the Speech2Text smartphone in the vehicle, and from there to PEDS. In some calibration, this could obviate the need for a ComBox in the test vehicle.

SUMMARY

The Porsche Engineering Data Service (PEDS) connects the test vehicles that are operating all over the world with the developers. Using the ComBox specially developed for this purpose, data can be sent to the PEDS servers almost in real time, where it is processed and automatically evaluated. This reduces the amount of work and shortens development times considerably.

Mastering the Nord-schleife with hydrogen

In a study, Porsche Engineering has examined the potential of hydrogen combustion engines. The result is a high-performance powertrain with emissions at the same level as ambient air.

Text: Richard Backhaus

Different powertrain solutions, including hybrid systems, electric drives and efficient combustion engines are currently all being developed in parallel for use in future vehicles. Hydrogen represents a potential alternative to conventional fuels or synthetic fuels (e-fuels) for use in combustion engines This was examined as part of a study on the subject by Porsche Engineering.

HIGH-PERFORMANCE HYDROGEN ENGINE FOR PASSENGER CARS

Work is currently proceeding on hydrogen engines worldwide, however this is predominantly being done for commercial vehicles with a relatively low specific output of around 50 kW per liter of displacement. "For the passenger car sector, this is insufficient. We have therefore developed a hydrogen combustion engine that aims to match the power and torque of current high-performance gasoline engines as a concept study. At the same time, we also had the objective of achieving low fuel consumption and keeping emissions at the same level as ambient air," says Vincenzo Bevilacqua, Senior Expert Engine Simulation at Porsche Engineering. "The starting point for our study was an existing 4.4-liter eight-cylinder gasoline engine—or rather, its digital data set, since we conducted the entire study virtually using engine performance simulations."

"We conducted the entire study virtually using engine performance simulation."

Vincenzo Bevilacqua
Senior Expert
Engine Simulation
at Porsche Engineering

Modifications to the engine model included a higher compression ratio and combustion adapted to hydrogen, but most importantly, a new turbo-charging system. "For clean combustion of hydrogen, the turbochargers have to, on the one hand, provide around twice as much air mass as they do in gasoline engines. On the other hand, however, the lower exhaust gas temperatures result in a lack of energy for their propulsion on the exhaust side," explains Bevilacqua. This discrepancy cannot be resolved with conventional turbochargers. Porsche Engineering has therefore examined four alternative, particularly powerful turbocharging concepts, some of which come from the motorsport context.

All systems consist of several electrically assisted turbochargers, some of them combined with additional control valves in the air system or electrically driven compressors. "In the benchmark studies, each turbocharging system showed specific advantages and disadvantages. The choice of the right concept is therefore highly dependent on the requirements profile of the hydrogen engine in question," says Bevilacqua. For the engine study concerned, the development team selected a turbocharging system with back-to-back compressors. The special feature of this design is the coaxial arrangement of two compressor stages, which are driven by the turbine or the supporting electric motor using a common shaft. The process air flows through the first compressor, is intercooled in the intercooler and then recompressed in the second stage.

With an output of around 440 kW, the hydrogen engine is on par with the original gasoline unit. In order to better assess the performance of the powertrain, Porsche Engineering tested it in a luxury-segment reference vehicle with a relatively high total weight of 2,650 kg on the Nürburgring Nordschleife—albeit entirely virtually: The drive was carried out using what is known as a digital twin, i.e. a computer-based representation of the real vehicle. With a lap time of 8 minutes and 20 seconds, the vehicle demonstrated

1 8:20:00

H

Hydrogen

2.2 0.09

3 6.94

Li

Lithium

4

B

Be

"As it turned out, nitrogen oxide emissions are close to zero over the entire engine map."

Matthias Böger
Specialist Engineer
Engine Simulation
at Porsche Engineering

high potential with regard to driving dynamics.
Due to its chemical composition, neither hydrocarbons nor carbon monoxide are released during hydrogen combustion, and nor do particulates play a role either, of course. In terms of optimizing emissions by the hydrogen engine, the experts at Porsche Engineering therefore concentrated on nitrogen oxides. In extensive optimization rounds, they adapted the engine's operating strategy for the cleanest possible combustion. Their approach was to keep the level of raw emissions low by means of extremely lean and therefore colder combustion, making it possible to dispense with an exhaust aftertreatment system.

EMISSIONS AT THE SAME LEVEL AS AMBIENT AIR

"As it turned out, the nitrogen oxide emissions are well below the limits set by the Euro 7 standard currently under discussion and are close to zero over the entire engine map," reports Matthias Böger, Specialist Engineer Engine Simulation at Porsche Engineering. In order to better contextualize the results of the emissions tests, he draws a comparison with the Air Quality Index. It is used by government authorities and other institutions as a benchmark for assessing the level of air pollution. In general, a concentration of up to around 40 micrograms of nitrogen oxide per cubic meter is equated with good air quality. "The hydrogen engine's emissions are below this limit. Operating it therefore has no significant impact on the environment," says Böger.

In addition to its barely measurable emissions, the hydrogen engine offers high efficiency in the WLTP measurement cycle as well as in customer-relevant cycles thanks to its lean combustion. "We have thereby fulfilled our self-imposed project goal: The development of a clean, economical and sporty hydrogen engine, across the board," Bevilacqua concludes. The cost of a hydrogen powertrain in series production could be comparable to that of a gasoline engine. Although the turbocharger system and a number of

AT A GLANCE: SIMULATED LAP ON THE NORDSCHLEIFE

Maximum speed

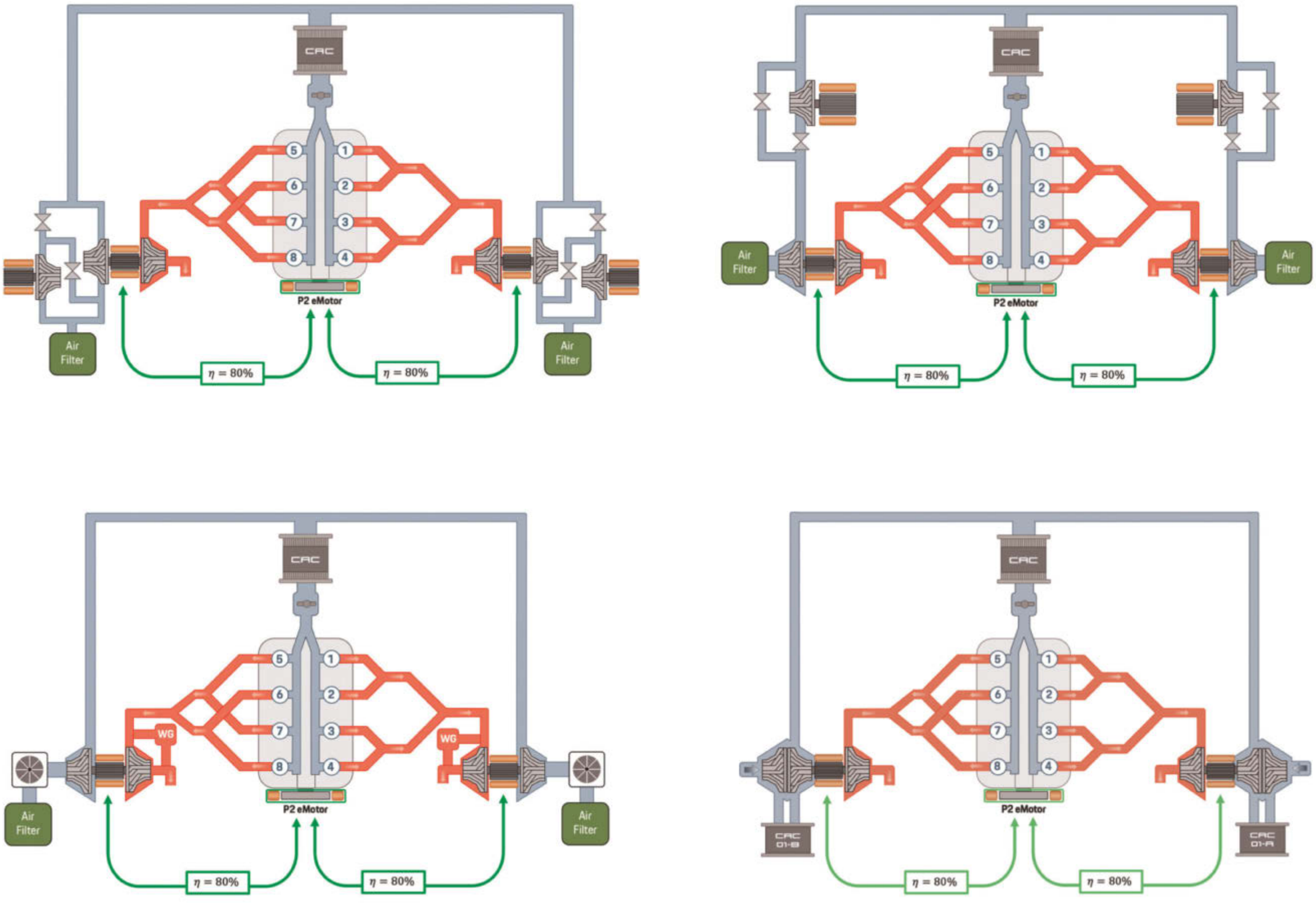
261
km/h

Time

8:20:00
Minutes

Simulated engine power

440
kW



Comparison of turbocharging systems: Parallel turbocharging system consisting of e-turbo and e-compressor technology with control valves for transient operation (top left); two-stage compression consisting of e-turbo and e-compressor technology with bypass to decouple the compressor stage (top right); mono-e turbocharger with inlet guide vanes between air filter and compressor inlet (bottom left) and mono-e turbocharger with back-to-back compressor and charge air intercooling (bottom right, selected concept).

mechanical components of the hydrogen engine are more complex and therefore more expensive, there is no need for the exhaust gas aftertreatment required for the gasoline engine under Euro 7.

CONSUMPTION ADVANTAGES OF UP TO FIVE PERCENT

The Porsche Engineering team was able to carry out all tests virtually and therefore very efficiently. The established simulation process provided the basis for this, along with the company's extensive experience in modeling and calculation. "It took us only six months from the initial idea to the completion of the study," says Bevilacqua. "That included fundamental work such as creating new simulation models that take into account the different chemical and physical properties of hydrogen compared to gasoline."

The hydrogen engine is unlikely to enter production in its current form, but that wasn't the goal of the project anyway. Instead, the focus was on examining the technical potential of the alternative drive technology and expanding the capabilities of existing engineering tools. "The study allowed us to gain valuable insights with regard to the development of high-performance hydrogen engines and add models and methods specifically for hydrogen to our virtual simulation methodology," explains Bevilacqua. "With this know-how, we are ready to efficiently handle future customer projects."

Headwind: Vehicle aerodynamics are optimized in the Porsche wind tunnel.

Winds of change

Manufacturers have been optimizing the aerodynamics of their vehicles for decades. With the transition to e-mobility, the latest models are making huge progress in Cd values. And the potential has yet to be exhausted: Active aerodynamic measures and new development methods promise even more improvements in the future.

Text: Christian Buck

“At roughly 80 km/h or more, aerodynamic drag becomes more important than the rolling resistance of the tires.”

Marcel Straub
Lead Engineer Aerodynamics and Thermal Management at Porsche Engineering

Forty years ago, many car drivers learned a new term: Cd value. When the new Audi 100 was launched in 1982, the manufacturer presented it as ‘the most streamlined production sedan in the world’. Its Cd value of 0.30, impressive by the standards of the time, was proof positive. The fact that the aerodynamic drag of vehicles had suddenly become a selling point was due to the oil crises of 1973 and 1979, which had occurred just a few years prior. Fuel prices had risen sharply since then, and the efficiency of vehicles was increasingly becoming a focus of interest.

This also increased the importance of aerodynamics. Aerodynamic drag plays an important role in fuel consumption, especially at higher speeds (see the box on page 32). “At roughly 80 km/h or more, it becomes more important than the rolling resistance of the tires,” explains Marcel Straub, Lead Engineer Aerodynamics and Thermal Management at Porsche Engineering. “And because it increases quadratically with speed, aerodynamics is quite decisive for fuel consumption, particularly when driving on the highway.”

A vehicle’s aerodynamic drag is determined by the product of its frontal area and Cd value. The latter indicates how streamlined a geometric shape is. There’s a simple rule of thumb: the smaller, the better. Drops of water come pretty close to the ideal because they are round at the front and have a long taper at the back. Their Cd value is a mere 0.05 (see the text on page 34). The problem, however, is that it is difficult to fit the powertrain, passengers and the payload into a drop-shaped vehicle.

Since the 1980s, the typical wedge shape with a rounded front and angular rear has come to prevail. Its main purpose is to minimize the wake behind the vehicle. Sharp edges allow the flow to separate in the manner intended and reduce negative pressure, which in turn reduces drag. Cd values were getting better all the time: The Opel Calibra came in at 0.26 in 1990, and ten years later the Audi A2 boasted a value of 0.25. “Those were real leaps ahead in aerodynamics,” recalls Prof. Andreas Wagner, Chair of Automotive Engineering at the University of Stuttgart.

The next leap is currently underway, driven by the transition to electromobility. “Electric powertrains have much higher efficiency than internal combustion engines, so other energy consumption factors become much more significant,” explains Dr. Thomas Wiegand, Manager Aerodynamics - Research & Development at Porsche AG at Porsche AG.
“In the WLTP driving cycle, aerodynamics account for 30 to 40 percent of the losses in electric cars, as opposed to less than ten percent in a vehicle with a diesel or gasoline engine. And because the average speed in realistic cycles is even higher than in the WLTP, this figure is likely to be even higher than 50 percent when electric vehicles are driven in real-world situations.”

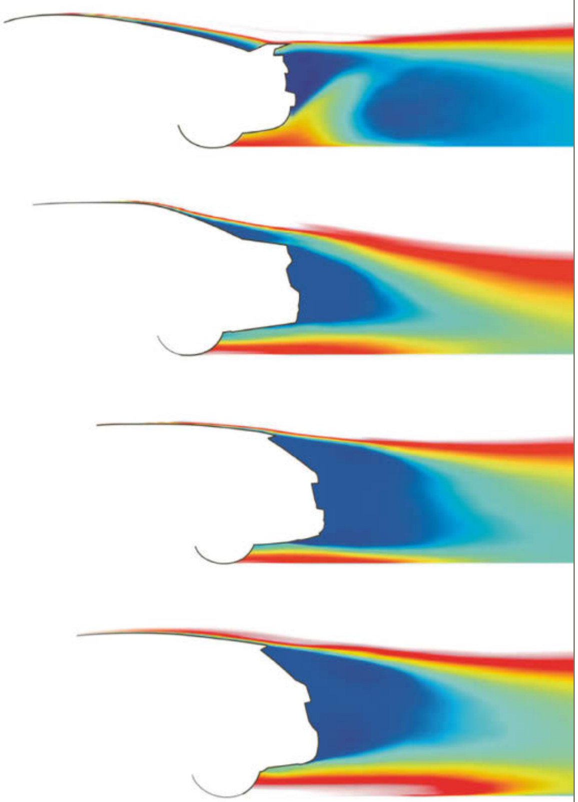
Manufacturers are, accordingly, placing great emphasis on optimizing the aerodynamics of their e-vehicles. The new drive technology is helping them to do so: Vehicles with combustion engines have a center tunnel in the underbody and an exhaust system that has to be cooled by ambient air. This irregular surface generates turbulence and increases driving resistance. In electric cars, on the other hand, the battery is found between the front and rear axles. Its underside is completely smooth, which promotes good aerodynamics.

ACTIVE AERODYNAMICS

Another advantage of e-mobility is that the motors generate less heat, which means that less energy has to be dissipated using the radiator. As a result, less or even no airflow is needed through the engine compartment, in turn reducing the aerodynamic drag of e-vehicles. In many e-vehicles, cooling air shutters for individual activation in the air intakes ensure that only the volume of air actually needed is directed over the radiators and brake discs. Because the technology actively intervenes according to the driving situation, experts refer to measures like these as ‘active aerodynamics’.

This also includes retractable spoilers and air-spring suspension chassis that lower the car at high speeds. “To implement these measures, at Porsche Engineering we build up on our expertise in function and software development,” says Straub. “This allows us to bring the active measures on the functional side safely to production readiness.” Modern e-vehicles make use of

Final test: Despite ever-improving simulations, testing in the wind tunnel remains the benchmark for every aerodynamics engineer. But computers are steadily catching up.



Influence of the basic vehicle shape: The size of the wake (in blue) is a major factor in a vehicle's Cd value. From the top: Sports car, sedan, station wagon and SUV.

"CFD simulations have become enormously important in the last 20 years."

Prof. Andreas Wagner
Holder of the Automotive Engineering Chair at the University of Stuttgart.

DEFYING THE WIND:
MILESTONES IN AERODYNAMICS DEVELOPMENT

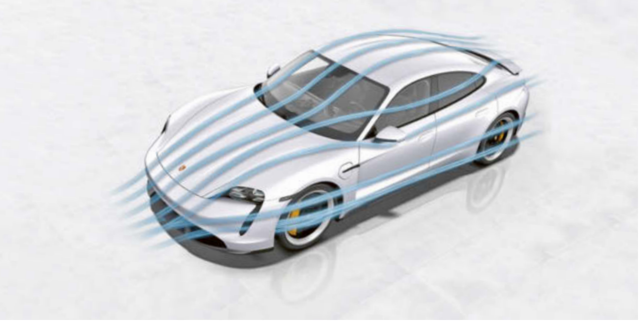
Drag is comprised of two components: **Frictional resistance** is caused by air molecules flowing over the surface of the vehicle. It only makes a minor contribution to the driving resistance. **Pressure resistance** is the dominant component: It arises from air accumulating at the front, which leads to overpressure, and a wake effect at the rear of the vehicle, which creates negative pressure. Both generate forces that slow down the vehicle and that the engine or motor must overcome. The greater they are, the higher the fuel or energy consumption and the smaller the vehicle's range.

Audi 100 *1982*

With a **Cd value of 0.30,** the Audi 100 caused a sensation 40 years ago. At the time, the oil crisis was feeding demand for more efficient vehicles.

VW XL1 *2014*

The one-liter car with two seats was very aerodynamic, with a **Cd value of 0.16**. Instead of exterior mirrors, it had cameras.



Porsche Taycan *2019*

Porsche's first all-electric sports car has a **Cd value of 0.22.** As an electric vehicle, it has a very smooth underbody.

PAC-Car II *2005*

The cigar-shaped single-seater had a **Cd value of 0.075**. The vehicle was of little practical use, however, with a top speed of 32 km/h.

The Taycan models

Consumption data in the NEDC:
Power consumption (combined): 27.4–25.4 kWh/100 km
CO_2 emissions (combined): 0 g/km

Consumption data in the WLTP:
Power consumption (combined): 26.4–19.6 kWh/100 km
CO_2 emissions (combined): 0 g/km

As of 06/2022

many of these technical capabilities: With Cd values of 0.22 and 0.20, the Porsche Taycan and Mercedes EQS respectively are miles ahead in terms of aerodynamics.

Active aerodynamics measures could play an even greater role in the future and significantly change the appearance of vehicles while driving. Mercedes-Benz, for example, has presented the Vision EQXX concept car with a Cd value of 0.17. One of the visible changes while driving is the diffuser on the lower edge of the rear: It automatically extends rearward by 20 centimeters at speeds above 60 km/h. Together with the sharp separation edge on the unusually long rear end, it ensures minimal drag. "With the EQXX, the focus was on energy efficiency," says Dr. Stefan Kröber, aerodynamics engineer at Mercedes-Benz and lecturer at the Karlsruhe Institute of Technology. "Optimized aerodynamics are an important element of that. The EQXX is expected to consume less than 10 kWh per 100 km, while the current EQS still comes in at 15 kWh or more." Expert Straub can also imagine that cars will change shape while driving in the future: "The rear end could, for example, become more angular at high speeds to form sharper separation edges. New shape-memory materials could provide the basis for this. They change their geometry according to temperature or applied voltage."

> **“AI algorithms could generate new data from a stock of existing data through interpolation and extrapolation.”**
>
> **Dr. Thomas Wiegand**
> Manager Aerodynamics - Research & Development at Porsche AG

At the University of Stuttgart, researchers are pursuing an entirely novel approach: “We are examining whether it is possible to reduce the Cd value at certain points in the car body by systematically introducing vibrations,” Wagner explains. “If you introduce a defined pulse into the flow around the car using speakers, its separation behavior can be influenced.” In the case of an SUV, he says, it was possible to reduce the Cd value by seven percent using this method. “But that still has some way to go before series production,” Wagner said. “We have to make sure, for example, that passengers don’t hear any buzzing or humming.”

BETTER AND BETTER SIMULATIONS

Engineers and designers assess how much their ideas affect the aerodynamics of new vehicles in the wind tunnel and by using CFD simulations (computational fluid dynamics). “CFD simulations have become enormously important in the last 20 years,” Wagner says. “People have better understood the mathematical methods, developed more accurate tools, and also increased the processing power of the computers.”

Today, however, computer simulations still encounter limitations. For example, it is currently only possible to calculate the effects of the rotating tires to a limited extent. Nor can their deformation under the weight of the vehicle be simulated with sufficient accuracy today. In the future, this should become possible, as should computer-aided optimization of the vehicle geometry. “Numerous parameters play a role here, such as the progression of the side profile, the A-pillar, the rear lid height and the diffuser angle,” Wagner explains. “This results in so many possible combinations that a human being can no longer keep track of them.” Intelligent algorithms, on the other hand, could move through the mass of variants and specifically find those combinations that promise a low Cd value. It would then also be possible to keep one parameter—such as the height of the rear lid—constant for design reasons and, taking this boundary condition into account, run through the remaining geometric variants.

In the future, artificial intelligence (AI) is expected to contribute to more efficient processes. “At the end of development, we are obliged to specify individual consumption or range values for each vehicle variant, in which weight and rolling resistance play a role in addition to the aerodynamics,” says Wiegand. “We therefore have to generate large volumes of data for the aerodynamics component.” At the same time, a large number of measurements from the wind tunnel and simulation results are already available from the previous development phases. This data will be better structured in the future, and be analyzed using modern methods. “AI algorithms could generate new data from a stock of existing data through interpolation and extrapolation. This would allow us to plan specific experiments and reduce their number. And we would no longer need to measure all variants for classification.”

REAL-TIME OPTIMIZATION WITH AI

Porsche Engineering is also working on using AI methods. The developers’ goal is to predict the effects of changes to the vehicle geometry in real time. While a time-consuming CFD simulation is still required for each variant today, in the future a neural network will calculate the influence on the Cd value much faster. “You change a shape with the mouse and immediately see what that means for the aerodynamics,” says Straub. “We have already used this AI-based method for the wing profile of a Porsche GT3.” Development of the new approach is continuing in collaboration with the AI experts at Porsche Engineering and the method development team at Porsche AG in Weissach.

Even so, there’s no reason to expect that all aerodynamically optimized vehicles will look the same in the future. “A good Cd value can be achieved in different ways,” says Wagner. “If you want to optimize the rear end, for example, you can change the rear lid height and the diffuser in the underbody. You then have to work with the design team to arrive at an ideal solution that fits the brand. This allows comparable aerodynamics to be achieved with different shapes.” Straub also downplays the notion that there will be a uniform design across the board in the future: “There will be no risk of mistaking one car for another—even for the best vehicles in terms of aerodynamics.” — ●

SUMMARY

With the transition to e-mobility, vehicle aerodynamics are currently taking a big leap forward. In the future, active measures such as modifiable shapes in the rear or vibrations that are introduced systematically will increasingly come into play. Great progress is also being made in simulations and test optimization using artificial intelligence.

ANY QUESTIONS?

Some questions just have to be asked. We have the answers—delivered with an amusing twist. This time:

What would an aerodynamically optimal car look like?

Text: Christian Buck
Illustration: Julien Pacaud

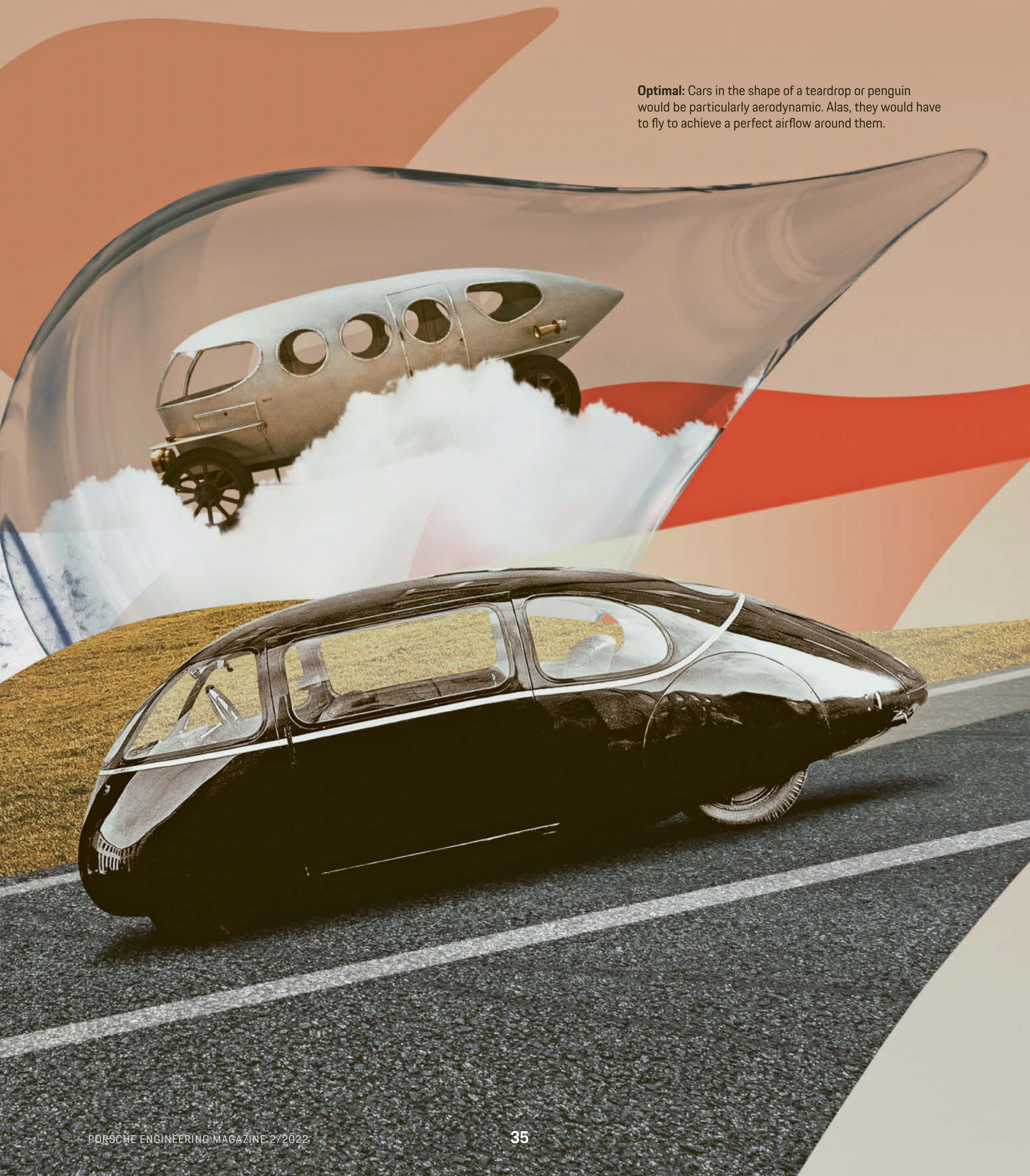
Saving energy and increasing range by using the most streamlined shape possible is the objective of every aerodynamics expert. "If vehicles were designed solely with this aspect in mind, they would probably have the shape of a teardrop," says Marcel Straub, Lead Engineer Aerodynamics and Thermal Management at Porsche Engineering. "That's because it has a shape that air can flow around with particularly low resistance—round at the front and tapered at the rear, so there's no 'wake' and no drag against the direction of travel." Of course, this can also be expressed in numbers: A teardrop has a Cd value of 0.05. This value, however, is impossible to achieve in the real-life implementation of a vehicle.

The reason: Although the drop shape would be close to ideal from the perspective of aerodynamics, it would obviously present major challenges in terms of housing the engine, passengers and luggage compartment. Wheels are also a major challenge from an aerodynamics development viewpoint. They cause air turbulence, and energy-sapping airflows occur in their wheel arches. An air cushion or magnetic levitation technology might solve the problem in this case.

Another issue is the vehicle's proximity to the ground, which prevents a perfectly symmetrical flow around the teardrop. A few centimeters above the road surface, it's effectively impossible. Fixing this would require 'driving' or flying at a height of several meters. We might well soon be seeing teardrop-shaped robotaxis that soar through the air with streamlined motions—sporting wings and a propeller at the pointy end. Practical implementation has proved elusive so far, however.

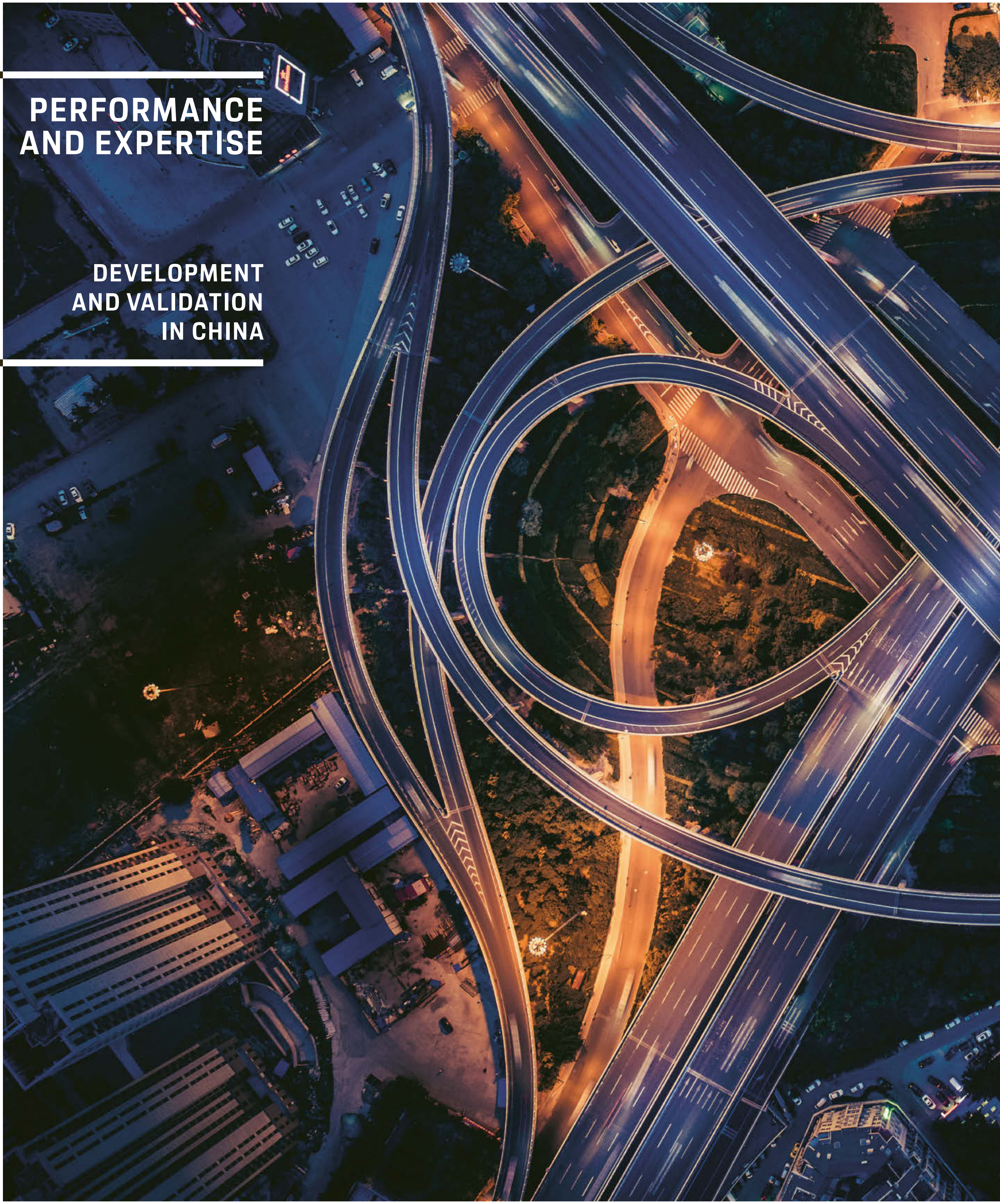
By the way: There is a form that occurs in nature that is even more streamlined than the teardrop: the penguin! Tilted horizontally, and with a Cd value *of* 0.03, the penguin would make for an aerodynamically optimized car paired with an unmistakable shape. In this case too, the ground-proximate driving position, the wheels and the requirements with regard to installation space would foil any attempt at turning this into reality. It is, in fact, no coincidence—and aesthetically speaking, that might just be for the best—that teardrop cars such as Alfa Romeo's '40-60 HP Aerodinamica' from 1914 or the 'Schlörwagen' of 1939 failed to make the grade.

Optimal: Cars in the shape of a teardrop or penguin would be particularly aerodynamic. Alas, they would have to fly to achieve a perfect airflow around them.



PERFORMANCE AND EXPERTISE

DEVELOPMENT AND VALIDATION IN CHINA



Challenge for technology: Driving in China is different to driving in Europe or the US. Development methods and vehicle systems must take this into account.

立足中国市场 服务中国市场*

*** In China, for China**

The Chinese automotive market forms a stark contrast to the European market – in terms of its legal framework, traffic management, customer requirements and its digital ecosystems with providers such as Baidu, Alibaba and Tencent. To cater to this market, Porsche Engineering is continuously expanding its local presence: Around 130 employees develop, test, and validate China-specific functions for the intelligent and connected vehicle. When it comes to connectivity, infotainment, and assistance systems in particular, localization is essential.

Text: Constantin Gillies

"The intelligent and connected vehicle is at the heart of Porsche Engineering's developments in China."

Uwe Pichler-Necek
Managing Director
of Porsche Engineering China

A **glance at the skyline** is enough to tell the casual observer that driving in China is a different experience. The cities are crisscrossed by multi-level elevated roads of a type that simply doesn't exist in Europe. They make very specific demands of navigation devices because the technology must identify which of the up to three levels the vehicle is traveling on. Stop signs in China sometimes lack the word 'STOP', which is something that image recognition programs first must learn. Many drivers also use the digital services from technology giants such as Baidu, Alibaba and Tencent, which are hardly known in Europe, while on the move.

As these examples show, vehicles must be adapted to the special characteristics of the Chinese market or be developed specifically for them. That's what Porsche Engineering has been working on for its Chinese customers for more than 30 years – as it continues to expand its local presence. This year alone, the number of employees at the Anting Development Center near Shanghai is expected to rise from around 130 to 160. The main task of the local experts is to develop, test and validate China-specific functions.

Given that the demands of sports car customers in China are exacting and very specific, Porsche AG made the decision to set up a development unit of its own there, known as the R&D satellite. It will work in close cooperation with Porsche Engineering as a local partner. The team at the R&D satellite largely originates from the electrics/electronics sector. "We aim for developing technology that is optimally adapted to the Chinese market," says Karina Steinmetz, Head of the R&D satellite. Charging stations, for example, have different plugs and protocols than European ones. Differences like this will need to be considered. "We are also developing a local test strategy for all technical topics," explains Steinmetz.

传统与未来*

*** TRADITION AND FUTURE**

For more than

30

years, Porsche Engineering has been working for Chinese customers—and is expanding its presence: In 2022 alone, the workforce is set to rise to approx.

160

staff members.

"We make sure that the technology is optimally adapted to the Chinese market."

Karina Steinmetz
Head of Porsche AG's R&D satellite

OBSERVERS AND TECH SCOUTS

In addition to technical validation, the experts at the R&D satellite play a role as observers and tech scouts. "We're keeping an eye on the market-specific technological regulations and standards," says Steinmetz. They are also keeping track of important technical developments in China, she says, such as ones with relevance for autonomous driving and parking, or high-voltage technology. The work being done by the team at the R&D satellite will rely heavily on the local network. "Porsche Engineering is an important strategic partner for us," emphasizes Steinmetz.

"The intelligent and connected vehicle is at the heart of Porsche Engineering's developments in China, as these services are in particularly high demand in the country", said Uwe Pichler-Necek, who took over the position of Managing Director of Porsche Engineering China on July (see page 8). This is partly due to the clientele, which is younger and more interested in technology than it is in Europe. The average visitor to the Porsche Center in China is only 35 years old – and

A driving style with a difference: Chinese traffic also requires adjustments, for example in the calibration of the adaptive cruise control.

one out of two is a woman. “Many customers belong to Generation Z, which grew up with digitalization and constant networking,” says Kurt Schwaiger who, after six years of successfully growing Porsche Engineering China as its managing director, is now retiring. “Customers expect seamless integration of the smartphone into the vehicle environment.” That’s why there are plans to make China-specific services usable on the road, such as the app WeChat, the Chinese equivalent of WhatsApp. To make them part of the vehicle, Porsche and Audi have developed a hardware module that is based on the Android cell phone operating system, and which will be integrated into the vehicle. Drivers could use the functions to have incoming messages read out to them in the future, for example.

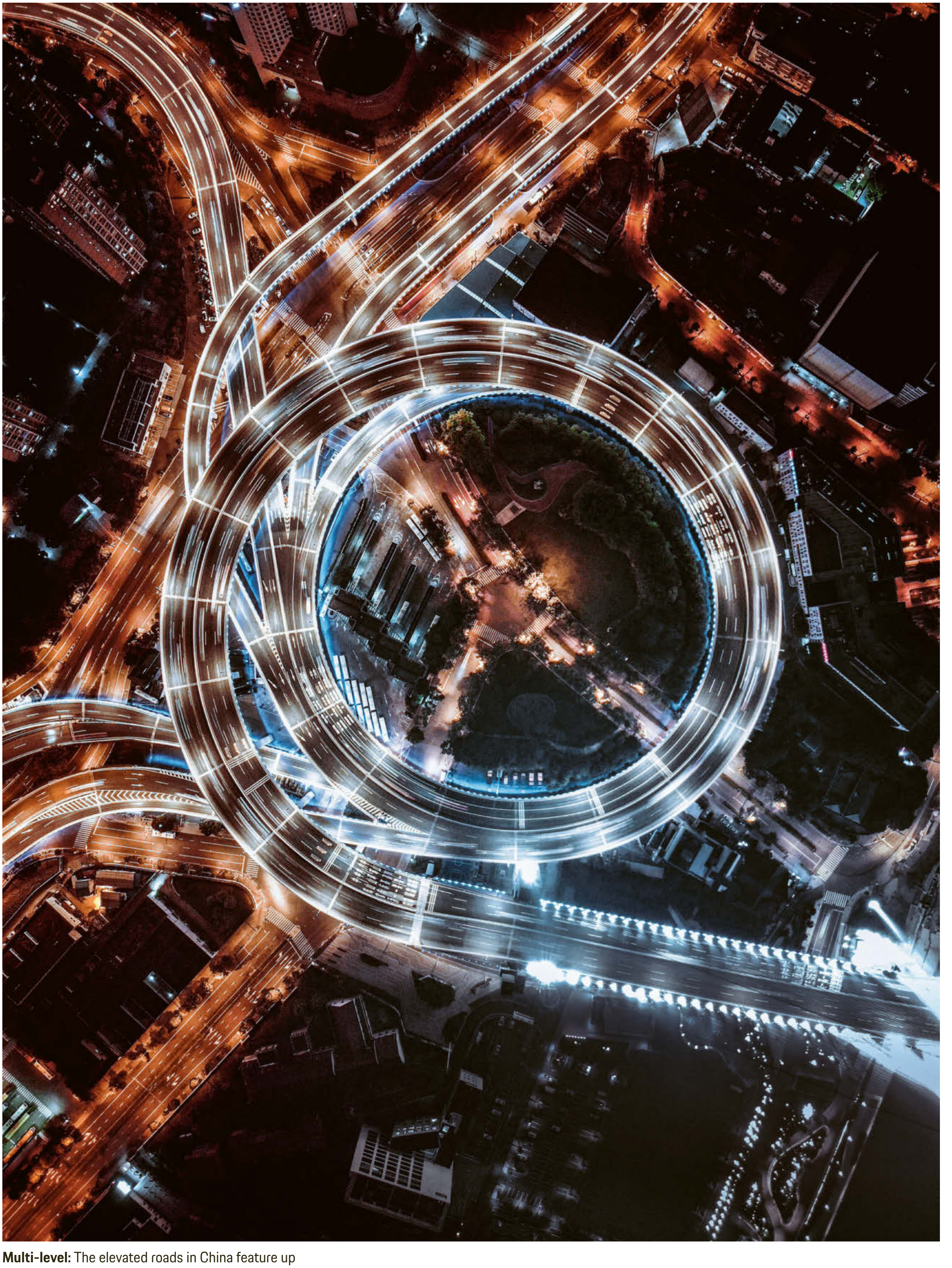
More local entertainment will be available in the vehicle as well. “The next generation of vehicles will allow Chinese customers to use both a local music streaming service and a popular podcast platform, in addition to Apple Music,” says Qi Cao, who is responsible for developing the infotainment system. Unlike Europe, where most customers prefer to operate their vehicles using buttons or touchscreens, voice control is a popular option for communication in China. Customers also expect single sign-on. “Anyone entering the vehicle wants to use all services immediately without having to enter passwords again,” explains Yasumasa Ibuki, who is responsible for testing and validating the infotainment system.

INTENSIVE LOCAL TESTING

At present, Porsche Engineering is intensively testing the infotainment package for the Chinese market locally. Test vehicles have already completed thousands of

“HiL systems allow testing to start before the real vehicle is even available.”

Naikai Du
Senior Manager for Electric & Electronics at Porsche Engineering China



Multi-level: The elevated roads in China feature up to three levels. The technology must reliably detect where the vehicle is at any given moment.

test hours. The experts also use hardware-in-the-loop (HiL) systems in which the infotainment package is connected to a replica of the real vehicle environment including, for example, the instrument cluster and the operating elements. "This allows testing to start before the real vehicle is available," explains Naikai Du, Senior Manager of Electrics/Electronics at Porsche Engineering China. Tests on test benches also save costs and make it possible to simulate situations that are difficult to carry out in a real-life scenario. One example would be the automatic emergency call sent after the airbag has been deployed.

Chinese traffic, too, requires adjustments. "The driving style in China differs enormously from the one in Europe," explains Uwe Pichler-Necek. Frequent lane changes, taking advantage of every gap and rule-flouting overtaking maneuvers are not uncommon in China. This must be considered, for example, when calibrating the Adaptive Cruise Control (ACC). "Cut-ins have to be detected earlier," says Pichler-Necek. "Moreover, the time gap to the vehicle in front may not become too large. Otherwise, so many cars will cut in that the vehicle will hardly make any progress."

CHINA-SPECIFIC ADAPTATIONS

To enable highly automated driving in the future, the systems must also be adapted to the elevated roads found in China – where each level has its very own speed limit. To find out which level the vehicle is on, for example, the system can detect the incline of a ramp.

年轻化女性化*

* YOUNG AND FEMALE

Porsche customers in China are, on average,

35

years old.

Of them,

50

percent are women.

"The reasoning is that camera-based functions will be developed and validated in China in the future."

Johannes Wiebelitz
Development Engineer
for Driver Assistance Systems
at Porsche Engineering

Automatic parking functions, which are also under development, also require a China-specific version due to features such as the colored barriers that delimit the parking spaces in many parking garages, among others. Algorithms that evaluate camera images must learn about these special features by using example images. The view blockers, for example, could cause an algorithm trained in Europe to brake too early.

Local development of assistance systems has recently become a challenge, however. In November 2021, a new law came into force in China that restricts the export of data recorded in the vehicle (Personal Information Protection Law). Commercially used photos or videos that show license plates, personal information, or people, for example, may not leave the country. The upshot for Western manufacturers: For each test drive, there must be an authorized Chinese service provider on board that will receive all data carriers after the test and 'desensitize' the information collected, for example by replacing all license plates with a generic plate. However, this image data then differs from the raw data available in the vehicle, which makes it difficult for AI to learn algorithms.

Geo-sensitive bus data from the vehicle and GPS information is likewise barred from leaving the country. "The reasoning is that camera-based functions will increasingly be developed and validated in China in the future," says Johannes Wiebelitz, Development Engineer for driver assistance systems at Porsche Engineering. This applies to autonomous driving functions for which camera data is essential.

DISTINCT DEVELOPMENT PHILOSOPHY

The development of the intelligent and connected vehicle in China is being pursued with a country-specific development philosophy: "In Europe, one expects a vehicle to be able to perform its tasks even without a data connection. In Asia, it's integrated into function development from the outset," says development engineer Wiebelitz. Here's an example: Some traffic lights in China broadcast their status wirelessly, so drivers can see at which speed they will have a green wave on their dashboard or in an app. Automated driving functions are expected to use this data from the outset (vehicle-to-infrastructure communication, V2I). China is also the leader in vehicle-to-vehicle (V2V) networking. Vehicles that were in accidents, for example, send out a signal that warns approaching cars.

China doesn't want to wait for new technologies to connect the vehicles. They are relying on the existing mobile networks, while Europe intends to use the standard WLAN. "The next generation of vehicles in China will be connected to the Internet by 4G or 5G,"

"The next generation of vehicles in China will be connected to the internet by 4G or 5G."

Estha Li
Senior Manager for Data and Connected Services at Porsche Engineering China

says Estha Li, Senior Manager of Data and Connected Services at Porsche Engineering China. To do this, the local experts are continuing to work on development of the central node for telecommunication in the vehicle. In the future, it will be used to enable remote diagnostics and software updates as well. This always requires localization of European technology. "In China, mobile radio uses different frequencies and interfaces," explains Thomas Pretsch, Senior Manager of the Connectivity discipline at Porsche Engineering. Interesting detail: To check the reaction of test vehicles to dead spots, local engineers must generate one artificially – because network coverage in China is so good. Another China-specific function is Real Time Monitoring (RTM): New electric and hybrid vehicles will be required to transmit dynamic vehicle-related data, and in particular the battery charge level, to public authorities to gain more insights into e-mobility, such as gaps in the charging infrastructure. No installation obligation applies for foreign manufacturers, though many customers are asking about the feature due to regional and national incentive programs. Porsche Engineering is developing RTM on behalf of Porsche AG and remains in close contact with the authorities to ensure that the latest legal requirements can consistently be implemented in development.

Porsche Engineering in China is still focusing on localization. But that could be just the beginning. "It is conceivable that in the future, new technology will first be developed in China before being rolled out globally," says Pretsch. This only makes it more important to be on the ground with a strong team. ●

Trendsetter: In the future, new technology could first be developed in China before being rolled out globally.

SUMMARY

Due to the legal and infrastructural circumstances as well as specific customer expectations, developments for China must largely be carried out locally. Porsche Engineering has therefore been active in China for more than 30 years and is continuing to expand its presence. Both vehicle systems and development methods are adapted to the special characteristics of the country.

"HIGHLY AUTOMATED DRIVING IS ONLY A MATTER OF TIME."

Prof. Hong Chen is dean at the College of Electronic and Information Engineering and holder of the Porsche Chair at Tongji University in Shanghai. In this interview, she talks about the special characteristics of road traffic in China.

How important are Highly Automated Driving (HAD) and Advanced Driver Assistance System (ADAS) functions in China?

— **HONG CHEN:** Traffic in China is much more specialized and complex than in Europe, not only due to China's population and density, but also due to the different culture. According to statistics, people in Beijing and Shanghai spend over two hours on their daily commute. During rush hours, drivers have to keep their eyes peeled to ensure their own safety and endure the stress of driving burden. Tired of driving in heavy traffic jams, Chinese drivers are eager for an alternative such as HAD and ADAS, to relieve them from this burden. To satisfy these expectations, OEMs in China are consistently investing in research and development of HAD and ADAS. As they are an effective solution to traffic jams and safety issues, the Chinese government is providing continuously support for HAD and ADAS in terms of policy, investment, and infrastructure construction.

What has to be considered in terms of local infrastructure, local topology, and legal requirements?

— **HONG CHEN:** In my opinion, the first and foremost issue to face is the legal requirement when it comes to HAD. When a car equipped with HAD is involved in an accident, legal responsibility remains a critical issue. Consent agreements could be concluded to delineate the shared operational responsibility between drivers and HAD systems, while insurance companies might also become involved. This might be the most critical concern for customers and car manufacturers. Regarding the local infrastructure and topology, from my perspective, if vehicle-road collaboration and vehicle-to-X communication become reality, it would undoubtedly accelerate the implementation of HAD. In this regard, China has obvious advantages and has already made rapid progress in recent years.

Where do Chinese OEMs stand on HAD?

— **HONG CHEN:** To our knowledge, most Chinese OEMs have expressed their optimism about HAD. They believe that intelligence and automation are the general trends in vehicle development in the new era; therefore, HAD is destined to become reality in the future, but it will happen gradually rather than suddenly. As described by the SAE "Levels of Driving Automation" standard, it would most likely be a long and gradual process.

Which tech players are involved in the development of HAD and ADAS?

— **HONG CHEN:** At present, many enterprises are involved in the development of HAD and ADAS in China. First of all, OEMs like FAW, Dongfeng, SAIC and Geely are focusing both on developing ADAS in production and HAD for ports and mines. The latter is very attractive for some high-tech companies like Baidu, Didi, and HUAWEI as well, which have launched their own HAD projects. Moreover, several startups such as HorizonRobotics, BlackSesame, RoboSense, Hesai and Xingshen, are actively involved in the development of HAD. Finally, some well-known international automotive suppliers, for example Bosch, Continental and ZF, have also invested considerable effort in the research of HAD in China.

What are you personally and the Tongji University working on in the area of HAD?

— **HONG CHEN:** Tongji is one of the top universities in the area of HAD. In regard to the facilities, Tongji has the first fully functional proving-ground for HAD in China. The associated research covers almost all of the requirements for HAD, from vehicle-road collaboration and Vehicle-2-X-communication to the actual autonomous vehicle. More specifically, Tongji has wide-ranging expertise in market and policy analysis, algorithm design, testing, and evaluation. As a Porsche Chair professor, my research focus on the development of the key technologies by using advanced control and learning-based methods for HAD. More specifically, we are working on the cooperative chassis control for autonomous vehicles, the predictive cruise control, Level 4 'Robotaxi' development, and the intelligence analysis of HAD. Meanwhile, to verify and validate the algorithms that we develop, we are also designing testing environments on different level, such as software-in-the-loop, hardware-in-the-loop, and vehicle-in-the-loop environments.

When will true level 4/5 be reality in China?

— **HONG CHEN:** It's hard to say. Although both academia and industry are pouring considerable resources into this area, it is still challenging to turn level 4/5 into reality in the a short term. However, level 3, as described in the SAE "Levels of Driving Automation" standard, may be achieved soon in specific scenarios like highway driving. Similarly, level 4/5 could be implementedd in limited areas, such as the port and mining area, first and then in traffic scenarios that are more open. The good news is that road tests for level 4 (Robotaxi) have been limited in China in several demonstration areas on open roads, which undoubtedly provides a better environment for the research and development of level 5 technologies. Nonetheless, level 5 HAD that is functional in all conditions will still need some time to realize.

Embedded in the landscape: The NTC attaches great importance to protecting nature at the proving ground.

In harmony with nature

There are many different facets to sustainability for the Nardò Technical Center (NTC) in Apulia. The range of measures to this end reflects this diversity—from climate protection to regional educational cooperation and voluntary work by employees.

Text: Mirko Heinemann
Photos: Mattia Balsamini

Ambitious: Managing Director Antonio Gratis has made sustainability a top priority at the NTC.

"We see ourselves as a driver of both automotive innovation and sustainability."

Antonio Gratis,
Managing Director of the NTC

T **he Nardò Technical Center (NTC)** in Apulia boasts a long and storied history. Since its founding in 1975, it has been the scene of countless speed and endurance records—most recently by the 'Blizz Primatist', a streamlined electric vehicle modeled on Bertone's legendary Z.E.R. This achievement also symbolizes a new era at the NTC: As the test center continues its tradition of technical excellence, sustainability is also playing an increasingly important role for Porsche Engineering's legendary venue in southern Italy.

"Climate protection and responsibility for the region are part of our DNA," says NTC's Managing Director Antonio Gratis. "We consider ourselves a driver of automotive innovation and sustainability in equal measure." In this regard, Gratis views sustainability as a multifaceted undertaking. NTC has embraced its parent company's climate goals: In 2030, Porsche aims to be CO_2 net neutral across the entire value chain and the life cycle of the newly sold vehicles. For Gratis, the social aspect is another important factor: the Nardò Technical Center is not only an important employer in Apulia, with the numerous initiatives it supports also making it an active partner for the people in the region.

The NTC is ambitious when it comes to climate protection. It has already started to reduce its carbon footprint and has launched a dedicated sustainability roadmap until 2030. To ensure that the ambitious plan can be fulfilled, sustainability has been made a top priority at the Nardò Technical Center: In addition to the managing director Antonio Gratis, almost all members of senior management are represented in the eight-member 'Energy Team'. Moreover, extensive investments have been made in technology and infrastructure in order to achieve climate neutrality.

MORE RENEWABLE ENERGY

To reduce its carbon footprint, the NTC is primarily focusing on avoiding carbon dioxide emissions by using renewable energy sources. This is complemented by extensive measures to increase energy efficiency. The NTC aims to reduce business travel and construct any new buildings on the site using sustainable materials in the future. This aims to offset unavoidable CO_2 emissions at all levels.

"Our mission is to reduce emissions every year."

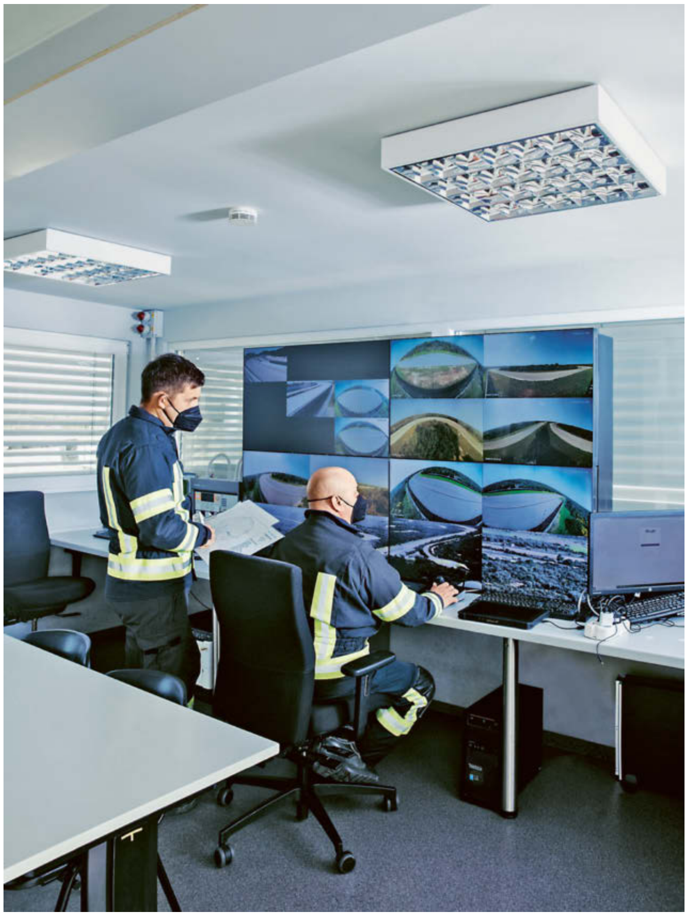
Salvatore Baldi
Senior Manager for Facilities Management at NTC

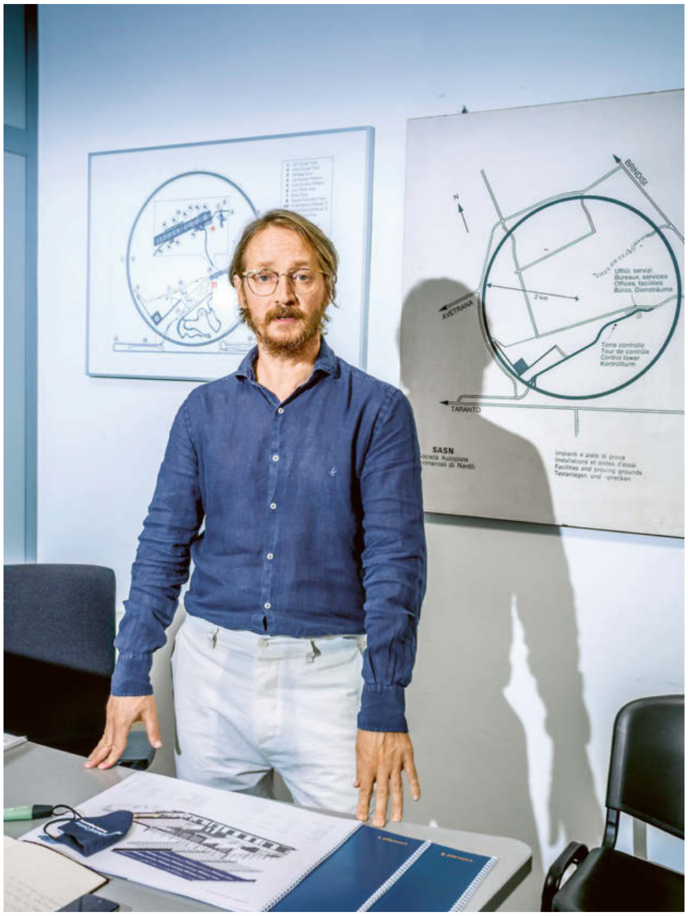
The Taycan Sport sedans

Consumption data in the NEDC:
Power consumption (combined): 27.4–26.0 kWh/100 km
CO_2 emissions (combined): 0 g/km

Consumption data in the WLTP:
Power consumption (combined): 24.7–20.2 kWh/100 km
CO_2 emissions (combined): 0 g/km

As of 06/2022





Facets of sustainability: NTC firefighters monitor the site with cameras to detect fires more quickly (above). Salvatore Baldi is reducing the NTC's CO_2 footprint. And the extensive charging infrastructure helps with development work on e-vehicles.

The progress made toward these objectives can only be measured effectively, however, when exact knowledge of the starting situation is available. That's why the first step was to take stock: "We determined our carbon footprint according to the international standard ISO 14064," reports Salvatore Baldi, Senior Manager for Facilities Management and member of the Energy Team. This standard for voluntary assessment of greenhouse gas emissions captures emissions across the entire value chain.

"Our mission is to reduce emissions every year," as Baldi says. When it comes to its own emissions, the NTC holds all the levers. Intelligent measuring devices (smart meters) provide a detailed overview and optimal management of energy flows. They monitor current consumption, for example in the offices or at the NTC charging stations.

When it comes to services and products sourced externally, on the other hand, the NTC has no direct influence on emissions. The guiding principle in this case: "What we can't neutralize, we have to offset," says Baldi. Reforestation is the method of choice. However, there is limited land and resources for this, he notes. "Since time is of the essence, we implemented the first low-threshold measures right away," Baldi explains. In 2021, the entire power supply was switched over to renewable sources.

PROTECTING ANIMALS AND PLANTS

In addition to climate protection, environmental protection also plays an important role for the Nardò Technical Center—not least because the testing grounds are also a refuge for native plants and animals.

NTC youngsters at work: Up-and-coming mechatronics engineers measure the axles of a test vehicle.

“Social change depends on each and every individual showing their commitment.”

Roberto Buttazzi
Senior Manager for Sales,
Customer Management & Marketing at NTC

Protecting it therefore means a lot to those responsible at the NTC: If there is a fire somewhere, the center’s fire brigade is quickly on the scene and protects the ‘macchia’, the Mediterranean shrubland biome, from being destroyed. And it doesn’t just do so on its own grounds, Antonio Gratis emphasizes: “Of course, we also extinguish scrub fires in the surrounding areas.”

The region of Apulia is characterized by scorching heat in summer, low precipitation and a scarcity of water. For the NTC’s outdoor facilities, the climatic conditions are already a challenge at the best of times, and which consequences climate change will have still remain to be seen. Preparation is, of course, essential. This is why a number of xeriscaping concepts will be tested within 2022 on the grounds. “Xeriscaping is the art of using as little water as you can to create the lushest vegetation possible,” explains Salvatore Baldi. “This involves selecting plants that can thrive despite drought, as well as taking steps to limit waste and evaporation.” Records will be kept of the xeriscaping trials, and successes presented in the sustainability report as well as in local media. “Any success we achieve here should also serve the common good,” Gratis says.

The NTC brings the same spirit to the community. As an employer, it offers attractive and secure jobs to people in the region. And it fosters young talent in southern Italy: NTC cooperates with several schools and universities, including the Polytechnic University of Bari and the University of Salento in nearby Lecce. As part of this cooperation, the company offers internships and supports students with expertise as well as NTC resources when they are working on their final theses. “We see this as our duty,” Gratis says. He intends to unite climate protection and sustainability with economic growth. This is why the company is also qualifying junior talent from the region: in partnership with a local vocational training institute, the Nardò Technical Center has established a dual training program. Over a two-year course of study, ten young graduates will receive training that will make them highly qualified mechatronics in the automotive field.

ACTIVE PARTNER OF THE COMMUNITY

Along with this, the NTC also assumes social responsibility in the region. “We want to be an active partner, as is the tradition in the Porsche Group,” explains Roberto Buttazzi, Senior Manager for Sales, Customer Management and Marketing who is responsible for the corresponding initiatives, such as the ‘Turbo for Talents’ initiative, which provides support for the soccer-playing youth of AC Nardò. The NTC also has been sponsoring a charity run over the last eight years. The proceeds from this run benefit the pediatric oncology department at the regional hospital. “But social change also depends on each and every individual showing their commitment,” says Buttazzi. That’s why, in addition to the NTC’s official partnerships, there are also campaigns involving employees. They get involved in social projects and the environment, and their employer supports them to the best of its ability. Last year, for example, dozens of NTC employees were given a paid day off from work to remove the plastic waste from a stretch of beach.

“The NTC is a respected player in the region as a business and as an employer,” says Gratis, who views the Testing Center as a driver of regional development, and one that combines sustainability with growth. “Achieving this requires not only close ties to local institutions, but also the involvement of each individual.” At the NTC, they know only too well: Motivated teams are the most likely to achieve great results. — ●

Conservationists: If a fire breaks out somewhere, the NTC’s fire brigade is quickly on the scene to protect the Mediterranean shrubland biome.

SUMMARY

The NTC considers itself a part of the local community in southern Italy and, in addition to automotive innovations, is also driving sustainability efforts. The NTC also sees itself as a partner to the people of Apulia—both in its role as an employer and training company and through its collaboration with regional universities.

TRENDS AND TECHNOLOGIES

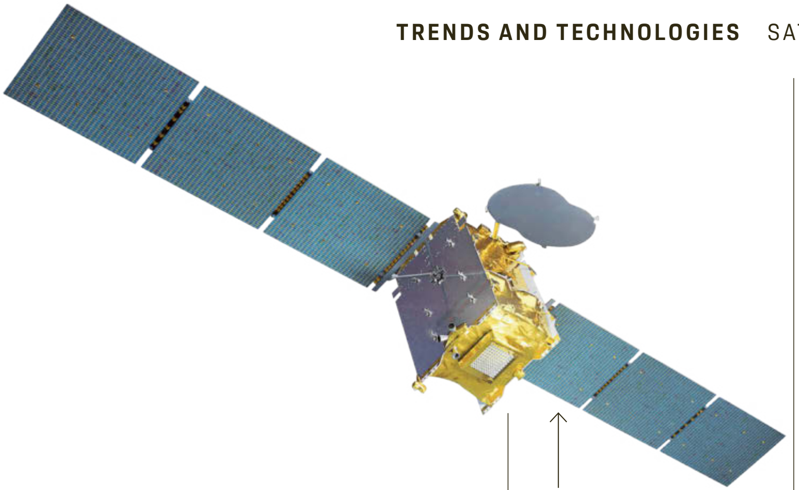
SATELLITES

Artificial satellites:
Around 4,900 active satellites orbit the Earth—in low, medium or geostationary orbit, depending on their mission.

CELESTIAL RADIO TOWERS

The vehicles of the future will be constantly connected, and satellites could play an important role in this. In addition to US providers, a European consortium also intends to build a network in space for this purpose. The first OEMs are already looking into collaborative ventures or satellites of their own.

Text: Ralf Kund



GEO

The main advantage of geostationary Earth orbit (GEO): Satellites in GEO always remain in the same position in the sky because they move around the Earth once a day. This technology is mainly used for television, communications and weather satellites.

The automotive industry is currently undergoing a profound transformation. In addition to the transition to electromobility, the function of the vehicle is also experiencing fundamental changes: "The industrial sector is telling us that the trend is moving from a function as means of transportation only to a function that provides a platform for new business models and services," says Dr. Björn Gütlich, Head of the Satellite Communication Department at the German Space Agency at the German Aerospace Center (DLR) in Bonn. "It's comparable to the transition from mobile phones to smartphones."

And as is the case with the smartphone, continuous connectivity will also play a crucial role for the vehicles of the future. New software-based functions such as autonomous driving can benefit enormously from uninterrupted connectivity, for example by allowing them to send or receive warnings about dangerous spots. Approaching vehicles would then still have enough time to adapt to the situation. "A fast, reliable and global connection to the internet would therefore be desirable in the future," explains Dr. Sébastien Chartier, Business Unit Manager for High-Frequency Electronics at the Fraunhofer Institute for Applied Solid State Physics. "5G and 6G mobile communications will play a crucial role in this regard. In addition, new generations of satellites are also likely to play a decisive role in ensuring global coverage and putting an end to dead spots."

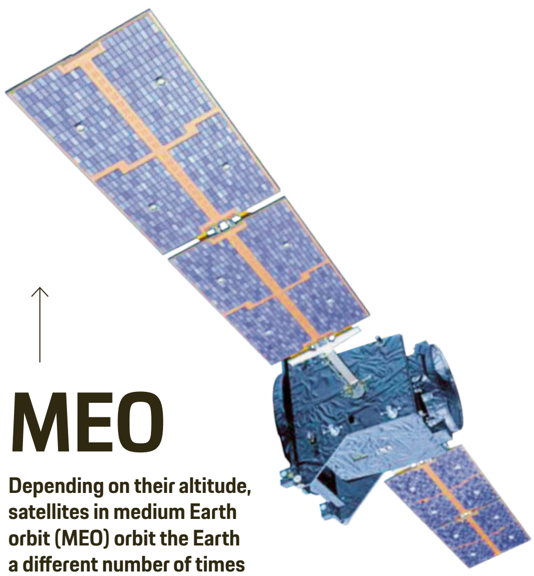
SATELLITES ARE AN IDEAL SOLUTION

DLR expert Gütlich agrees: "The existing terrestrial communications infrastructure alone is unlikely to be able to provide nationwide coverage for the foreseeable future." As he points out, the limited radius of the future 5G cells, with a radio mast at every streetlight, will make it necessary to supplement mobile communications with "celestial radio towers". "Satellites are the ideal solution," says Gütlich.

In the future, satellites will not only provide support for autonomous driving. "They could also send up-to-date information about traffic volumes to the navigation system or new software statuses to the vehicle electronics in real time. Finally, data from space could enable interference-free enjoyment of internet-based on-board entertainment services—even in remote areas with poor networks. This means there's a wide range of uses for satellites in the automotive sector," says Lutz Meschke, Deputy Chairman and Member of the Executive Board – Finance and IT at Porsche AG and Member of the Executive Board for Investment Management at Porsche Automobil Holding SE.

The prerequisite for the new services, however, is additional technology in the car, in particular for reception of the data from space. Dish-shaped antennas of the kind used for stationary applications are out of the question for the car roof because of their size and shape. Instead, phased array antennas provide an option: They consist of many small antennas and special electronics that can consistently adjust the transmit and receive direction to the position of the satellites (see box on page 53), thereby ensuring uninterrupted data reception. Phased array antennas are also completely flat and can be integrated into a sunroof.

The satellite fleets for the new services will orbit the Earth in low Earth orbit (LEO) and geostationary Earth orbit (GEO). Closer to home, the LEO satellites are up to 2,000 km from the Earth's surface, while their GEO counterparts are stationed at an altitude of around 35,800 km and always remain above the same spot. Both orbits have their specific advantages and disadvantages, particularly with regard to the propagation time of the signals between transmitter and receiver (latency). "The low LEO orbit is suitable for very fast communication because of its low



MEO

Depending on their altitude, satellites in medium Earth orbit (MEO) orbit the Earth a different number of times per day. Well-known examples are the satellites used for the GPS, Galileo, GLONASS and BeiDou navigation systems.

"There's a wide range of uses for satellites in the automotive sector."

Lutz Meschke
Deputy Chairman and Member of the Executive Board – Finance and IT at Porsche AG

latencies of about 0.04 seconds, while the GEO orbit with approximately 0.5 seconds of latency is ideal for distributing the same content to many users," explains Walter Ballheimer, CEO of satellite manufacturer Reflex Aerospace.

LEO is already bustling with activity today: Of the nearly 4,900 active satellites orbiting the Earth, about 4,100 are in low Earth orbit. By comparison: There are currently only about 600 satellites in GEO orbit. And the number of LEO satellites is growing rapidly: In 2021 alone, roughly 1,660 of them were launched into space, compared with only about 30 satellites placed in other orbits. The keen interest in space is related to changing framework conditions: While access to space used to be reserved for states and their space agencies, today more and more companies are discovering the transport and operation of satellite fleets as a business model of the future.

EUROPEAN ALTERNATIVE FOR SPACE

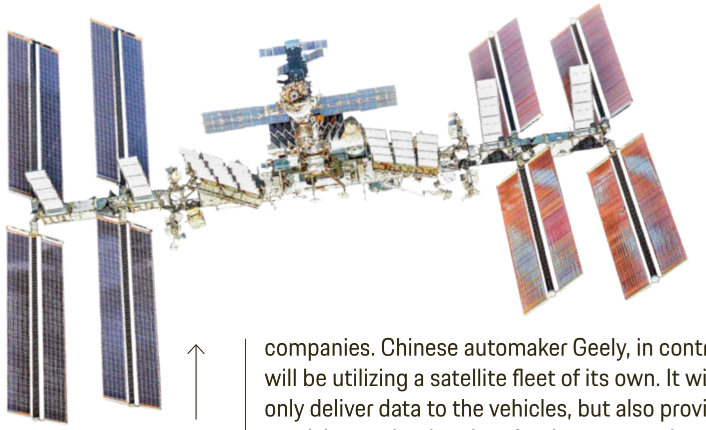
This boom has been made possible by advances in technology and the increasing privatization of the space industry: Satellites are becoming smaller and cheaper, and the cost of flying them into orbit is also falling due to cheaper rockets and greater competition among providers. By far the largest and best-known of these is Elon Musk's US-based space company SpaceX. By the end of 2021, it had put nearly 1,800 LEO satellites into space for its Starlink network. They were launched to bring the internet to remote areas. SpaceX also intends to provide trucks, boats and aircraft with data.

So far, there is no European alternative to Starlink. To change this situation, Munich-based rocket manufacturer Isar Aerospace, together with Reflex Aerospace and laser communications specialist Mynaric, founded the UN:IO consortium at the end of 2021. It will receive 1.4 million euros from the EU to design a study for a dedicated European satellite constellation by 2025. In addition to applications such as broadband connectivity, border surveillance and civil defense, the UN:IO project also regards connected and autonomous vehicles as potential users of its services.

"Services such as video telephony, streaming or even autonomous driving applications will only be possible once there are enough satellites in orbit," Ballheimer says. Compared to Starlink, however, UN:IO is planning to launch far fewer artificial satellites into space. "We plan to have a few hundred satellites in LEO for fast communications, and a few dozen in a higher orbit for distributing content such as software updates," Ballheimer says. "Instead of clogging the low Earth orbit with tens of thousands of satellites, we'll achieve an even higher communications performance by intelligently combining different orbits with just a few hundred satellites."

Several European automakers are showing a keen interest in cooperating with satellite operators such as Starlink or UN:IO. This would allow them to profit from the existing infrastructure and expertise of space companies. Chinese automaker Geely, in contrast, will be utilizing a satellite fleet of its own. It will not only deliver data to the vehicles, but also provide high-precision navigation data for the company's autonomously driving cars. It is still unclear whether other OEMs will follow this model. As operators of a satellite fleet of their own, this would make them independent of existing companies, allow them to optimize the technology for their needs, and determine their launch slots to suit their needs.

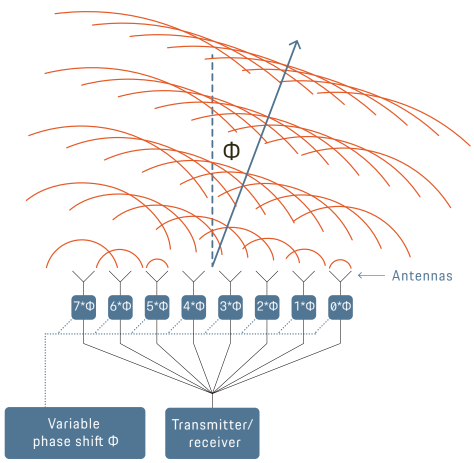
Porsche SE is also investing in the space business: It has held a stake in Isar Aerospace since July 2021. The company develops its rockets near Munich and stands apart from competitors due to its high level of vertical integration in particular: All major components are developed by Isar Aerospace itself. Isar Aerospace is planning to launch the first test flight of its two-stage 'Spectrum' launch vehicle from the Norwegian island of Andøya at the end of 2022. Later on, it plans to launch small satellites into space for customers such as the UN:IO consortium, among others—and thereby contribute to making traffic on earth a little safer and travel more pleasant.



LEO

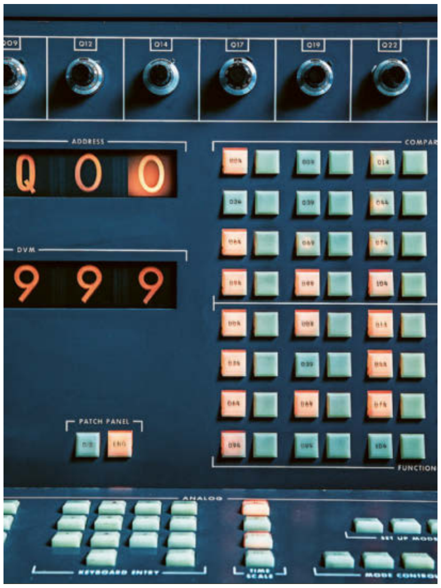
Low Earth orbit (LEO) is home to the International Space Station (ISS) as well as many weather, Earth observation, and communications satellites. It is currently in high demand: The vast majority of new satellites, for instance those for the Starlink network, are launched into LEO.

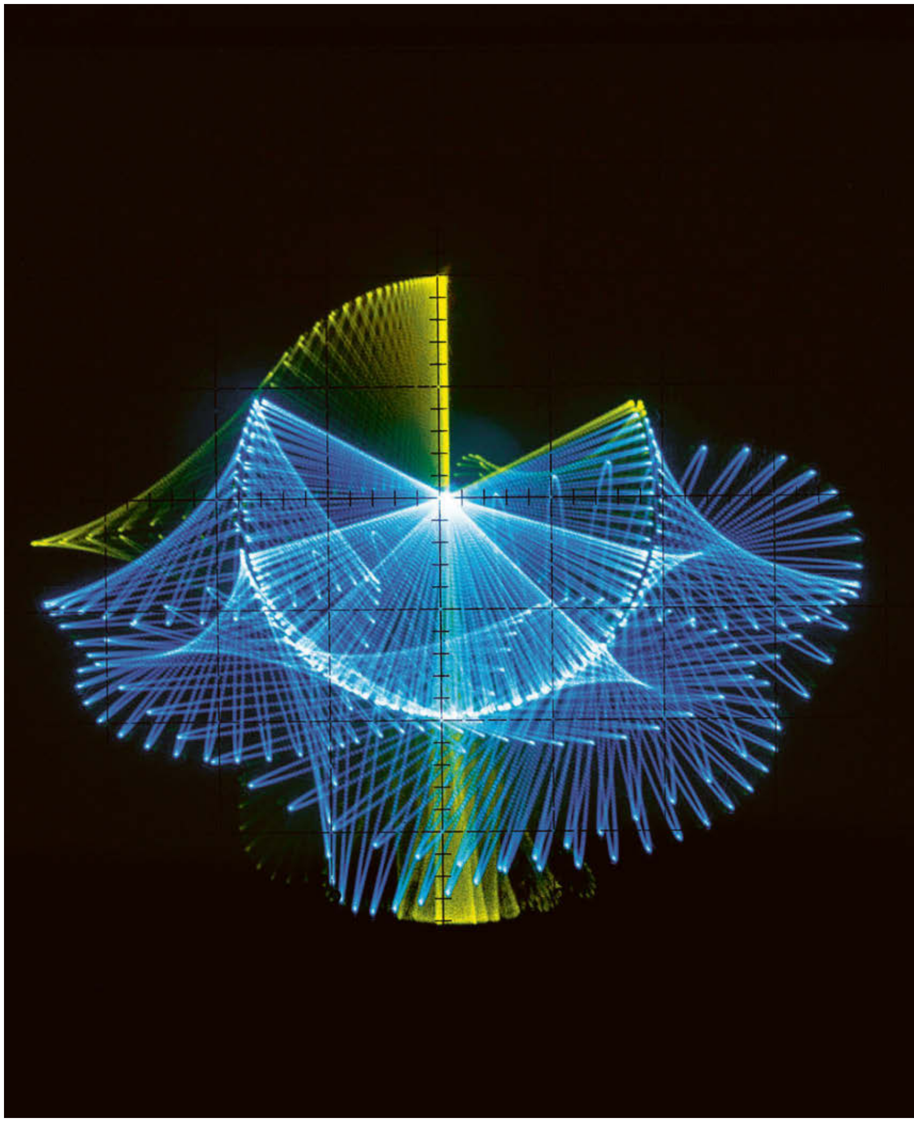
Electronically aligned



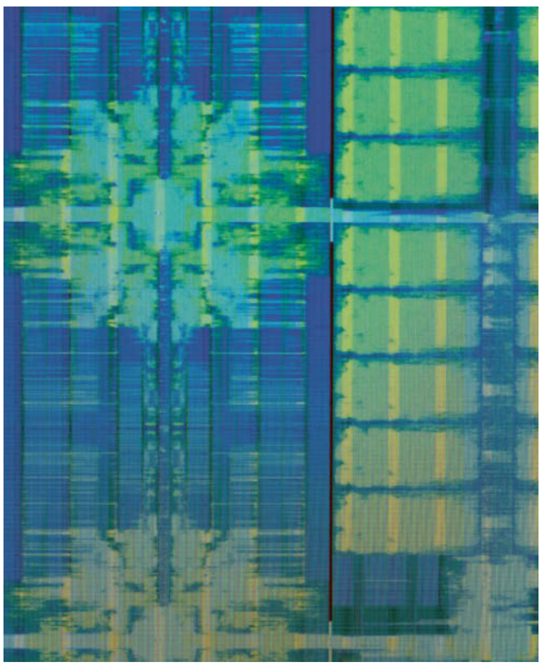
To **exchange data**, a vehicle's antenna must be pointed toward a satellite. This is precisely what **phased array antennas** do: They consist of individual antennas, each of which is controlled using a different signal phase during transmission. This allows the direction of the **maximum transmitted energy** to be tilted by an angle Φ fully electronically. When receiving, the phase shift makes it possible to determine the direction of greatest sensitivity.

Changes for the better: Innovations such as computers, microelectronics and biotechnology have changed people's lives by leaps and bounds.





THE



Which technical innovations yield human progress? And how can we find better solutions to the great challenges of our time? A guest article by Rafael Laguna de la Vera and Thomas Ramge.

Photos: Mattia Balsamini

BIG

Disruptive innovations do not optimize. They create new and better solutions. Disruptive innovations don't just make our lives a bit more comfortable—they fundamentally change them for the better, just like the first cultivated plant, the einkorn, some 10,000 years ago. With that first grain, agriculture began, and people started forming settlements.

The invention of the sailboat 6,000 years ago changed the world, as did later the nail, cement, the printing press and optical lenses. The digital computers of the 1940s unleashed the digital revolution and a series of disruptive innovations, including microchips, the PC and, of course, the internet, which has changed our lives more than any other new technology in the last three decades. With the current disruptive innovation of mRNA vaccines, we are able to arm ourselves against new epidemics.

What's next? No one can know for sure, because unpredictability is in the nature of disruptive innovation. Individuals, societies and states can, however, help it along—and also ensure that new technology does more good than harm. There are three levers that are particularly effective in this regard:

→ **FIRST:** Highly innovative people need more support and freedom. Disruptive innovations are often brought into the world by 'nerds with a mission'. At the Federal Agency for Disruptive Innovation, we call them 'high potentials' ('HiPos'). They usually exhibit three outstanding characteristics: an extreme, often obsessive interest in their field, a high level of resilience when faced with setbacks, and a deep-rooted desire to have an impact for the good of the world. Social interaction is often not the forte of these individuals. Starting at an early age, educational systems need to create open spaces and support opportunities for 'HiPos' who think outside the box. After all, it's not conventional wisdom that produces innovation. In many school and university support programs, however, socially awkward high-fliers fall through the cracks.

→ **SECOND:** Venture capital must live up to its name (again). Almost unlimited venture capital is available worldwide for digital platforms, which are often mere copies of business models tried and tested elsewhere. This is understandable: The risk, after all, is generally fairly predictable for investors. But wherever big leaps are being made with 'deep tech', for example in climate technologies and biotech, capital is scarce. In this case, the state and the market must work hand in hand to create better financing conditions for disruptive innovators. The state has the wherewithal to do this—by using smart tax incentives, its purchasing power (contracts for new technologies that still need to be developed) and by cutting red tape, including spinning off science-related startups from universities and publicly funded research institutions. And venture capitalists might ask themselves more often what impact they want to achieve with their investments other than short-term returns. The growing number of so-called 'impact investors' is an encouraging signal in this area.

→ **THIRD:** As a society, we need to sharpen our understanding of what kind of innovations we want to develop in the future, and which values they will be based on. This doesn't mean we need to reinvent the wheel. The philosophy of the Enlightenment provides orientation. The goal is disruptive innovations that make life better for the greatest possible number of people to the greatest possible extent. Valuable and meaningful benefits emerge when we focus on human needs, from the basic necessities of life to the potential for individual self-realization. Psychologist Abraham Maslow's 'pyramid of needs', with its different levels ranging from basic needs to self-actualization, provides valuable guidance in this context, as do the United Nations' 17 Sustainable Development Goals.

LEAP

Where will all this lead us? As technological optimists, we believe that science and technology will find many answers to the great challenges of our time in the coming decades. They will bring us green energy from the wind and sun, hydropower and nuclear fusion in abundance. It could conceivably be so cheap that it will hardly be worth charging for it. CO_2-free energy for less than two cents per kWh could radically reduce poverty and hunger worldwide. We can use it to remove large quantities of carbon dioxide from the atmosphere and halt climate change. That will make the world a much more peaceful place.

Meanwhile, biomedical researchers are gaining a better understanding of the blueprint of life. With the help of genetic engineering and the health data revolution, we are on the scientific threshold of conquering major diseases: Cancer and dementia, cardiovascular disease and autoimmune disorders, mental illness and paralysis, blindness and severe hearing loss. We hope to succeed in slowing down the cell aging process significantly so that we can grow older in better health. And maybe even spend time with our great-great-grandchildren.

Over the next 20 years, we will develop a system to redirect large asteroids heading toward Earth. And even though at least one of us two authors would not be willing to make the trip: We hope to establish a permanent colony on Mars by 2050. Why? That will help us humans rediscover our old spirit of discovery and develop the courage again to take the really big leaps.

"We believe that science and technology will find answers to the great challenges of our time."

Rafael Laguna de la Vera and Thomas Ramge

THE AUTHORS

Rafael Laguna de la Vera is the founding director of the Federal Agency for Disruptive Innovations. **Thomas Ramge** is an author and keynote speaker. Recently, Econ-Verlag published their book "Sprunginnovation—Wie wir mit Wissenschaft und Technik die Welt wieder in Balance bekommen" [Disruptive innovations—How we can restore the world to balance with science and technology].

PORSCHE
AND PRODUCT

THE NEW 911 SPORT CLASSIC

BACK TO

Re-interpreted: The 911 Sport Classic was primarily inspired by 1973's 911 Carrera RS 2.7. It's a car that brings back memories of the 1960s and early 1970s.

FUTURE
THE

The new 911 Sport Classic is the second of four collector's items that Porsche is presenting from its Heritage Design strategy. The limited-edition series by Porsche Exclusive Manufaktur will total 1,250 vehicles and resurrects the style of the 1960s and early 1970s.

Text and photos: Dr. Ing. h.c. F. Porsche AG

“The new 911 Sport Classic is the first vehicle to feature Sport Grey Metallic paintwork.”

Michael Mauer
Vice President Style at Porsche AG

Wing shape: The new 911 Sport Classic draws on the Fuchs rim from 1967.

Like its immediate predecessor—the 911 Sport Classic based on the 997 model series, which was presented in 2009—this vehicle is inspired by the original 911 (F model) from the years 1965 to 1973, and in particular by the 911 Carrera RS 2.7 from 1973. This makes the new 911 Sport Classic a tribute to the Porsche tradition, and one that evokes memories of the 1960s and early 1970s for customers and fans alike.

The exceptional quality of the 911 Sport Classic is immediately underlined by its wide body, which is otherwise reserved for the 911 Turbo models. However, while two side air intakes in the rear wings supply the engine air, the process air intake in the 911 Sport Classic only uses the opening below the rear wing. The side air intakes have therefore been removed in order to create a unique look.

A large, fixed spoiler made of carbon-fiber reinforced plastic (CFRP) is the defining feature of the rear styling on the 911 Sport Classic. It references the shape of the legendary ‘ducktail’ spoiler of the 911 RS 2.7 from 1972. The third brake light is integrated into the spoiler. Another highlight is the dynamic recess profile on the bonnet and double-dome roof, which has been adapted to the painted twin stripes. Both components are made of CFRP, which saves weight. Standard matrix LED main headlights in Black, including Porsche Dynamic Light System Plus (PDLS Plus) and the unique paintwork on the fixed spoiler lip complete the sporty design at the front of the vehicle.

The Porsche crest on the 911 Sport Classic adorns the front bonnet as well as the hub covers of the rims. Nearly identical to the historic crest of 1963, it rounds off the overall Heritage look. Other exceptional details include the gold-colored Porsche logo and the model designation at the rear. The extraordinary shine of the lettering is down to the fact that the surface is finished with real gold.

INSPIRED BY THE GRAY OF THE PORSCHE 356

The front wings bear gold-colored ‘Porsche Exclusive Manufaktur’ badges. Porsche revived the tradition of placing classic manufacturer badges here when the first 911 Sport Classic was launched in 2009. These badges used to indicate the coachbuilder—such as Reutter or Karmann—whereas now they show that the vehicle was created by Porsche Exclusive Manufaktur. The grille of the rear engine cover bears a ‘Porsche Heritage’ badge, the design of which is reminiscent of the Porsche 356 badge that was awarded in the 1950s when a vehicle reached the 100,000 km mark. The new badge is a hallmark of all four Heritage Design

The new 911 Sport Classic

Consumption data in the NEDC:
Fuel consumption (combined): 12.8 l/100 km
CO_2 emissions (combined): 292 g/km

Consumption data in the WLTP:
Fuel consumption (weighted): 12.6 l/100 km
CO_2 emissions (combined): 285 g/km
Energy efficiency class: G

As of 05/2022

vehicles—the 911 Targa 4S Heritage Design Edition was the first of these collector's items to bear it.

As with the first 911 Sport Classic (type 997), the designers were inspired by the Fashion Grey paintwork of the Porsche 356 when choosing the exclusive paint finish for the new limited-edition series. "The new 911 Sport Classic is the first vehicle to feature Sport Grey Metallic paintwork", says Michael Mauer, Vice President Style at Porsche AG. "No matter how often we all looked at the vehicle together during the development process in the design studio at Weissach, we always came to the same conclusion: grey is never boring; it often makes a statement and it's always very cool."

ALL PAINTWORK APPLIED BY HAND

As an alternative to the exclusive Sport Grey Metallic finish, the new 911 Sport Classic is also available in solid Black, Agate Grey Metallic or Gentian Blue Metallic. Double stripes on the bonnet, roof and rear spoiler emphasize the origins of the design in sport. They are painted in light Sport Grey and all elements of the painting process are carried out by hand, from marking out the design to painting the stripes. Multiple coats and intermediate sanding processes provide the perfect transition across the various body parts.

The graphics on the flanks of the vehicle reference the brand's motorsport tradition. It also comes in light Sport Grey and includes a Porsche logo, a round car number panel ('Lollipop') and, as an option, an individual black start number. The drive concept is also unique: The 3.7-liter, twin-turbo flat-six engine puts 405 kW (550 hp) on the road and transfers its power to the asphalt using the rear wheels only, placing the 911 Sport Classic between the 911 GTS and 911 Turbo from the perspective of performance. The engine is based on the options available for the current 911 Turbo models. Variable turbine geometry (VTG) and wastegates help to achieve the superior power delivery. The standard sports exhaust system has been specially modified to suit the model and provides an even more emotive sound thanks to the fact that some of the car's interior insulation also has been removed.

The boxer engine is coupled with a seven-speed manual gearbox. This makes the 911 Sport Classic the most powerful manual 911 available today. The gearbox includes an auto-blip function that compensates for speed differences between the gears with a brief burst of revs when shifting down. The shortened shift lever provides a quick shift action and a crisp feel. The suspension, based on that of the 911 Turbo and 911 GTS models, meets high performance

405 kW

are delivered by the twin-turbo flat-six engine.

7 gears

are offered by the manual gearbox. The 911 Sport Classic is the most powerful manual 911 available today.

Classic: The highlight in the interior is the iconic 'Pepita' pattern. The instrument cluster with two high-resolution displays also borrows from history.

“It’s not just the look of the 911 Sport Classic that makes it special. Its extensive technical modifications are some of its most striking features.”

Frank-Steffen Walliser
Vice President Model Line 911 and 718 at Porsche AG

Unmistakable: The carbon-fiber-reinforced plastic (CFRP) spoiler references the shape of the ‘ducktail’ spoiler of the 911 RS 2.7 from 1972.

Distinguishing feature: The ‘Porsche Heritage’ badge adorns all four Heritage Design vehicles.

requirements: thanks to the standard Porsche Active Suspension Management (PASM), the shock absorbers respond to dynamic changes at lightning speed. PASM is combined as standard with the sports suspension, which features a ride height that has been lowered by 10 millimeters. The 911 Sport Classic features rear-wheel drive, meaning the axle load at the front is lower than on all-wheel drive models. This is the reason why the Porsche suspension engineers have slightly reduced the spring rate on the front axle. The steering system, including the standard rear-axle steering, has also been modified especially for the 911 Sport Classic.

The 911 Sport Classic sits on 20- and 21-inch center-lock wheels. The faces of the wide spokes and the rim flange are polished, making them stand out against the black rim base and black sides of the spokes. The wing or clover leaf-style of the design is a reference to the legendary Fuchs rim, one of the most famous Porsche wheels. Porsche and Otto Fuchs KG presented the first forged light-alloy wheel for the 911 S in 1967. The Porsche Ceramic Composite Brake (PCCB) is part of the standard equipment for this vehicle. The brake calipers are painted in High-Gloss Black and feature a white Porsche logo.


Racing look: The new 911 Sport Classic and the 911 Targa 4S Heritage Design Edition from 2020 have a car number panel on the flanks.

OUTSTANDING DRIVING CHARACTERISTICS

"It's not just the look of the 911 Sport Classic that makes it special. It also boasts extensive technical adaptations," says Frank-Steffen Walliser, Vice President Model Line 911 and 718 at Porsche AG. "The sports suspension with lowered ride height and vehicle-specific tuning deliver excellent lateral dynamics when cornering."

A highlight of the interior is the iconic 'Pepita' houndstooth pattern on the door panels and seat centers. The pattern comprises small squares connected by diagonal stripes. Pepita was available for the first time as an official option in a Porsche 911 in 1965. The pattern made its first comeback in 2013 as part of the '50 years of the 911' special model launch. The original Pepita houndstooth pattern made another one-off appearance inside the '911 no. 1,000,000'—a specially made, unique specimen.

The two-tone, semi-aniline leather upholstery in Black/Classic Cognac not only provides an elegant contrast to the exterior, but also makes a statement. Porsche previously used semi-aniline leather in the 918 Spyder. The 911 Sport Classic is the first vehicle to be decked out with this type of leather in the characteristic color of Classic Cognac: It is protected by a thin layer of coating that preserves the visible texture and soft feel of the leather. The historic Porsche crest is found in the interior as well. The headrests of the adaptive Sports seats Plus, the GT sports steering wheel and the embossed 'Porsche Exclusive Manufaktur' logo on the storage compartment lid all emphasize the extraordinary craftsmanship behind the design. A gold-colored limited-edition badge with the personalized vehicle number is positioned on the trim panel above the glove compartment, referencing the exclusivity of the 911 Sport Classic.

The modern instrument cluster with two high-resolution seven-inch displays also borrows several historic details: for example, the analogue rev counter features a classic-style needle. White hands and scale markings provide maximum contrast. The green digits pay tribute to the legendary Porsche 356, while the Sport Classic logo showcases the sports car's modern credentials. The digital displays have also been modified for the Heritage Design strategy.

In addition to owning a limited-edition model, 911 Sport Classic drivers become eligible for a unique watch from Porsche Design. The dial on the Chronograph 911 Sport Classic can be configured to match the vehicle. One option is a matt black Heritage Design dial. The green digits and scale markings, as well as the white hands, are based on the rev counter in the vehicle. Alternatively, the watch dial is available with either the Sport Classic stripes in light Sports Grey or the Pepita houndstooth pattern from the vehicle interior.

Like the Porsche logo at the rear of the car or the badge in the interior, the Porsche Design logo on the dial is applied in gold. The design of the winding rotor was inspired by the wheels of the vehicle, and includes a cover that looks like the center-lock nut on the alloy wheels. The two wristbands included in the set—one in Black, one in Classic Cognac—also draw parallels with the vehicle. They are made from the same leather as the upholstery in the vehicle interior and feature an embossed '911'. Like all watches by Porsche Design, this special model is produced at the dedicated Porsche watch factory in Solothurn, Switzerland.

SUMMARY

The new 911 Sport Classic is the second of four collector's items that Porsche is presenting from its Heritage Design strategy. It resurrects the style of the 1960s and early 1970s. In the interior, the iconic Pepita pattern adorns the door mirrors and the seat centers. Porsche is launching four limited-edition series over an extended period.

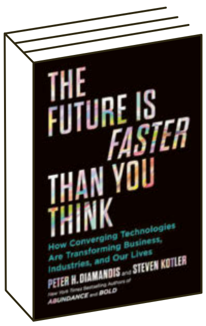
Deeper knowledge

PODCAST

Diving into the future

These podcasts by the renowned US magazine 'MIT Technology Review' discuss cutting-edge topics such as artificial intelligence and the fight against fake news. Listeners will be well informed when joining the discussion on the latest developments.

Deep Tech – MIT Technology
www.technologyreview.com/podcast/deep-tech



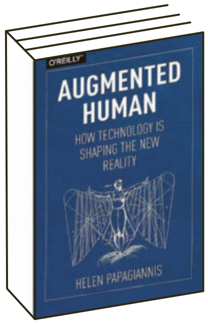
BOOK

More upheavals than ever before

The authors show how technological developments will change our world over the next ten years. Their thesis: We will experience more upheavals and create more prosperity than we have in the last hundred years.

The Future Is Faster Than You Think
Peter H. Diamandis, Steven Kotler
Simon & Schuster

The big picture

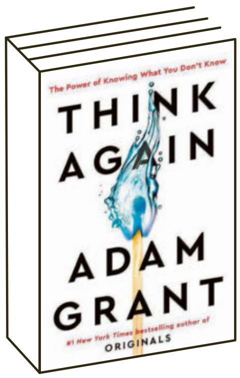


BOOK

The augmented experience

A world-leading expert explains where augmented reality is heading. The book covers topics ranging from machine vision and haptic technology to augmented sound and digital scents. Readers will also learn all about electronic textiles and avatars to stand in for humans.

Augmented Human
Helen Papagiannis
O'Reilly Media



BOOK

Flexible thinking

In a world that is rapidly changing, one thing is particularly important: flexible thinking. And yet at the same time, it is difficult to abandon your convictions and leave your comfort zone. The author shows how people can cultivate open-mindedness.

Think Again
Adam Grant
Piper

For the child in all of us

GADGET

Mini speed demons in the original Porsche design

This kit is perfect for Porsche fans young and old. It contains a race car with a friction motor in the authentic design of the real Formula E Porsche race car. And with the LEGO Technic Augmented Reality app, the race track comes to life.

LEGO Technic Formula E Porsche 99X Electric

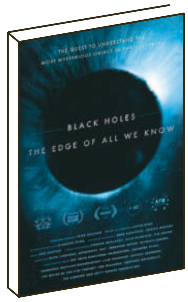
GADGET

Hydraulic DIY hand

This kit contains a precisely controllable robot hand that is three times the size of its human counterpart. Its fingers are controlled intuitively by the motion of the user's own hand and powered by water pressure alone. A completely new grasping sensation—for lefties and righties.

Kosmos Cyborg Hand

Intelligent entertainment



FILM

At the frontiers of knowledge

They are arguably the most mysterious objects in the cosmos: Black holes, from whose stupendous gravitational pull nothing can escape. The film shows shots of the Event Horizon Telescope (a worldwide network of radio telescopes) and combines them with the theoretical considerations of physicist Stephen Hawking.

Black Holes: The Edge of All We Know
Netflix

SERIES

Loads of action and black humor

The television series 'The Umbrella Academy' is based on the series of comics of the same name by Gerard Way and Gabriel Bá. In the third season, the heroes tangle with the 'Sparrow Academy'—a group of seven children born on the same day.

The Umbrella Academy 3
Netflix

2001

A REVOLUTION ON TWO WHEELS

Harley-Davidson
'V-Rod'

Engine
Two-cylinder V2

Displacement
1,131 cm³

Power
86 kW (117 hp)

The name said it all: The 'Revolution Engine' would indeed usher in a small revolution at the American motorcycle manufacturer Harley-Davidson. The two-cylinder V2 engine with 1,131 cm³ engine displacement was designed to power a completely new category of bikes, the 'Sport Cruisers'—based on the classic US motorcycle types from the period between the 1930s and 1960s, but with significantly more engine power.

The 117 hp engine was created as part of the 'Revolution Powertrain' joint venture formed by Porsche and Harley Davidson in 1996, in which the Stuttgart-based sports car manufacturer held 49 percent of the shares. The transatlantic collaboration was already a well-oiled machine at the time, as the development partnership between Porsche and Harley-Davidson extended back to 1969. It reached a new dimension with the founding of the joint venture, however.

The Porsche engineers also wanted to set standards with the performance of the new engine. "We began with a blank sheet of paper and developed everything from scratch," recalls Klaus Fuoss, who joined the project in 1998 as a development engineer and today is the Director Powertrain Development at Porsche Engineering. "With its four valves and double camshafts, the engine was technologically state-of-the-art."

For Fuoss, the project is still one of the highlights of his career: "I've rarely had the chance to work in the non-automotive sector. I'd also never had the opportunity to develop an engine as part of a joint venture." Moreover, the technology was demanding as well: Due to the geometry of the V2 engine, the engineers had to counter strong engine vibrations and absorb high peak torques. Even the test bench in Weissach had to be adapted for the engine. "It was small, but due to its high torque it was a small beast," recalls Fuoss, who got to know the new engine on numerous test drives in the US and the Black Forest.

In the end, all of the technical challenges were overcome, and the new engine also passed the 500-hour endurance test, which simulated an average speed of 160 km/h on the test bench. "That engine was resilient, so it could easily exceed the 100,000-kilometer mark—a quantum leap in quality, too," says Fuoss. It also looked good: 'Function follows styling' was the motto during development. Only metal parts were visible; all hoses and cables were hidden from view.

The Harley-Davidson 'V-Rod' model with the new engine, dubbed the 'Porsche Harley' by the press, went into series production in 2001. It thrilled a demanding customer base both with its performance and the sound of its water-cooled engine. Only in 2018 did the US motorcycle manufacturer send the model into retirement.

"With its four valves and double camshafts, the engine was technologically state-of-the-art."

Klaus Fuoss
Director Powertrain Development at Porsche Engineering

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