Porsche Engineering

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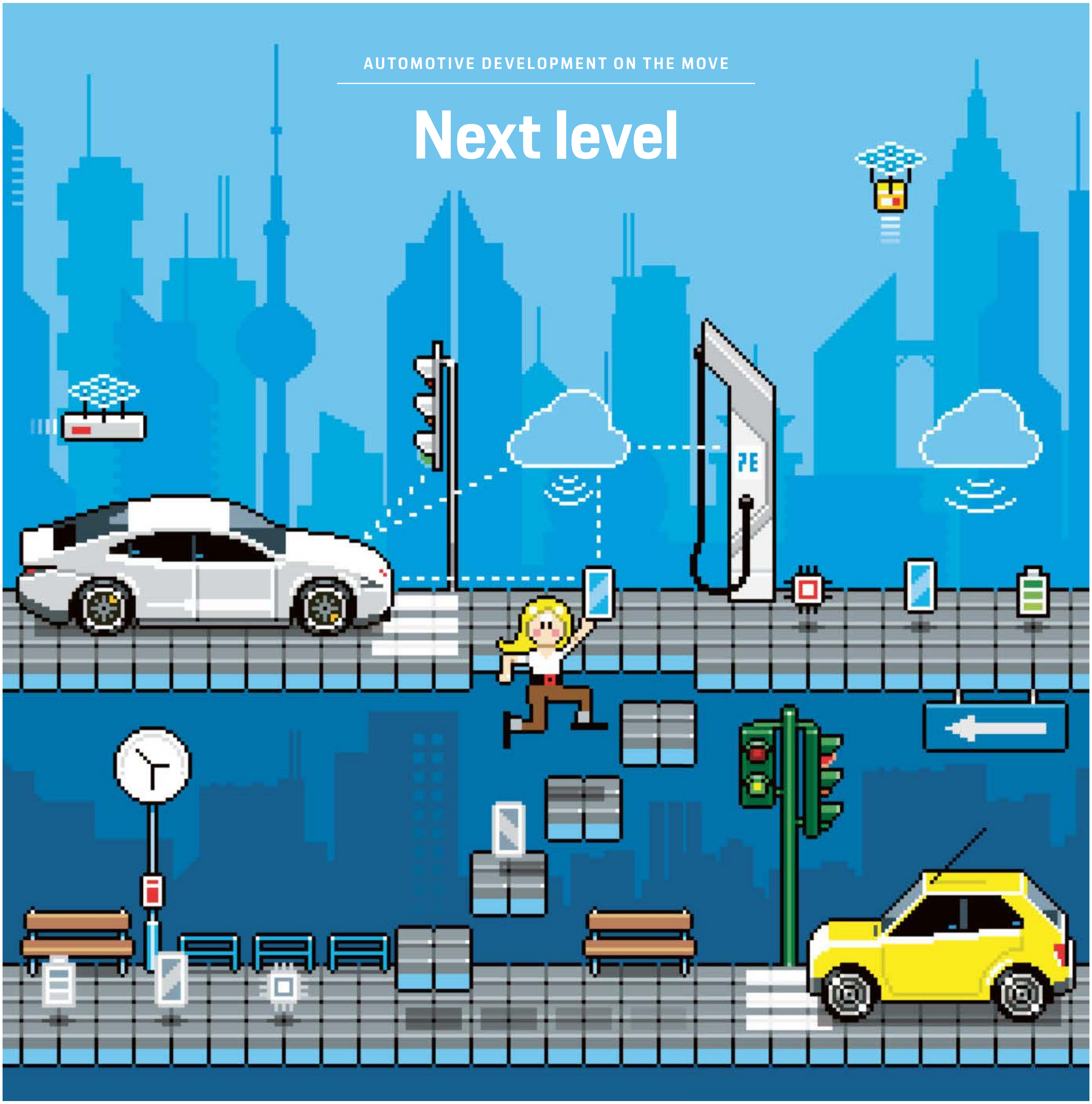


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As always, our strongest motivation: our own standards.
The new Panamera 4S E-Hybrid. Drive defines us.
How can you measure progress? The new Panamera and its numbers make for a good start. Its 2.9-litre twin-turbo V6 engine combines with the electric motor to produce a system output of 412kW (560PS). And this new power is backed with an increased electric range. Only the best to drive your next project forward. Discover more at www.porsche.com/Panamera
Fuel consumption (in l/100km) combined 2.2–2.0; CO_2 emissions (in g/km) combined 51–47; electricity consumption (in kWh/100km) combined 18.1–17.4

Dirk Lappe
Managing Director Porsche Engineering

Dear Reader,

“Next level”—scarcely any other expression sums the situation in which we currently find ourselves more succinctly: In many fields, we simply have to reach the next level. We are familiar with the term from the worlds of computer games and sports. Those who have reached a certain level there often move on to the next level right away. This also applies to our work in automotive development: We cannot rest on our laurels.

We see this in trends such as artificial intelligence, the use of game engines in vehicle development and future E/E architectures, which we examine in the title series. They exemplify the increasing complexity of our work. We also have to reach the next level in our methods. In his article, Marius Mihailovici, Managing Director of our digital branch in Cluj, explains what this looks like in the software development sector.

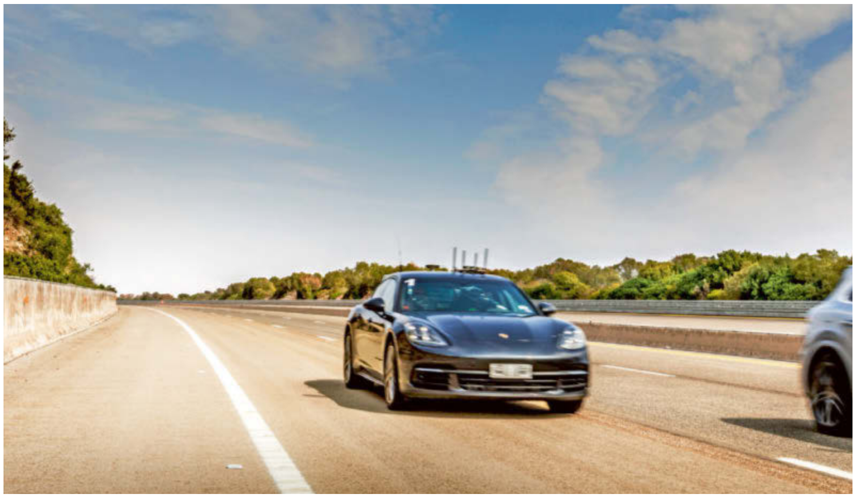
The coronavirus pandemic has greatly accelerated the demand for digital topics. New forms of work, for example, have found their way into development more quickly than anyone would have thought possible. The working world has changed for good. Completely new work and leadership concepts are now needed.

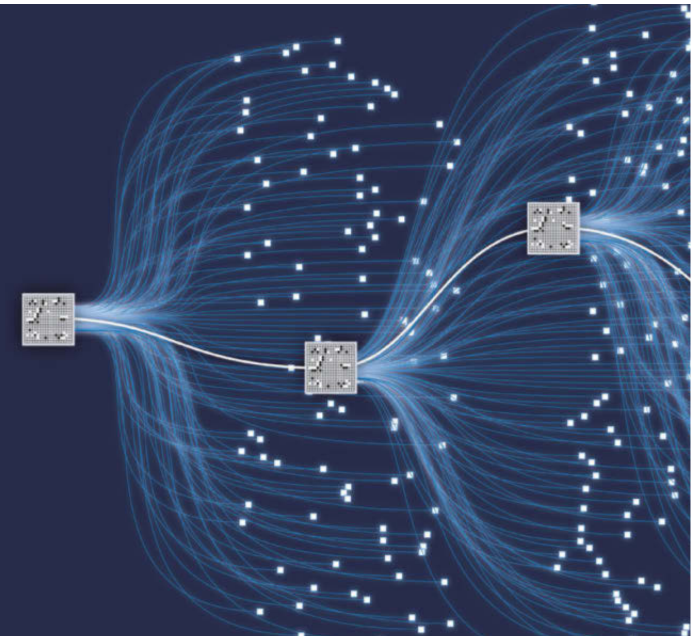
Sports, computer games, and work are most fun when the challenge of the next level and one’s own abilities are in balance. That’s why we continually usher our employees into the new era, train them early in future fields of activity and promote lifelong learning. In this way, we enrich what we love—the development of automobiles—with the next level of digital acumen. And in doing so, we are continuing a tradition that Ferdinand Porsche cultivated almost 90 years ago: the joy of tinkering and continuous further development—in short, the joy of the next level.

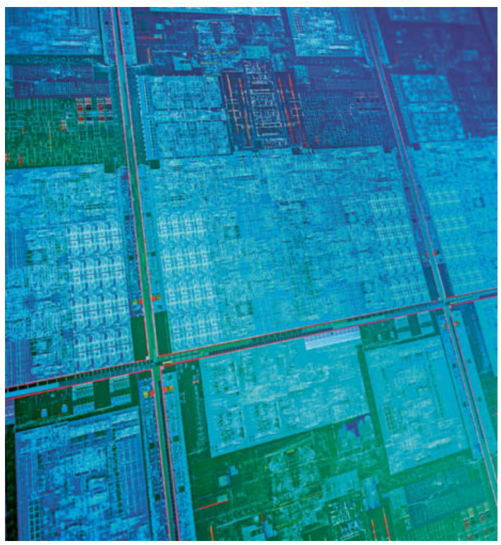
I hope you enjoy reading this issue of our magazine.

Best regards,
Dirk Lappe

ABOUT PORSCHE ENGINEERING: Creating forward-looking solutions was the standard set by Ferdinand Porsche when he started his design office in 1931. In doing so, he laid the foundation for today’s Porsche customer developments. We renew our commitment to that example with each new project that we carry out for customers. Porsche Engineering combines expertise from vehicle and system development with the latest innovations from function and software development and validates these using comprehensive simulation and testing facilities.







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Authors

34 **Christian Buck** is a science journalist from Berlin with a focus on IT/AI, energy, and mobility.

01 **Totto Renna (“Supertotto”)** is an illustrator and runs a one-man pixelart design studio based in Naples and Berlin.

46 **Theodor Barth** is a freelance photographer from Cologne who works in the fields of automotive, reportage, and portraiture.

News

Long-term collaboration with Tongji University

Close cooperation between industry and science

Porsche Engineering is continuing its long-standing commitment and traditional collaboration with Tongji University in Shanghai. One component of this is supporting the Tongji DIAN Racing Team in its Formula Student Electric campaign. In October, the new race car was presented at the Porsche Experience Center in the presence of Dr. Jens Puttfarcken, Managing Director of Porsche China, and Kurt Schwaiger, Managing Director of Porsche Engineering Shanghai. In mid-August, a driving training course for twelve team members was held by Porsche experts at the Porsche Experience Center Shanghai. The Tongji DIAN Racing Team has been in existence since 2013 and has about 100 members.

An essential part of the cooperation with Tongji University is the collaboration between instruction and business. In November, for example, 80 Tongji students took part in the Porsche Engineering Short Courses, in which Porsche Engineering engineers passed on their knowledge of vehicle dynamics, brake systems, electric motors, suspension design, batteries, and other topics. These events are intended to contribute to further expanding and intensifying the exchange between science, research, testing, and engineering. In addition, Porsche Engineering and the university are organizing the Tongji Porsche Engineering Symposium in Shanghai—an international conference featuring 100 experts for a professional dialog between business and science. The latest result of the collaboration is a new professorship at the School of Automotive Studies (SAS) at Tongji University. It is dedicated to the topic of Intelligent Connected Vehicles (ICV) and is intended to provide students the optimal training for this topic of the future. The professorship was created in cooperation with Porsche China, Porsche Engineering and the Chinese German Graduate School (CDHK). The agreement began on September 1, 2020 and will end on August 31, 2025.

Growing team and new R&D office

Porsche Engineering continues expansion in Ostrava

The Czech branch of Porsche Engineering in Ostrava has moved to a new research and development office in the Science and Technology Park. The 1,000 m² of office, laboratory, and workshop space are designed to meet the requirements of a growing team of experts. By moving directly to the university campus, Porsche Engineering is also aiming to intensify its collaboration with the Technical University of Ostrava.

Meeting needs in the time of the coronavirus

Company and staff step up to offer help

Porsche Engineering and Porsche AG are committed to helping those affected by the coronavirus pandemic. The Nardò Technical Center, for example, has donated almost 10,000 euros to the Italian Department of Civil Protection (for respirators and protective equipment). The Cluj location donated around 9,000 euros to the Beard Brothers aid organization (for medical equipment) and another 4,500 euros to the CERT Transilvania aid organization (for laptops and tablets for children). Furthermore, the AI team at Porsche Engineering has created a model to predict infection behavior, and employees from the Prague and Ostrava locations have supported the development of open-source medical ventilators. Porsche AG has launched a platform called "Porsche hilft" ("Porsche helps") to find institutions, companies, and organizations that need support. In addition, the company has increased its donation volume by five million euros, and hundreds of employees have volunteered, for example by going shopping for older neighbors.

PLEASE NOTE THAT THE PHOTOGRAPH WAS TAKEN BEFORE THE OUTBREAK OF THE CORONAVIRUS PANDEMIC.

Dual study program at Porsche Engineering

Shaping the future of automotive development

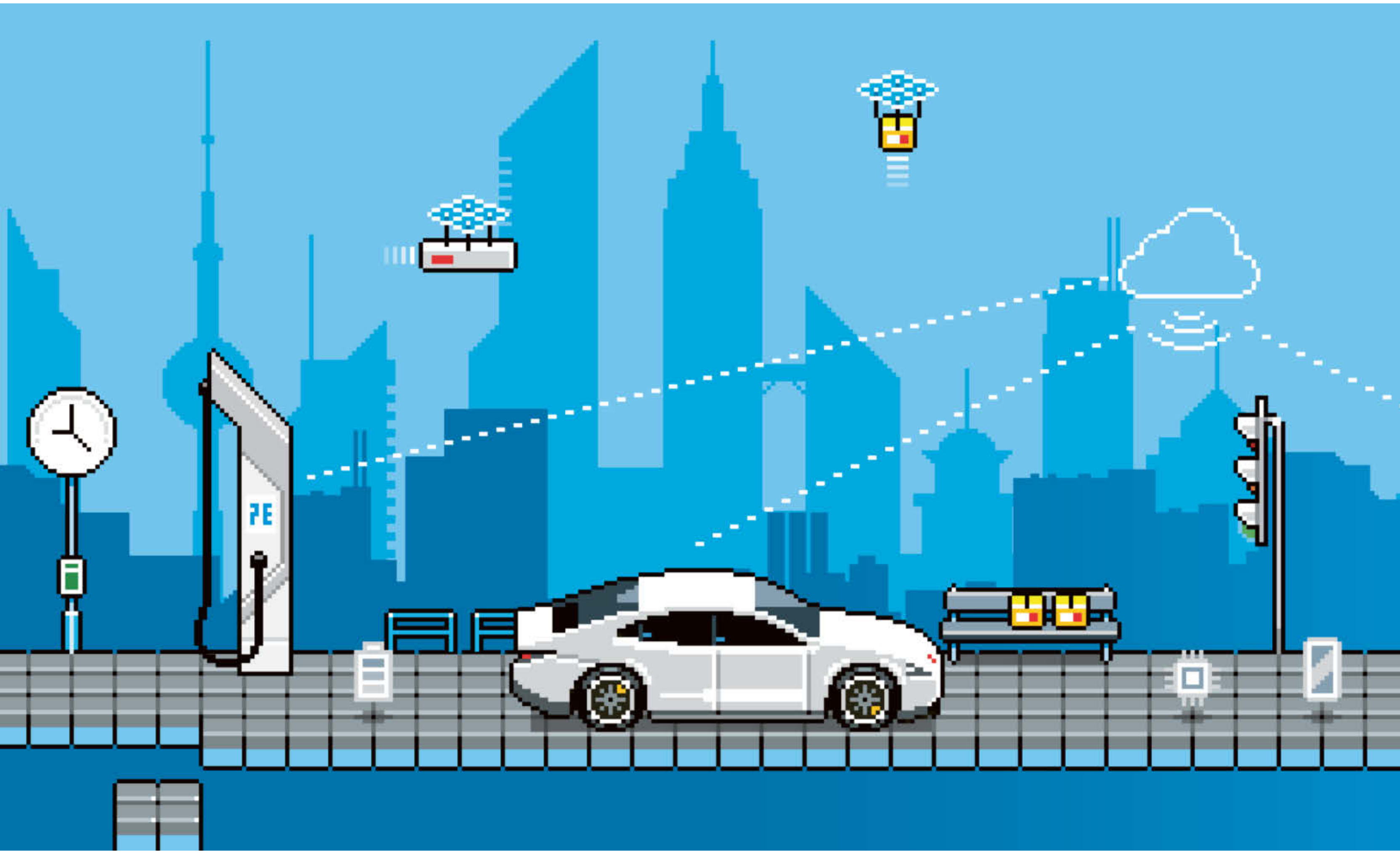
Acquire theoretical knowledge and apply it in practice: this is what a dual study program at Porsche Engineering offers. It starts in October, lasts six semesters and includes alternating three-month blocks of theory at the Baden-Wuerttemberg Cooperative State University in Stuttgart and three months of practical training at one of the engineering service provider's locations. Twelve students are currently studying mechanical engineering, mechatronics, and computer science at Porsche Engineering. The Computer Science with a major in IT Automotive program has been offered since 2018, and Computer Science with a major in Computational Data Science since 2020. Students immerse themselves in the world of computer science, help shape future IT systems, and drive key technologies such as AI.

90 years of engineering services by Porsche, 50 years of R&D Center Weissach

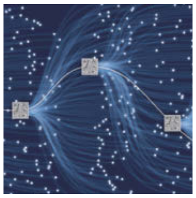
Two great reasons to celebrate in 2021

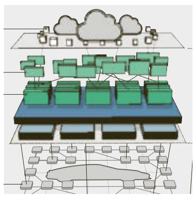
Next year it will be 90 years since Ferdinand Porsche founded his engineering office. On July 25, "Dr. Ing. h.c. F. Porsche GmbH, Konstruktionen und Beratungen für Motoren und Fahrzeugbau" was entered in the Stuttgart commercial register in 1931. The tradition lives on: development on behalf of customers continues under the name Porsche Engineering to this day. 50 years ago the construction, testing, design, and racing departments moved from Zuffenhausen to Weissach. The Porsche Development Center in Weissach started operations on October 1, 1971. Construction of the test track had already begun there ten years earlier: the ground-breaking ceremony for the Skid Pad was performed by Ferry Porsche. Just one year later, a Porsche 356 drove on the test track for the first time.

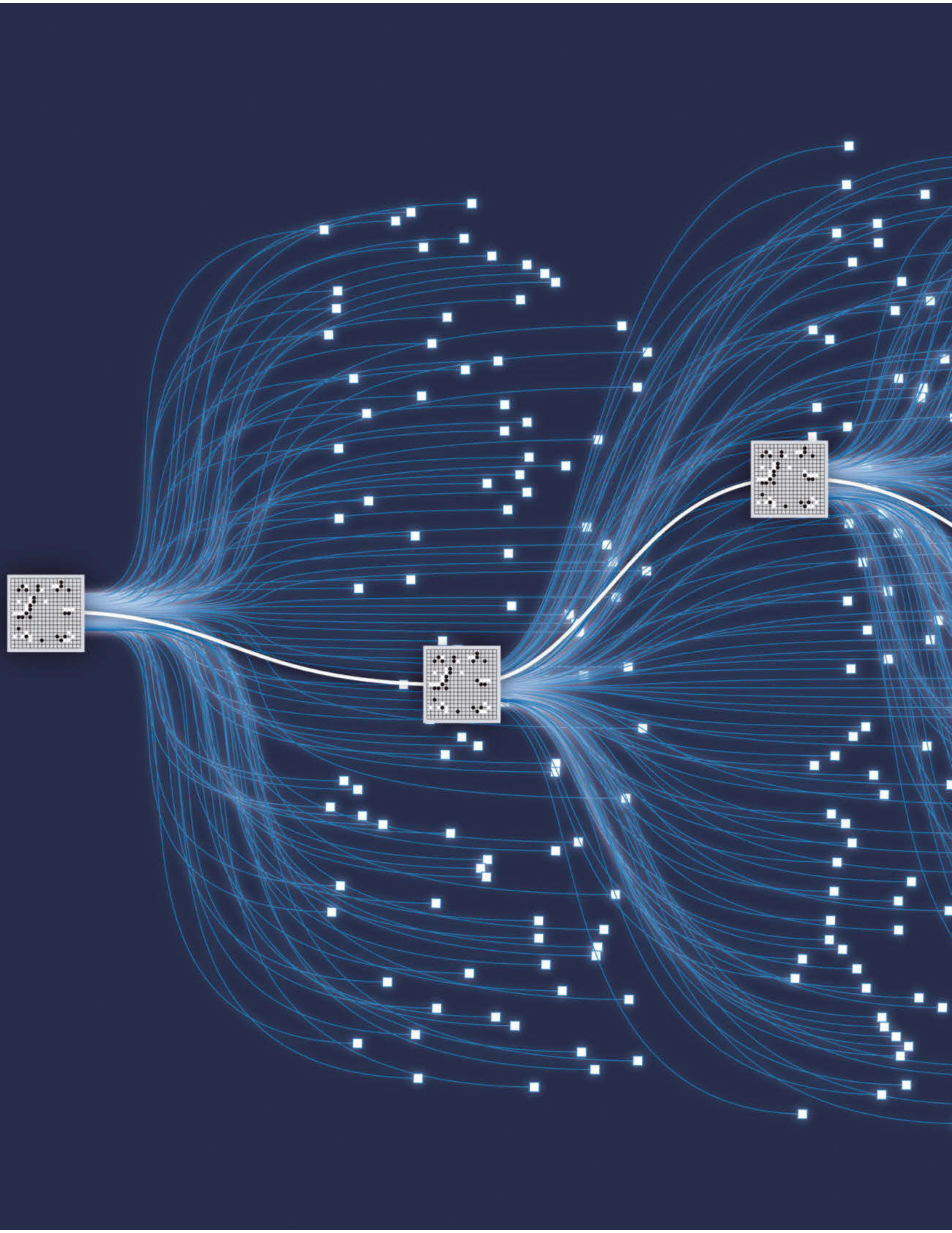
Next level



Automotive development is entering a new phase. Increasingly, digitalization is shaping the work of engineers—through the advent of innovative tools and methods and to enable new vehicle functions. Today, not only artificial intelligence is part of the everyday life of developers, but also technology from the field of computer games.





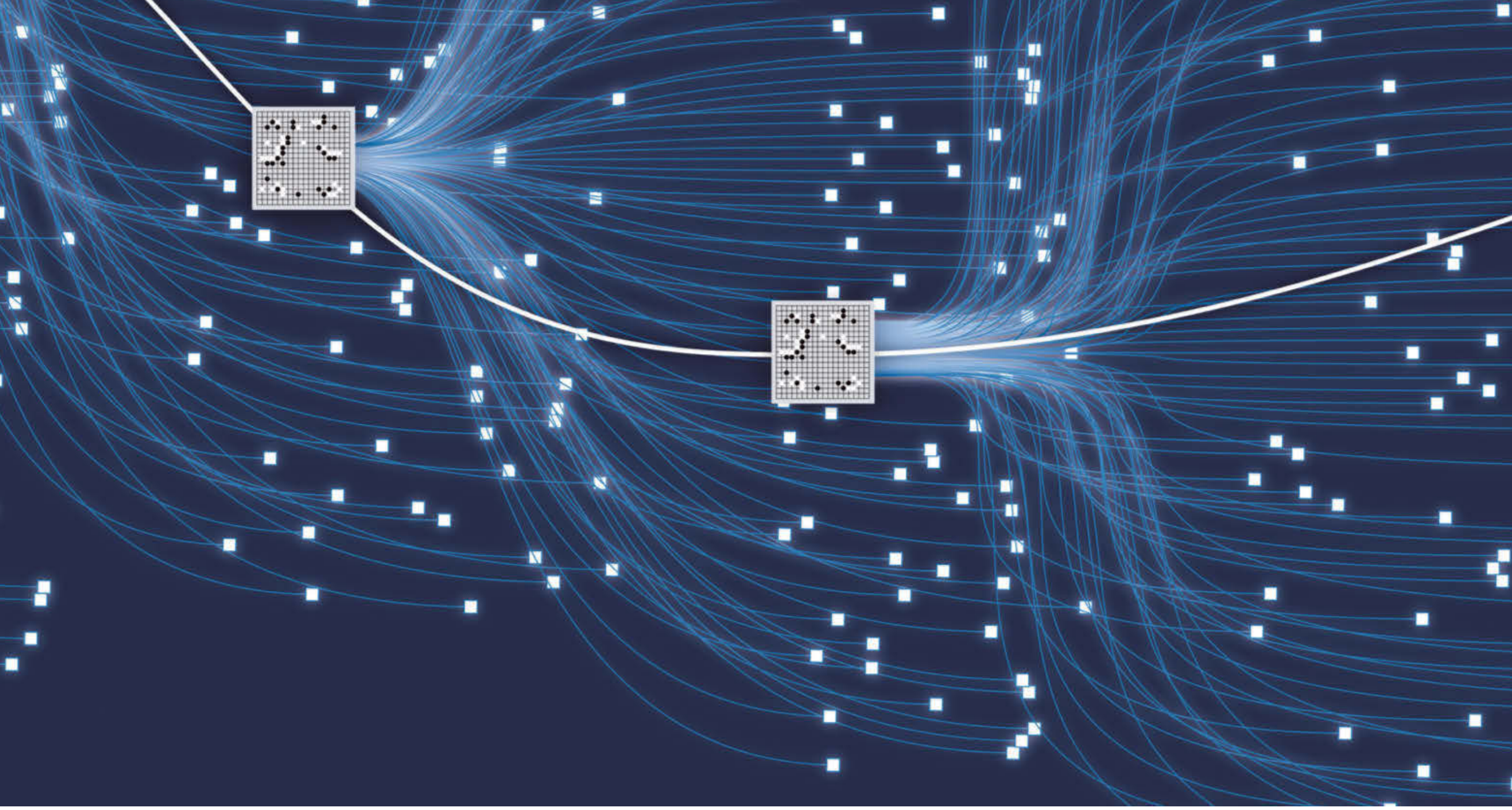


Chronicle of a milestone: The graphic shows the progression of the go game between Lee Sedol and AlphaGo in 2016 (big squares). The small squares represent alternative courses of the game.

Success strategy courtesy of the AI agent

Text: Richard Backhaus Contributors: Matteo Skull, Dr. Matthias Bach

As the scope of functions in modern vehicles expands, so too does the calibration work involved. This is why Porsche Engineering has developed PERL: the innovative calibration methodology is based on deep reinforcement learning and considerably reduces the time and cost of the calibration.



Experts regard 2016 as a milestone in the history of artificial intelligence (AI). Largely unnoticed by the general public in Europe and the USA, the computer program AlphaGo competed against the South Korean world-class player Lee Sedol in the board game go and won four of the five games. This was the first time that a computer was dominant in the traditional Asian strategy game. Until then, it had not been possible to teach software the complex strategy of the board game—the required computing power and computing time would have been too great. The turning point came when the AI in the go computer was trained using deep reinforcement learning.

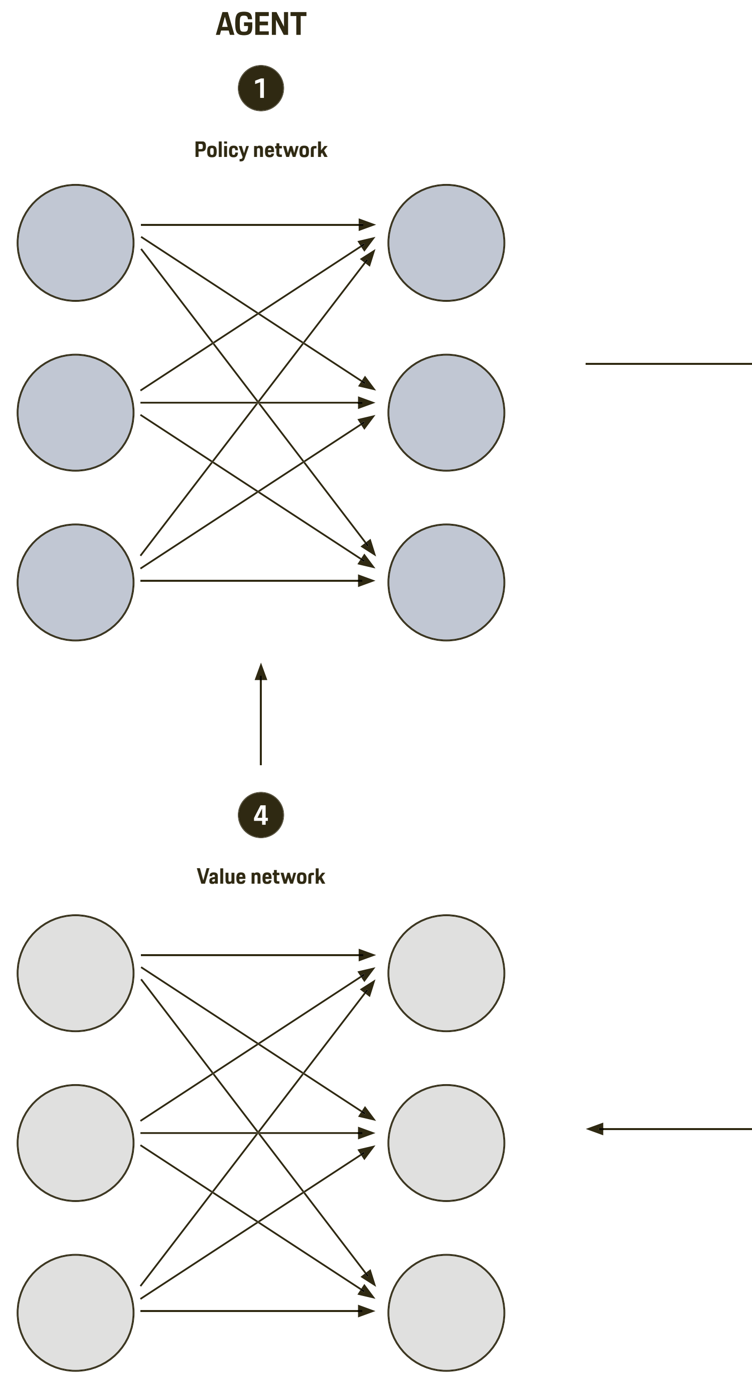
One of the superlative disciplines of AI

Deep reinforcement learning, still a relatively new methodology, is considered one of the supreme disciplines of AI. New, powerful hardware in recent years has made it possible to use it more widely and to gain practical experience in applications. Deep reinforcement learning is a self-learning AI method that combines the classic methods of deep learning with those of reinforcement learning. The basic idea is that the algorithm (known as an "agent" in the jargon) interacts with its environment and is rewarded with bonus points for actions that lead to a good result and penalized with deductions in case of failure. The goal is to receive as many rewards as possible.

To achieve this, the agent develops its own strategy during the training phase. The training template provides the system with start and target parameters for different situations or states. The system initially uses trial and error to search for a way to get from the actual state to the target state. At each step, the system uses a value network to approximate the sum of expected rewards the agent will get from the actual state onwards if it behaves as it is currently behaving. Based on the value network, a second network—known as the policy network—outputs the action probability that will lead to the maximum sum

How PERL learns the best calibration strategy

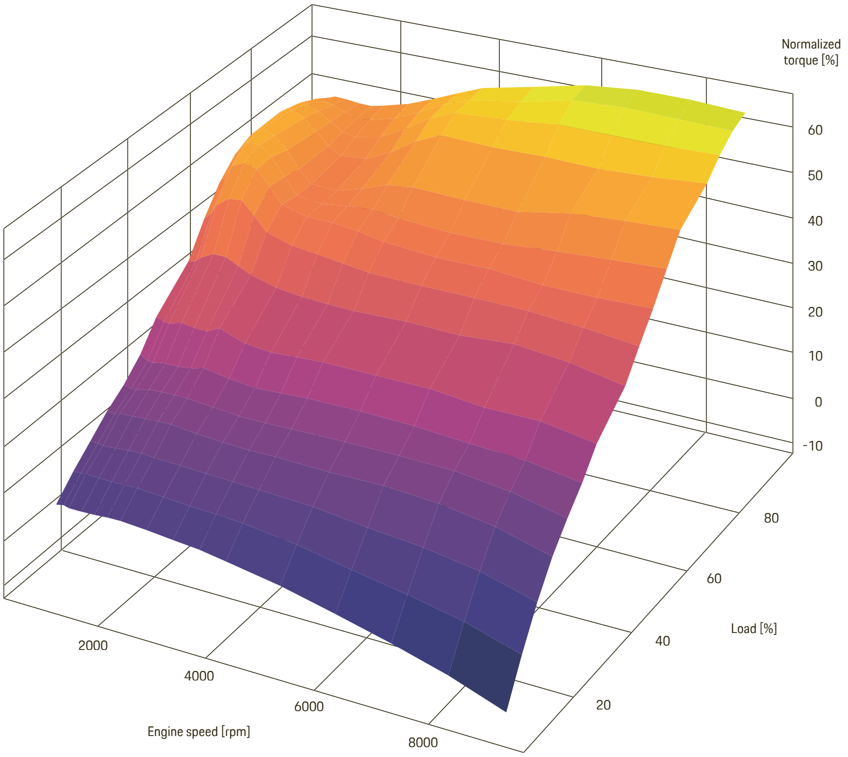
PERL uses two neural networks to determine the best calibration strategy: the policy network and the value network. An algorithm (the "agent") interacts with the environment to iteratively improve the weighting factors of the two networks. At the end of the training, the optimal calibration methodology is found—even for engines with varying designs, charging systems, and displacement.



ENVIRONMENT

2

Characteristic map



ACTION

Increase or decrease the values in the map

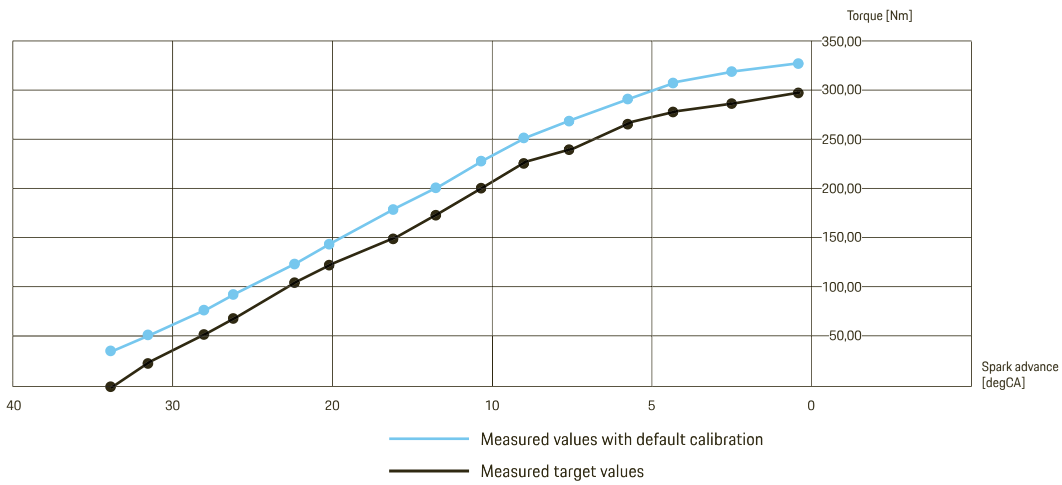
Agent on a mission

The aim of the calibration task is to minimize the deviation betwen the target measured values (black curve in the graph below) and the one with the default calibration (blue curve). To do this, the agent uses the policy network (1) to change the values in the map (2). Based on the resulting deviation (3) the agent gets positive rewards if it further reduced the deviation, negative rewards if the deviation increased. The value network (4) is used to approximate a value function, on the basis of which the agent plans the next possible action. The calibration task is finished once the deviation has been minimized to within a certain range.

3

Measured engine torque at the test bench [Nm]

Positive or negative rewards depending on the resulting deviation from the target value



"PERL is highly flexible because parameters such as the engine design, displacement or charging system have no influence on learning success."

Matteo Skull, Engineer at Porsche Engineering

of expected rewards. This then results in its methodology, known as the "policy," which it applies to other calculations after completing the learning phase.

In contrast to other types of AI, such as supervised learning, in which learning takes place based on pairs of input and output data, or unsupervised learning, which aims at pattern recognition, deep reinforcement learning trains long-term strategies. This is because the system also allows for short-term setbacks if this increases the chances for future success. In the end, even a master of the stature of Sedol had no chance against the computer program AlphaGo, which was trained in this way.

Use in engine calibration

The performance of deep reinforcement learning in a board game gave the experts at Porsche Engineering the idea of using the method for complex calibration tasks in the automotive sector. "Here, too, the best strategy for success is required to achieve optimal system tuning," says Matteo Skull, Engineer at Porsche Engineering. The result is a completely new calibration approach: Porsche Engineering Reinforcement Learning (PERL). "With the help of Deep Reinforcement Learning, we train the algorithm not only to optimize individual parameters, but to work out the strategy with which it can achieve an optimal overall calibration

Unimaginable complexity

Go is among the classic strategy board games. The goal is to occupy more squares on the board with your stones than your opponent. In contrast to chess, for example, there are only two types of pieces in go—black and white pieces—and only one type of move, namely placing a stone. The high complexity of the game of go results from the large number—10^{170}—of possible constellations on the 19 by 19 board—a sum that is beyond all training possibilities for human go players. Since the success of the game is highly dependent on human intuition during the game and chance has no influence on the course of the game, go is predestined for the use of artificial intelligence, as AlphaGo impressively proved with its game against Lee Sedol. By the way, the former go champion has drawn his own conclusions from the superiority of AI: in late 2019, Sedol announced his retirement from competing professionally in go.

result for an entire function," says Skull. "The advantages are the high efficiency of the methodology due to its self-learning capability and its universal applicability to many calibration topics in vehicle development."

The application of the PERL methodology can basically be divided into two phases: the training phase is followed by real time calibration on engine dyno or in vehicle. As an example, Skull cites the torque model with which the engine management system calculates the current torque at the crankshaft for each operating point. In the training phase, the only input PERL requires is the measurement dataset from an existing project, such as a predecessor engine. "PERL is highly flexible here, because parameters such as engine design, displacement or charging system have no influence on the training success. The only important thing is that both the training and later target calibration use the same control logic so that the algorithm implements the results correctly," says Skull.

During training, the system learns the optimal calibration methodology for calibrating the given torque model. At critical points in the characteristic map, it compares the calibrated value with the value from the measurement dataset and approximates a value function using neural networks based on the resulting rewards. Using the first neural network, rewards for previously unknown states can be estimated. A second neural network, known as policy network, then predicts which action will probably bring the greatest benefit in a given state.

Continuous verification of the results

On this basis, PERL works out the strategy that will best lead from the actual to the target value. Once training is complete, PERL is ready for the actual calibration task on the engine. During testing, PERL applies under real-time conditions the best calibration policy to the torque model. In the course of the calibration process, the system checks its own results and adjusts them, for example if the parameter variation at one point in the map has repercussions for another. "In addition, PERL allows us to specify both the calculation accuracy of the torque curve and a smoothing factor for interpolating the values between the calculated interpolation points. In this way, we improve calibration robustness with regards to influences of manufacturing tolerances or wear of engine components over engine lifetime." explains Dr. Matthias Bach, Senior Manager Engine Calibration and Mechanics at Porsche Engineering.

"With PERL, we improve calibration robustness with regards to the influences of manufacturing tolerances or wear of engine components over engine lifetime."

Dr. Matthias Bach, Senior Manager Engine Calibration and Mechanics at Porsche Engineering

In the future, the performance of PERL should help to cope with the rapidly increasing effort associated with calibration work as one of the greatest challenges in the development of new vehicles. Prof. Michael Bargende, holder of the Chair of Vehicle Drives at the Institute of Automotive Engineering at the University of Stuttgart and Director of the Research Institute of Automotive Engineering and Vehicle Engines Stuttgart (FKFS), explains the problem using the example of the drive system: "The trend towards hybridization and the more demanding exhaust emission tests have led to a further increase in the number of calibration parameters. The diversification of powertrains and markets and the changes in the certification process have also increased the number of calibration that need to be created." Bargende is convinced of the potential of the new methodology: "Reinforcement learning will be a key factor in engine and powertrain calbrations."

Significantly reduced calibration effort

With today's conventional tools, such as model-based calibrations, the automated generation of parameter data—such as the control maps in engine management—is generally not optimal and must be manually revised by the calibration engineer. In addition, every hardware variation in the engine during development makes it necessary to adapt the calibration, even though the software has not changed. The quality and duration of calibration therefore depend heavily on the skill and experience of the calibration engineer. "The current calibration process involves considerable time and cost. Nowadays, the map-dependent calculation of a single parameter, for example the air charge model, requires a development time of about four to six weeks, combined with high test-bench costs," said Bach. For the overall calibration of an engine variant, this results in a correspondingly high expenditure of time and money. "With PERL, we can significantly reduce this effort," says Bach, with an eye to the future.

→ IN BRIEF

The innovative PERL methodology from Porsche Engineering uses deep reinforcement learning to develop optimal strategies for engine calibration (the "policy"). Experts regard the new AI-based approach as a key factor in mastering the increasing complexity in the field of engines and powertrain systems in the future.

“There are no limits to your imagination”

Interview: Richard Backhaus
Photos: Steffen Jahn

New functional scopes are increasingly represented by the overall system networking within the electrics/ electronics (E/E) architecture of the vehicle. Dr. Oliver Seifert, Vice President Electrics/Electronics Development at Porsche AG, and Dirk Lappe, Managing Director of Porsche Engineering, will discuss the effects this has on E/E development, the opportunities it offers, and what the E/E platform of the future will look like.

A conversation with electrics/electronics experts: Dr. Oliver Seifert (left) and Dirk Lappe.

Looking ahead: E/E architectures must be flexible enough to meet all future requirements.

What are the central trends in E/E development, and what are the challenges?

— **DR. OLIVER SEIFERT**: The first trend is the further development of the battery electric vehicle, driven by the requirements of legislation and the markets—but also by our own claim at Porsche to make electric driving even more attractive, for example in terms of range and charging performance. The second trend is the seamless integration of the vehicle into the customer's digital ecosystem. The resulting challenges affect the development processes of the E/E system architecture in particular. This is because the demands placed on us are changing very dynamically. We must optimize our processes so that we can react quickly to new market needs. It is therefore a combination of new tasks and short timeframes that will shape future developments.

What will the E/E architecture of the future look like?

— **SEIFERT**: Future E/E architecture must perform a difficult balancing act. On the one hand, it must offer a high degree of flexibility in order to be able to cover the requirements of the future—although they have not yet been defined in detail, of course. In doing so, we must not lose sight of aspects such

"Future E/E architecture must perform a difficult balancing act. On the one hand, it must offer a high degree of flexibility and, on the other hand, we must guarantee a high degree of functional stability."

Dr. Oliver Seifert

as costs and the vehicle package. On the other hand, we have to guarantee a high level of functional stability of the E/E system so that the system developers have a valid platform on which to present the new functional scopes. With our current E/E architectures we have created a good basis for this. The core of future architecture concepts is the E^3 approach. The vehicle functions run on a few highly complex control units, the HCPs (High Performance Computing Platforms). In addition, there are a large number of simple controllers for controlling the mechatronic sensors and actuators in the E/E network. We will probably have as many electronic and mechatronic components in the vehicle as we have today, but the intelligence and complexity will be distributed differently.

— **DIRK LAPPE:** In the practical implementation of the E/E architecture, we will have to comply with strict legal requirements in the automotive sector, for example with regard to cyber security. This gives us a clear framework for designing future system architectures. Compared to consumer electronics products, we therefore face completely different tasks. Another point is product life. A smartphone is considered obsolete after six years at the latest, at which point software updates for the operating system are no longer offered. When we bring a vehicle onto the market, it must still be capable of being updated after ten or 15 years. The E/E development has the important cross-sectional task of keeping the vehicle's functions safe and running throughout the vehicle's service life.

E^3

is the approach for future E/E architecture concepts, a combination of HCPs and simple controllers.

HCP

High Performance Computing Platforms (HCPs) are powerful computers that perform the tasks of many of today's control units.

To what extent do functions and software characterize the Porsche of the future?

— **SEIFERT:** Software is already the backbone of our vehicles today. No modern car can drive without bits and bytes. And it is precisely this software that gives us the opportunity to design Porsche-specific vehicle characteristics that would previously have been impossible or difficult to implement via mechanics. One example is the matrix light, which has turned yesterday's simple headlights into a modern assistance system. In the past, headlights were only used to illuminate the road. Today's matrix system does the same, but controls the light intensity so intelligently that oncoming traffic is not dazzled and disturbing reflections from road signs at the edge of the road are avoided. And if a person is standing at the side of the road, the matrix light illuminates this area in particular to draw attention to the potential hazard situation. We create the preconditions for integrating new features into the vehicle through the underlying E/E architecture.

“We see ourselves as a complete vehicle developer that implements new functions holistically, including the software.”

Dirk Lappe

It must therefore be designed with the future in mind, so that we can react to requirements that we cannot even foresee today.

What does Porsche Engineering do in the area of function and software development?

— **LAPPE:** We see ourselves as a complete vehicle developer that implements new functions holistically, including the software. This is a big difference to competitors who can only create software and have no know-how about vehicle development. Software gives us the opportunity to optimally implement the potential of a hardware component. For example, an air suspension system can be applied with a standard set-up, or you can take advantage of the scope for design and use the same hardware to create a chassis that glides over potholes in a highly comfortable manner and, at the touch of a button, offers dynamic cornering ability typical of a sports car. We are car freaks who also love to program.

How does the E/E collaboration between Porsche and Porsche Engineering work?

— **SEIFERT:** Porsche Engineering is a constant in our E/E development. I assume that this collaboration will be much more intensive in the coming years. This is particularly true for developments in the future fields of connectivity and e-mobility. The nice thing about Porsche Engineering is that the engineers there can do both: software and cars.

— **LAPPE:** One of our most important efforts in recent years and decades has been to support the development of E/E competence within Porsche AG. The result is a symbiosis that continues to this day. Today we work as a strategic partner on larger software scopes and other E/E topics.

How important are local E/E solutions for different markets?

— **SEIFERT:** In regions like Asia or North America, customers today demand their own specific solutions. While there are similarities, there are also major differences due to the respective cultural backgrounds, digital ecosystems and legal requirements. The ever-increasing diversification of the markets poses great challenges for the entire

Dr. Oliver Seifert has been Vice President Electrics/Electronics Development at Porsche AG since the beginning of 2020. Seifert, who holds a doctorate in physics, previously worked for Porsche as Director of Integration, Maturity & Quality and in other management positions, in particular in Integration Management. Before joining the sports car manufacturer, he was Managing Director of a medical technology company and Quality Engineer E/E at Daimler AG.

Perfect context:
Dirk Lappe and Dr. Oliver Seifert met for talks at Porsche's Electrical Integration Center (EIZ) in Weissach.

industry. The variants must be taken into account throughout the entire development process, right up to the functional validation, which can only take place locally in the respective markets. To do this, we need development partners such as Porsche Engineering that understand the special characteristics of the individual regions and the cultural background there.

— **LAPPE:** We have found that you have to be on site in China in order to understand the market there and to be able to implement certain developments quickly and purposefully. For around four years now, we have therefore been using our capacities in China to develop and verify locally specific solutions for Porsche, among other activities. Our team in China consists primarily of local colleagues who, like us, have gasoline and electrons in their blood, but who also have a local connection. During development, they work closely with their Chinese colleagues from Porsche China and Porsche Digital, but of course also with our experts in Germany.

Dirk Lappe has been the Managing Director of Porsche Engineering since 2009. The electrical engineer joined the company in 2002, where he initially took over as Director of the Electrics/Electronics department. Prior to that he worked for Harman Becker and Bosch.

What role does E/E development at Porsche play compared to other development areas such as body, powertrain, or chassis?

— **SEIFERT:** Today's functions are no longer developed by one department alone. Our task is to ensure that the infrastructure for all development areas involved is uniform. This includes scopes such as control units, basic software, diagnostic functions, and the entire electronic architecture. With the electronics platform, we create the stable foundation, so to speak, on which colleagues from the other development areas can then implement the functions.

How are Porsche and Porsche Engineering dealing with the transformation in automotive development?

— **LAPPE:** The importance of software and the expertise to develop it grows with the transformation. We have set up a change process to integrate experts from the classic trades more closely into the software development area. We have a large number of engineers with 20 or more years of professional experience on board who are prepared to leave their original fields of work and contribute to the further development of our software capability. The employees are particularly valuable to the company after the transformation, as they bring both mechanical and electronic understanding to the function development discipline.

— **SEIFERT:** It is important to actively pursue a transformation process and not to wait until you are forced to do so by external factors. We don't want to chase the proverbial carrot, but rather lead the race. And as you know, we feel very comfortable on the race track. However, we do not have the aspiration to follow every trend as a matter of course. You always need a stable basis as the starting point for a successful transformation into new worlds of working, processes, and products. And we must never forget that there are people behind every transformation. We see ourselves as one family and make sure that we do not overburden our employees, but give them the necessary support.

What role does sustainability play in the E/E development of the future?

— **SEIFERT:** A very big role. We pursue the idea of sustainability throughout the entire value chain. In component development, we take these requirements into account, for example, in material selection and component design. But with our E/E architecture and our functions, we also contribute to sustainability in terms of vehicle operation. For example, we design the system so that the available energy in the vehicle is always used as efficiently as possible. Another point is to ensure that the vehicles in the field last as long as possible. Our flexible electronics architecture can be upgraded to the latest state of the art over the years, so that customers can and want to use their vehicles for a long time.

Is there a Porsche feature that you would not digitalize or electrify?

— **SEIFERT:** The design of our vehicles is an emotional experience and certainly something that cannot be digitalized per se. Otherwise, there are no limits to one's imagination. However, it is important that the result feels typical for Porsche; otherwise digitalization makes no sense. We have already shown how typical Porsche electrification works in a variety of areas: whether it's steering, brakes, powertrain units or other systems, regardless of the model series. And I can only recommend it to anyone who has not yet experienced these characteristics themselves: Try them out in the Porsche Taycan!

— **LAPPE:** We will not be able to replace humans with computers in the development process. We need the creativity of our engineers to improve individual functions and develop new features. This is an innovation process that can never be digitalized.

Which E/E project outside of automotive development would you like to dedicate yourself to?

— **LAPPE:** It would be fascinating to develop a translation tool that works in real time and allows you to communicate with everyone around the world in their native language. By communicating together, many misunderstandings could be cleared up and some of the current global challenges could be overcome more easily.

— **SEIFERT:** I can only agree with that. Communication is the be-all and end-all. This is the case with people—and also with vehicles.

"We pursue the idea of sustainability throughout the entire value chain."

Dr. Oliver Seifert

"We need the creativity of our engineers. This is an innovation process that can never be digitalized."

Dirk Lappe

Taycan 4S

Power consumption (combined) (Performance Battery): 26.2 kWh/100 km
Power consumption (combined) (Performance Battery Plus): 27.0 kWh/100 km
CO_2 emissions (combined): 0 g/km
Energy efficiency class: A+

Taycan Turbo

Power consumption (combined): 28.0 kWh/100 km
CO_2 emissions (combined): 0 g/km
Energy efficiency class: A+

Taycan Turbo S

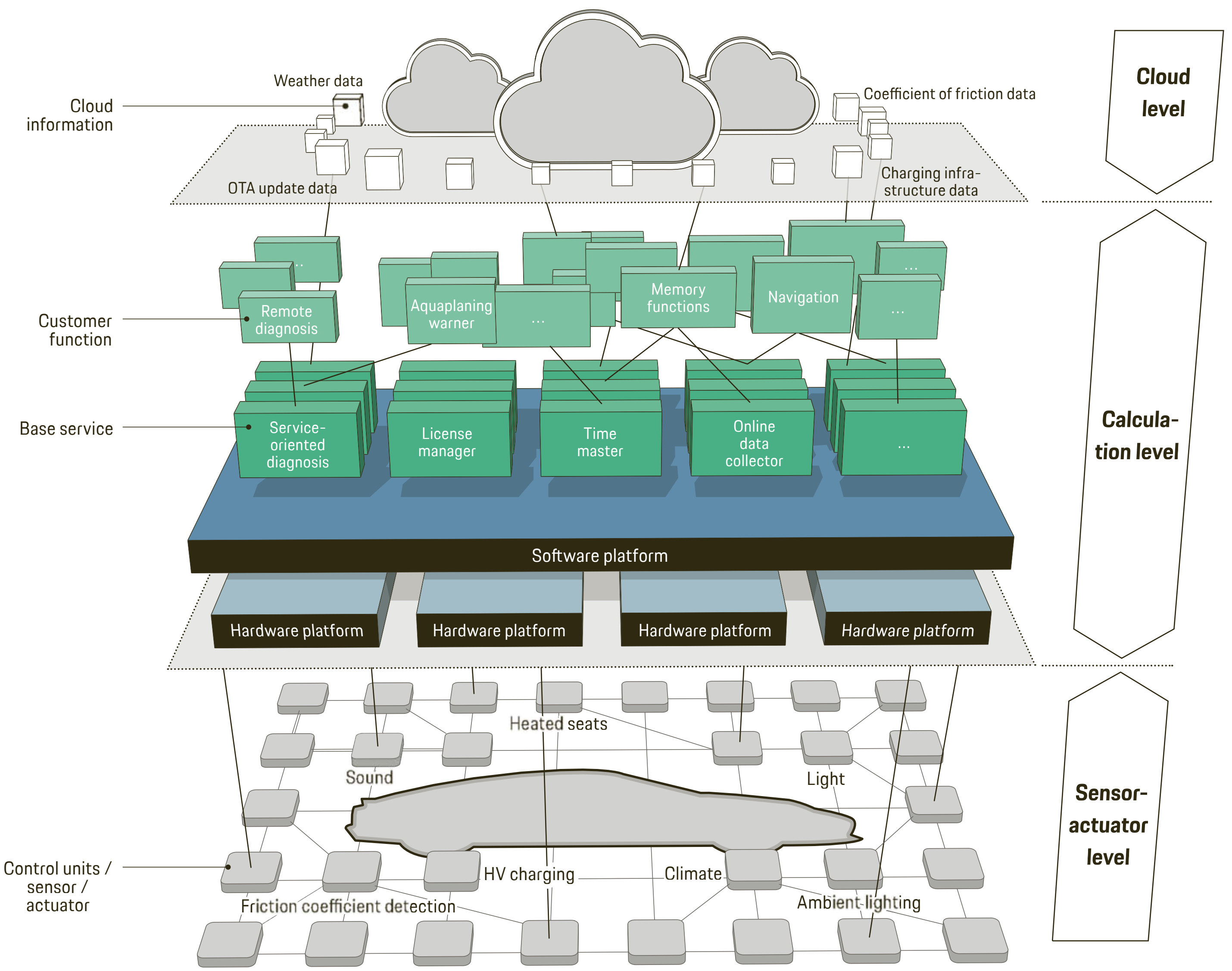
Power consumption (combined): 28.5 kWh/100 km
CO_2 emissions (combined): 0 g/km
Energy efficiency class: A+

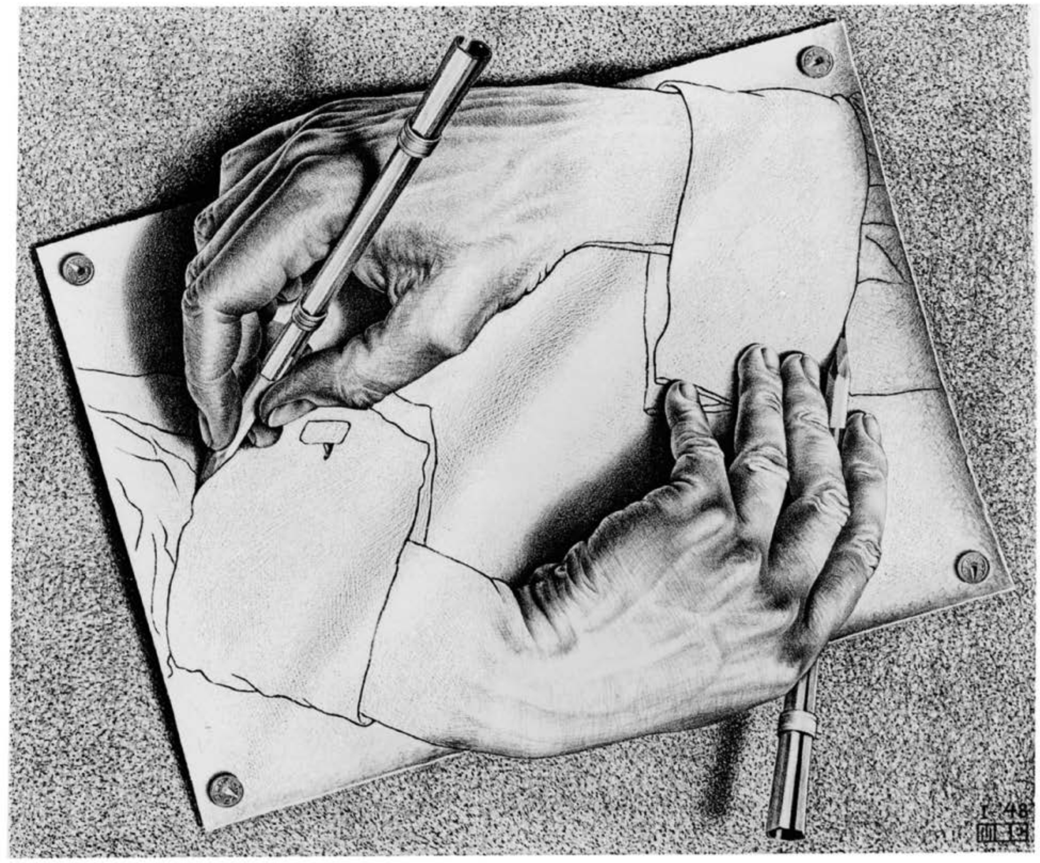
E³: End-2-End Electronics architecture

The vehicles of the future will have revolutionary functions. In addition to current trends such as electromobility, connectivity and autonomous driving, the need to network the vehicle with the environment will increasingly become the focus of future architectures. Applications in subject areas such as remote update and diagnosis, car-2-infrastructure and big-data and cloud functions will play an increasingly important role in the future. In order to implement modern functions in the vehicle and thus keep it up-to-date and maximally useful for the customer, Porsche is continuously developing a new E³ architecture (End-2-End Electronics architecture). Its structure is open and modular—based on a holistic approach of an end-to-end architecture with a vehicle backend as an integral component. It comprises several levels: the sensor-actuator level includes functions such as sound, light, heating, and ambient lighting. The basic services and customer functions such as navigation, remote diagnosis, or the aquaplaning warner run on the computing level. The final level is the cloud level: this level contains information that is stored in the cloud, such as weather or friction coefficient data.

In addition to new demands on the technical infrastructure, such as high-performance central processing units, high-speed networking, new diagnostic concepts, and adequate security concepts, the E³ architecture also focuses on the consideration of corresponding changes in the environment of associated development processes and collaboration models.

The trend towards shifting functions from the vehicle to the vehicle backend requires a consistent and service-oriented software architecture—both in the vehicle and in the backend. It enables the cross-domain interoperability of all services and the seamless usability of powerful cloud services. With the help of the E³ architecture, the vehicle is integrated into an overall ecosystem of services, which will provide the customer with a variety of new functions in the future—and enable a new level of comfort and mobility.





When software writes software

Text: Marius Mihailovici

Software is increasingly becoming the determining factor in automotive development. In his article, Marius Mihailovici, Managing Director of Porsche Engineering Romania, takes a look into the future of software development and explains why the job of a programmer could change completely in the next 20 years.

There are 100 million lines of code in a modern car. A Boeing 787 Dreamliner boasts a mere 14 million lines.

Even today, cars are very much rolling computers. They contain a network of dozens of computing units: between 70 and 100 of these electronic control units (ECUs) are installed in modern vehicles. ECUs control fuel injection, regulate braking behavior, and monitor the air conditioning system. The next step will be HCPs (High Performance Computing Platforms), which will enable significantly more computing power to be integrated into an ECU.

The higher computing power and integration are necessary because the number of lines of code and the complexity of the functions in the vehicle are increasing year by year. One number may make this clear: 100 million. This is the number of lines of code in a modern car. By comparison: a Boeing 787 Dreamliner only has 14 million lines of code.

There are also many lines of code behind the entertainment system and navigation. Added to this is the possibility of connecting smartphones and other devices to the car, which is also only possible with complex software. And it doesn't stop there. Software is taking over more and more important tasks in the car. The most important functions today and in the future include data exchange with other road users and the infrastructure, updating vehicles from the cloud, and eventually even autonomous driving.

The balancing act in development

The development of automotive software has become a rather tricky balancing act. Safety regulations and customer requirements in the form of voluminous specifications need to be fulfilled. The conventional development processes in the industry are usually time-driven: there is a predefined schedule that defines certain milestones. Our clients expect regular results at predetermined dates.

100

electronic control units can be located in a modern vehicle to control central functions such as fuel injection or brakes.

Added to this are the official approval processes known as homologation. For example, it stipulates that vehicles not be brought to market until they have been built and accepted in a certain quantity. In the end, the industry is always about moving from one "finished" state to the next.

All these different challenges mean that fast and flexible work is required. Targets are often set at short notice and change quickly. One might say that software is developed in a results-driven process.

Agility and continuous integration

In Cluj our software developers work with tools that have proven themselves in software development for 20 years. We use agile methods wherever possible. They are based on small development steps whose results are checked in daily feedback rounds. The individual teams have a great deal of freedom and work directly with each other to support each other with their respective capabilities. They flexibly set their own goals each day. Team leaders often have only a moderating function here and keep an eye on the big picture.

Another current paradigm of software development is "continuous integration." This is a highly automated

Moderator: Marius Mihailovici's teams have great freedom and set their own goals.

The use of agile methods and continuous integration ensures greater efficiency and also offers our customers added value.

process in which software elements are checked at the end of a working day to see if they are ready to run and integrated into the overall system. In this way, we can quickly identify and eliminate errors and problems. The use of agile methods and continuous integration ensures greater efficiency and also offers our customers added value: it makes it easier to present interim results and gives them the opportunity for quick feedback.

For the next five years, I expect to see an increasing use of the methods described above. Our work will be even more results-driven than time-driven. Team hierarchies are likely to become less important, and I foresee a higher degree of flat and self-organizing teams with clear responsibilities. Moreover, it will become much more prevalent to work flexibly from different locations, based on the idea of putting people to work where the expertise exists. We will also see increasing automation in the coming years. More and more often, software is tested by software and not by people. Manual testing will disappear completely.

The software is no longer developed and installed just once, but is constantly further developed, even when the car is already in the customer's hands.

The boundaries between car and environment are blurring

Developments outside the automotive industry will also force us to rethink things, as cars are increasingly integrated into the digital lives of their drivers. For example, the smartphone automatically connects to the vehicle when getting in. Media use, navigation, and communication merge seamlessly.

It is use scenarios like these that will change the content of our software developers' work—for the simple reason that the boundaries between pure "automotive software" and other applications are becoming blurred. Incidentally, this also requires a certain mindset on the part of our developers: we employ people who live the digital lifestyle themselves. They not only know what our clients demand, but also what vehicle users expect from their cars.

ECUs of the future influence software development

New ECU architectures are also changing the way automotive software is developed. I assume that in the car of the future there will be a few central, very powerful computers of the HCP type, which, together with subordinate, simpler units, will control the entire vehicle. These central units will also run all applications that go beyond basic functions, such as entertainment, data traffic, or passenger communication applications. These central computers with a real operating system truly turn the car into a PC on four wheels.

For developers, this means that the methods of their work do not change that much. What changes are the systems they are dealing with: they are more hierarchical, have fewer components, and are controlled by one overall software. And this—like any software—will receive regular updates. So the software of a car is not developed and installed once, but is constantly being further developed, even when the car is already in the customer's hands.

AI

could take over some software development tasks over the next two decades. Software engineers will still be needed.

A future without software developers?

The question is by no means absurd: will there still be software developers in the future? Some experts assume that artificial intelligence (AI) will take over software development completely in the next two decades—even in the automotive industry. Opinions differ on this, however. Personally, I can imagine that we will continue to set the framework and that AI will then implement it. We will still need software architects, requirements engineers, and software engineers to define what AI or neural networks will do: generate software functions based on the defined requirements, test them automatically, and correct them continuously until the software quality is at the expected level.

The developers of the future must therefore be able to think in terms of complete systems. They must know how end customers use their vehicles. Their work is not only determined by the specifications of the OEMs, but increasingly by the consumers. There is one thing, however, that I cannot imagine: a software completely without "bugs." There will always be mistakes. We just don't have to find and fix them ourselves; the future new system will do that, monitored by human software experts.

Marius Mihailovici has been Managing Director of Porsche Engineering Romania since 2016. Previously, he headed research and development at Alcatel-Lucent S.A./Nokia Oyj, where he also worked as a software manager for 2G and 3G projects. At World Telecom he worked as a communications engineer.

Deceptively real: Game engines create fascinating landscapes for computer games...

Game

Text: Constantin Gillies Contributors: Frank Sayer, Tobias Watzl, Ionut Tripon, Sebastian Oebels

Game engines generate the images of computer game hits like *Fortnite* and *Cyberpunk 2077*. In the meantime, however, these software packages have also become an integral part of automotive development. For example, game engines generate the images used to train driver assistance systems or enable customers to configure their new vehicle on the computer or with VR glasses.

…and make computer-generated views of a Porsche 911 Carrera 4S look like photos.

Engines

When Tobias Watzl comes home from work, he occasionally sits down in front of the Playstation to relax. However, the 28-year-old sees the games with different eyes to most players. “Sometimes I wonder, for example, how the developers managed to get a certain reflection or texture—instead of defeating my enemies,” says Watzl with a chuckle. There’s a reason he looks so closely: as an engineer at Porsche Engineering, he too creates virtual worlds every day. For example, Watzl uses the computer to recreate parts of highways in order to train driver assistance systems.

It is no coincidence that the digital road looks like a computer game. This is because Watzl uses the software Unreal in his work, a game engine that generates the images in the computer game *Fortnite*, for example. What otherwise brings virtual battles to the screen is an everyday tool at Porsche Engineering: game engines teach assistance systems or help designers to visualize components. Thanks to game technology, customers will soon be able to take a virtual seat in the vehicle they have just ordered, long before it leaves the assembly line.

"Game engines provide the technology to create the necessary environment for simulating driver assistance systems as a standard feature," explains Frank Sayer, Senior Manager Virtual Vehicle Development at Porsche Engineering. The background: the algorithms of Advanced Driver Assistance Systems (ADAS) need a lot of training and validation. For example, they have to learn how to detect a traffic situation at lightning speed using various sensors and react appropriately over a number of test kilometers. This would require many real test drives—and by no means every event necessary for training would occur.

Every eventuality can be played out

This is why Porsche Engineering is moving training into the virtual world: game engines simulate the drives with which the algorithm practices. Every scenario and every eventuality can be played out in this way—even those that cannot be rehearsed in real life for safety reasons: The car in front brakes unexpectedly; an animal jumps onto the road; the sun blinds the on-board cameras. Mixed operation is also conceivable: a real vehicle reacts to virtual objects.

Some of the virtual test tracks have real-life models, for example the A8 autobahn near Stuttgart Airport. "Our colleagues know every exit and every sign – even though they've never been there before," smiles Ionut Tripon of Porsche Engineering Romania in Cluj. He's part of the team that builds the digital test tracks and is one of the new types of developers entering the automotive industry: software developers with a gaming background and an understanding of the automotive industry are shaping the future of mobility every bit as much as AI experts and mechanical engineers. "Here, passion for video games and their development is combined with conventional skills—this is highly motivating, exciting, and of immediate relevance for our projects," confirms Tudor Ziman, who heads up function development in Cluj.

"What takes hours in reality can be reduced to seconds."

Ionut Tripon,
Head of the team for the digital test tracks at Porsche Engineering Cluj

The drives simulated with the help of game engines have the advantage that they can be repeated as often as required and can be controlled down to the smallest detail. They also take less time than real ones. "What takes hours in reality can be reduced to seconds," says Tripon. The only limiting factor here is the computing power of the hardware used.

But even this limit is diminishing. Porsche Engineering has started to move virtual development to the cloud: the driving simulations are outsourced to the data center of service providers such as Amazon Web Services, where they run in parallel on dozens of machines. When thousands of simulated cars (called instances) do their laps, the development time is drastically reduced.

Virtual tests instead of real prototypes

Game engines are used in design to make visible what does not yet exist. Current example: During the development of the Cayenne Coupé, consideration was given to reducing the black frit band on the glass roof. This area at the edge of the glass prevents the track of the sunblind from being visible underneath. But how wide must the frit band be? Until now, welding and sawing have been used in such cases: One prepares a vehicle and tries out several glass roofs with different frit band widths. The virtual test, by contrast, for which Porsche Engineering used the Visual Engineering Tool (VET) developed in-house and based on the Unity game engine, was much faster and more cost-effective. Using the original CAD data, the engineers virtually reconstructed the vehicle including the glass roof. After a few hours they were able to view the model from all sides using VR glasses. The result was that the black edge was correctly dimensioned. "To do a real-life modification, we would have needed considerably more time and money," sums up engineer Watzl.

The images generated by game engines are so good nowadays that even professionals have to look closely to see the difference to reality. This should soon enable a completely new customer experience in sales:

Engine of a computer game

The game engine is literally the engine of a computer game. It is a whole range of programs. At the core is the graphics engine, which generates the actual image: it first takes the 3D model of an object to be depicted (in its original state it consists only of grid lines) and covers it with a digital surface. This texture, as it is known, can look like wood or metal, for example. Then it is calculated where light falls, which parts of an object are in the shade and where something is reflected. The calculation of the image is called rendering. The physics engine ensures that things in the game behave as they do in the real world. It calculates, for example, how often a thrown rock skips over the ground before it stops. To make the developers' work easier, a kind of editor is also included with which new simulations can be created without having to program them from scratch. Millions of designers worldwide use these modular systems to create digital worlds—from mobile phone games to Hollywood action movies.

New developer types: Porsche Engineering in Cluj employs software experts with a gaming background and an understanding of the automotive industry.

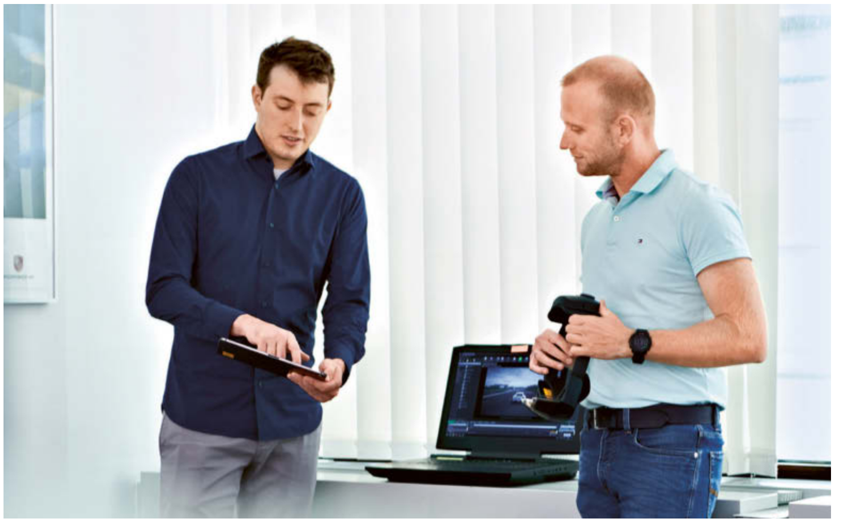
Virtual highway: This is what the A8 autobahn near Stuttgart Airport looks like—in a simulation created at Porsche Engineering in Cluj.

Cayenne Coupé

Fuel consumption (city): 11.7–11.4 l/100 km
Fuel consumption (highway): 8.3–8.2 l/100 km
Fuel consumption (combined): 9.5–9.4 l/100 km
CO_2 emissions (combined): 217–214 g/km
Energy efficiency class: D

911 Carrera 4S

Fuel consumption (city): (manual transmission): 14.8 l/100 km
Fuel consumption (city): (PDK): 13.1 l/100 km
Fuel consumption (highway): (manual transmission): 7.4 l/100 km
Fuel consumption (highway): (PDK): 7.8 l/100 km
Fuel consumption (combined): (manual transmission): 10.1 l/100 km
Fuel consumption (combined): (PDK): 9.7 l/100 km
CO_2 emissions (combined): (manual transmission): 231 g/km
CO_2 emissions (combined): (PDK): 222 g/km
Energy efficiency class: G



Creators of virtual worlds: Tobias Watzl (left) and Frank Sayer use game engines for testing and visualization.

More than real: Game engines can be used to create augmented reality applications that enhance real images with digital information.

“Game engines provide the technology to create the necessary environment for simulating driver assistance systems as a standard feature.”

Frank Sayer, Senior Manager Virtual Vehicle Development at Porsche Engineering

Porsche is currently in the test phase for the so-called Virtual Reality Car Configurator, which will then be rolled out in the centers. This system consists of a gaming PC with connected VR glasses and presents the customer on site with a three-dimensional simulation of their future vehicle. To do this, they need only briefly put together their desired model with the consultant—paint color, rims, equipment. The Car Configurator then uses Unreal to calculate an image, which is initially presented on a 65-inch screen with 4K resolution. “The appearance is much better than with configurators on the Internet—almost photo-realistic,” says Sebastian Oebels, digital marketing expert at Porsche AG, enthusiastically.

60 times

per second, the game engine in the “Virtual Reality Car Configurator” calculates an image for the left and right monitor of VR glasses from a different perspective. This gives customers the impression that the vehicle is standing directly in front of them.

Customers can also put on VR glasses and inspect their dream car in three dimensions. The game engine then calculates a different perspective image for the left and right eye 60 times per second, giving the customer the impression that the vehicle is standing directly in front of them. They can walk around it, look at the rims from up close, take a virtual seat, and inspect the interior right down to the seams of the leather seats. It is even possible to look into the glove compartment. If desired, the scenery can be switched from day to night so that the headlights can be seen.

The game engine uses original design data as raw material. However, the data has to be adapted. “We make

It's like a showroom: The Virtual Reality Car Configurator presents customers with a three-dimensional simulation of their future vehicle.

many real-time-specific improvements," explains Lukas Kays from Mackevision, a Stuttgart-based specialist for computer-generated imagery (CGI). The company creates photorealistic special effects for film and television—including for the *Game of Thrones* series—and developed the Car Configurator together with Porsche. The fact that CAD files cannot simply be used for the virtual vehicle is due to their level of detail. A design engineer describes each part down to the last detail with its geometry. Calculating an image from this 60 times per second can overwhelm a computer and lead to flickering in the display. The models must therefore be simplified. For example, instead of calculating a speaker grill with all its wires, the 3D designers use a high-resolution photo of the grill. Displaying this costs much less computing power, and the untrained viewer cannot see the difference anyway.

Realistic effects without much effort

The decisive advantage of a game engine is that it can be used without much programming effort. "Unreal 4 makes it easy to create materials," designer Kays offers as an example. "The reflections on the car paint, for example, don't need to be programmed." Programming your own renderer to handle such effects would be far too complex and expensive.

Game engines are also inexpensive. Corporate users like Porsche Engineering can use Unreal completely free of charge. They even receive the source code of the software so that they can adapt it to their requirements. "We want as many companies as possible to use the engine," explains Stefan Wenz, Business Development Manager at Epic Games, the US game company that developed Unreal over 20 years ago. The company only earns money indirectly, for example through paid support.

For around five years now, the creators of the game engine have been actively courting industrial customers—mechanical engineers, architects, and automobile manufacturers. "B2B promises the greatest growth," explains Wenz. To make the work of industrial users easier, Epic Games recently put together a free material package: It contains finished materials from Alcantara to walnut wood that designers can assign to the objects. In addition, last year the games manufacturer launched a support program called MegaGrants, from which any company working with Unreal Engine can receive capital. So the development of computer games and automobiles continues to converge. In this respect, the self-driving car of the future will owe a little to gamers.

THE PLAYERS IN THE GAME ENGINES MARKET

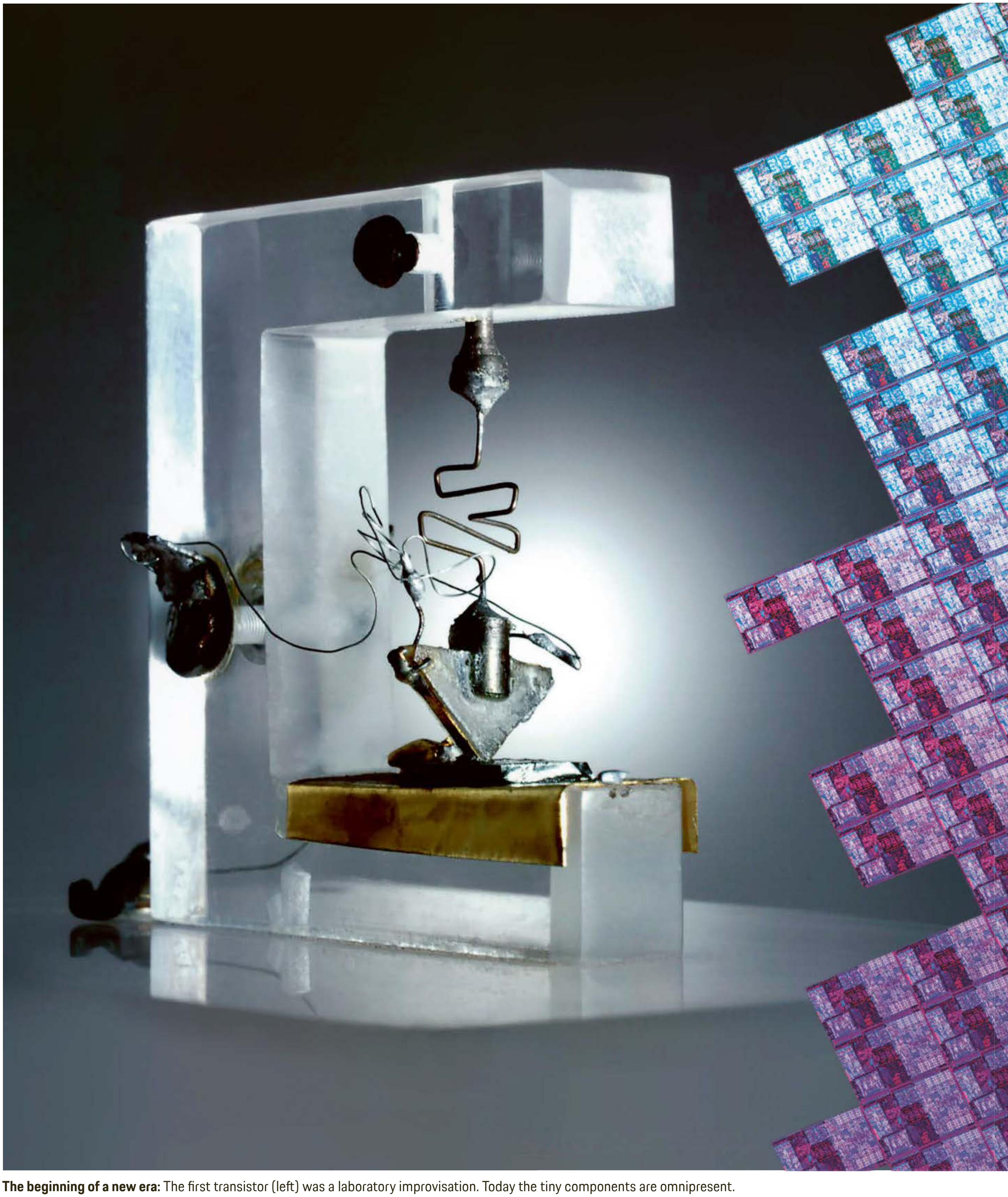
unity

Name of the game engine
Unity
Manufacturer
Unity Technologies
Successful games
Pokémon Go
Monument Valley
Call of Duty Mobile
Super Mario Run
Cuphead

Name of the game engine
Unreal
Manufacturer
Epic Games
Successful games
Fortnite
Valorant
Final Fantasy VII remake
Borderlands
Minecraft Dungeons

IN BRIEF

Game engines bring computer games to life—and help develop new driving functions, for example by training driver assistance systems with synthetic sensor data. Every scenario and every eventuality can be played out. In Porsche's Car Configurator, they help customers choose a new vehicle.



The beginning of a new era: The first transistor (left) was a laboratory improvisation. Today the tiny components are omnipresent.

More than Moore

Text: Christian Buck

For decades, transistors in integrated circuits have been shrinking, resulting in ever more powerful chips. Now this process is reaching its end. For this reason, in addition to completely new types of transistors, other chip and computer architectures should also enable a further increase in computing power in the future. The automotive industry will also benefit from this in the long term.

The birth of modern electronics took place on December 16, 1947 at Bell Labs in Murray Hill, New Jersey. It was then that physicist Walter Brattain succeeded for the first time in amplifying an electric voltage with an improvised semiconductor component. The transistor was born. For the first time, an alternative to the bulky, unreliable, and energy-hungry vacuum tubes was available. From an appearance standpoint, Brattain's laboratory set-up, consisting of a germanium plate, a plastic triangle, gold foil, and a paper clip, had very little in common with modern chips—but it did herald the era of personal computers, smartphones, and self-propelled cars.

The new electronic component could be used as an amplifier and as a switch—and together with its peers and other components such as resistors and capacitors, it could be accommodated as an integrated circuit (IC) on a single semiconductor wafer. In the decades that followed, semiconductor companies succeeded in making the components ever smaller and accommodating an ever greater number of them on the same surface. As early as 1965, Gordon Moore (see box) predicted that the number of transistors per unit area would increase exponentially.

Simple scaling reaches its limits

Moore's prediction has proven to be essentially correct over decades. But now it is finally reaching its limits, because the gradual reduction in size of the proven MOSFETs (Metal-Oxide-Semiconductor Field-Effect Transistor, see box on page 37) as switches on the chips no longer works: "About 15 years ago, people realized that simple scaling had reached its limits," reports Dr. Heike Riel, IBM Fellow at the IBM Research Center in Rüschlikon, Switzerland. "That's why manufacturers first replaced silicon dioxide as the insulating material in the transistors with so-called High-K materials while retaining the same MOSFET geometry. This made it possible to produce chips with structures 45 nm in size."

But even this trick could only keep Moore's Law alive for a few years. For this reason, chip manufacturers began using a new transistor architecture for even smaller components in the first half of the 2010s: the FinFET. The conductive channel between the source and drain terminals is shaped like a fin and is enclosed on several sides by the gate (see box on page 38). "This makes it much easier to control the current flow in the transistor," says Riel. "FinFETs starting at 22 nm in structure size were used and are now standard in integrated circuits."

But their successor is also already available. Starting at structure sizes of five nanometers, the GAAFET (gate-all-around FET) will take over the work in the chips. "In the GAAFET, the conductive channel between source and drain consists of several parallel silicon nanowires, each of which is completely enclosed by the gate electrode," explains Riel. "This is the optimal geometry for controlling the current flow. It also saves space on the chips because several of these nanowire structures, which form the channel of the transistor, are superimposed on each other." Automotive applications will also benefit from developments such as GAAFET in the future—because both the new, powerful High Performance Computing Platforms (HCPs) as successors to the many decentralized control units and the special processors for autonomous

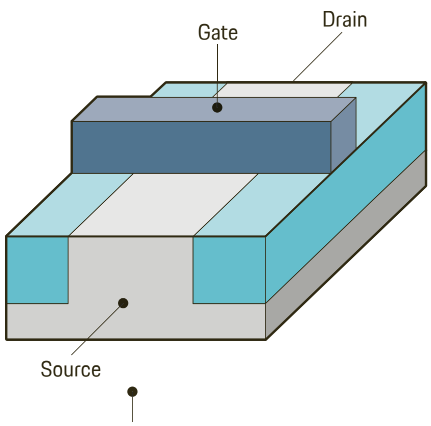
Moore's Law

55 years ago Gordon Moore made a remarkable prediction in *Electronics* magazine: the then-research director of the US semiconductor manufacturer Fairchild Semiconductor and later Intel co-founder in 1965 asserted that the number of transistors per chip would double every year in the future. As early as 1975, it would therefore be possible to accommodate around 65,000 of them on a tiny silicon wafer. "Moore's Law" has been continually tweaked over the years, but has proven to be correct in principle and has become the guideline for semiconductor manufacturers: To this day, they have repeatedly succeeded in doubling the number of transistors per unit area at short intervals. In the future, however, this will no longer be possible. A higher performance of the chips must then be achieved by other means.

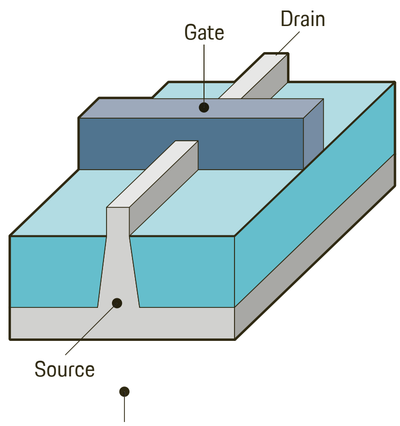
The man behind the law: Gordon Moore (to the left of Intel co-founder Robert Noyce) made his famous prediction in 1965.

MOSFET, FinFET, and GAAFET

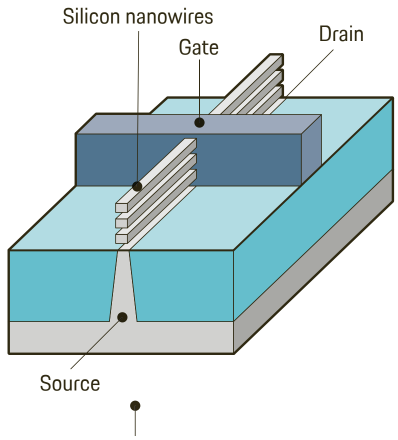
The MOSFET (left) has been the workhorse switch for digital technology for decades and has kept Moore's Law alive through its continual miniaturization. The voltage between the gate and source electrode determines the current flowing through the channel from source to drain. In the FinFET (center), the channel has the shape of a fin so that the gate can surround it on three sides. This improves current flow control compared to the MOSFET, where the gate can only act on the channel from above. In the GAAFET (right), the gate completely encloses the channel of silicon nanowires. This is the optimal geometry for controlling the current flow.



Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET)



Fin Field-Effect Transistor (FinFET)



Gate-all-around Field-Effect Transistor (GAAFET)

driving depend on chips with high computing power. However, even GAAFET won't be able to save Moore's Law in the long run: beyond a structure size of three nm, things will get tight. This limit could be reached in three to four years.

"An ingenious phase of improvement is thus coming to an end," says Prof. Thomas Schimmel, Director at the Institute of Nanotechnology at the Karlsruhe Institute of Technology (KIT). "Until now, a technical solution has always been found that enabled further miniaturization of the classic transistor—but now atomic dimensions have been reached in the chips. Thanks to the quantum mechanical tunnel effect, electrons can pass through insulators, which would render the components useless. This is because, contrary to the ideas of classical physics, the electrons can overcome barriers even when they do not actually have enough energy to do so." But even the targeted introduction of foreign atoms into the highly pure silicon during the production process—a procedure known as "doping"—no longer functions reliably with ever smaller structures.

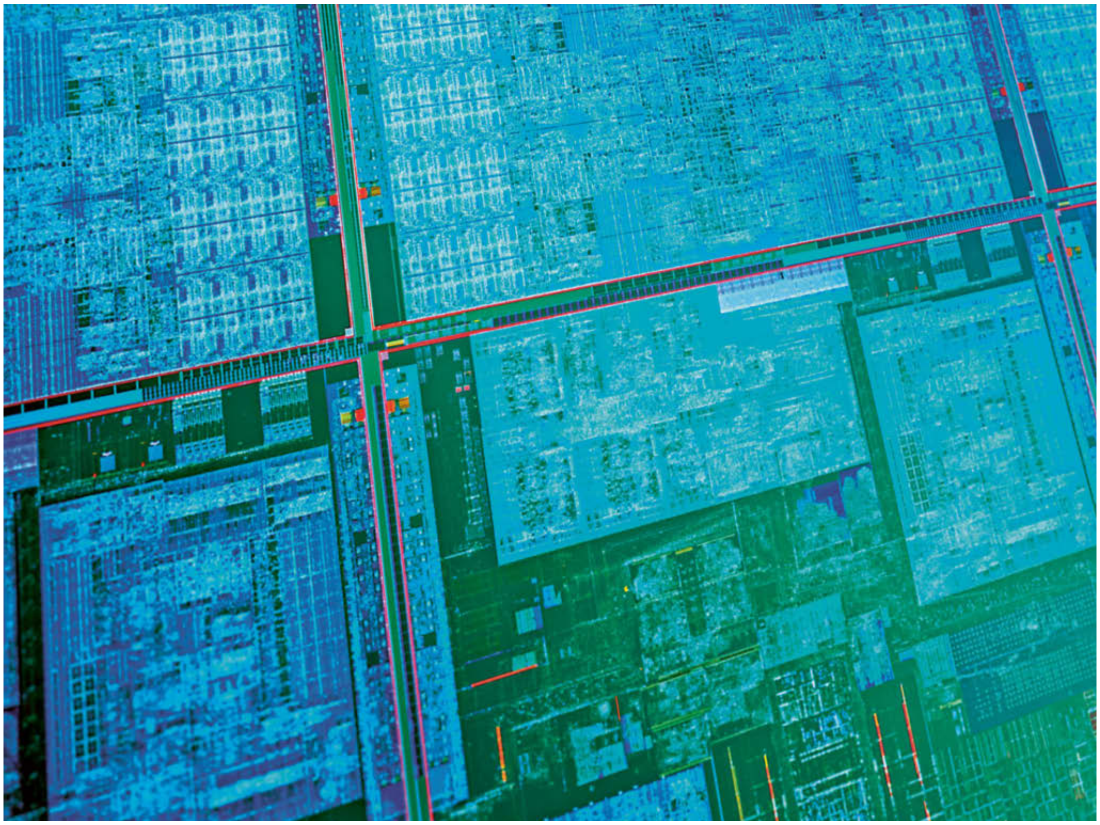
54 billion

transistors are in the graphics processor Nvidia Ampere. According to the manufacturer, it is the largest 7-nm chip ever built.

No clear successor in sight

The search is therefore on for a successor to the transistor that will further increase the performance of electronic circuits in the future. IBM researcher Riel lists a whole range of MOSFET alternatives, including the carbon nanotube field-effect transistor (CNFET) and the tunnel FET (TFET). In the CNFET, current flows through tiny carbon tubes. This year, researchers from MIT have shown that the fast and energy-efficient switches can be produced in conventional chip factories. TFETs are similar in design to conventional transistors, but put the quantum mechanical tunnel effect to their advantage for switching. They are energy-saving and fast. Whether CNFET, TFET, or any other approach will win the race is completely open. "There is currently a lot of research, but no clear front-runner to succeed the optimized silicon MOSFET," says Riel.

KIT researcher Schimmel is therefore betting on the single-atom transistor in the long term: in this transis-



3D chip: Intel's Lakefield processors already consist of several layers (the computing layer is depicted in the image).

Node

is the word used by the semiconductor industry to denote the various generations of chips; the structures become smaller and smaller from node to node.

5 nm

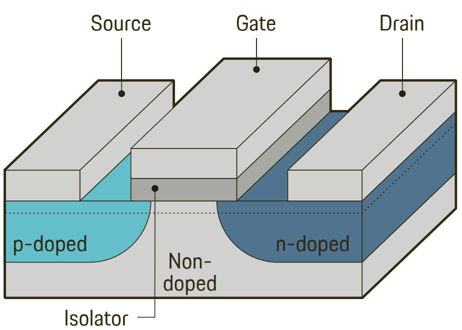
The most advanced chips today belong to the five-nm node. One example of this is the Apple A14 Bionic.

4 nm

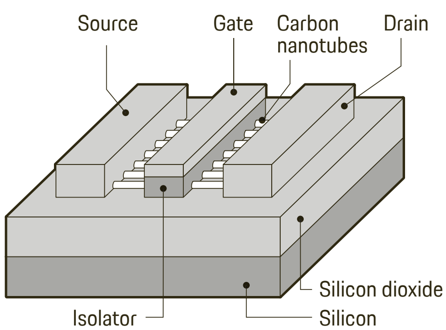
The four-nm node is the next step. It is expected to take place in 2022.

Future alternatives to the conventional transistor design

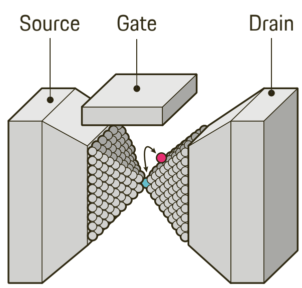
In the TFET (left), unlike the MOSFET, the source and drain are differently doped. It uses the quantum mechanical tunnel effect: the voltage between gate and source determines whether charge carriers can "tunnel" through the energetic barrier between source and drain and whether a current flow is possible. In the CNFET (center), the channel between source and drain consists of carbon nanotubes. Here too, the gate-source voltage determines the current flow. In the single-atom transistor (right), the voltage between source and gate shifts a single atom, which either closes or opens the circuit between source and drain (green/red position).



Tunnel Field-Effect Transistor (TFET)



Carbon Nanotube Field-Effect Transistor (CNFET)



Single-atom transistor

"There is currently a lot of research, but no front-runner to succeed the optimized silicon MOSFET."

Dr. Heike Riel, IBM

tor, a control electrode shifts an atom that can close the tiny gap between two terminals and thus enable the flow of current. "In principle, it works like a relay with two stable states," says Schimmel, who developed the first single atom transistor with his team in 2004. "This makes the single-atom transistor not only a switch, but also a non-volatile memory. It could also replace conventional RAM chips as the main memory in computers. Since it retains its state even without power, computers would no longer have to be restarted in the future, but could continue working immediately after a break."

Another advantage is that the single-atom transistor requires significantly less voltage than the MOSFET and would therefore only consume about one ten-thousandth of the energy per switching operation. This would solve the heat problem in today's chips, and clock frequencies of up to 100 gigahertz would be within reach. Schimmel has already built a first IC with two of his novel transistors, and for a later series production a mix of proven processes of the semiconductor industry and galvanic procedures could be used. "It's like galvanizing a car body—only on an atomic scale," says the Karlsruhe scientist.

New chip and computer architectures

As an alternative to the ever-advancing miniaturization of components, new approaches to chip architecture are also possible, for example the path into the third dimension: in order to pack more power into the circuits, several electronic layers could be stacked on top of each other—already practiced today with flash memories. In the future, manufacturers could also apply a layer of compound semiconductors, as they are known, such as indium gallium arsenide (InGaAs) to a layer of conventional silicon transistors. They are suitable for special tasks such as particularly fast amplification, for the emission or detection of light, and also as possible quantum components. Many experts are counting on the integration of such additional functions into the chips to compensate for the demise of Moore's Law. They're taking a new approach: instead of "more Moore" (further miniaturization), they prefer "more than Moore" (the combination of digital and non-digital functions on the same chip).

In-memory computing, which is intended to eliminate the spatial separation of the computing unit and memory in common computers, promises much higher computing power and energy efficiency. This would eliminate the time-consuming and energy-intensive transport of bytes between microprocessor and RAM. For example, the vector-matrix calculations in a neural network can be performed using a crossbar architecture—analog rather than digital. In this approach, two bundles of horizontal and vertical lines cross, each of which acts as an input and output of the neural network. At their intersection points, the lines are connected to each other via non-volatile memory elements that represent the weighting factors (the "knowledge") of the neural network. The input values of the neural network are applied as analog voltage values to the horizontal lines. The results of the calculations are available almost instantaneously on the vertical lines, also in analog form—and without any data transport.

Non-volatile memories at the crossing points of the lines include memristors, novel electronic components whose resistance can be permanently changed by an externally applied voltage and which can be combined with existing manufacturing processes in the semiconductor industry. Memristors can be used to perform calculations in neural networks ten to a hundred times faster, depending on the application, and their energy efficiency can also be improved by a factor of ten to a thousand. Autonomous vehicles in which neural networks play a major role could also benefit from such performance and efficiency improvements. The example shows that even if Moore's Law soon reaches its limits, the continuous increase in performance of electronics is far from over.

IN BRIEF

The further miniaturization of the MOSFET transistor and its variants FinFET and GAAFET is likely to reach its limits in the coming years. In order to make chips increasingly powerful in the future, research scientists and industry are working on new transistor designs such as tunnel FETs, as well as on new architectures such as in-memory computing.

Hello, human!

Artificial intelligence (AI) is about to enter a new era: researchers around the world are working on the "third wave" and want to make AI even more human-like. In his guest article, Kristian Kersting, Professor of Artificial Intelligence and Machine Learning at the TU Darmstadt and co-speaker of the Hessian Center for Artificial Intelligence, explains what computers will be able to do in the future—and how we will benefit from them in everyday life.

GUEST AUTHOR

Prof. Dr. Kristian Kersting is Professor for Artificial Intelligence and Machine Learning at TU Darmstadt and winner of the first German AI Prize (2019). Since 2020, he has also been the co-speaker together with Prof. Mira Mezini for the new Hessian Center for Artificial Intelligence, in which 13 universities from the state participate. As part of the effort, the state of Hesse is establishing 20 additional professorships and providing 38 million euros in the five-year start-up phase. The focus of the work will be the third wave of AI.

Think about the following situation: you are driving in a town and see a traffic sign with a top speed of 120 km/h. What would you do? Hit the gas and max out the speed limit? Probably not—because you know that you are only allowed to drive a maximum of 50 km/h in built-up areas.

But what would today's artificial intelligence (AI) do? It would recognize and correctly interpret the traffic sign without any difficulty. Without additional knowledge, it would conclude that the speed limit here is 120 km/h. It would never occur to the AI that the sign could have been placed on the side of the road by accident or with malicious intent.

Because the AI lacks a typical human ability: reflection. In a situation like this, any human being would reflect and form hypotheses. Or they would ask their passenger for a second opinion. This is exactly what we want to achieve with the "third wave of AI": The aim is for AI systems to become more human-like in the future—by taking knowledge of the world into account when making decisions, and asking people for their opinions when necessary.

This is demonstrated by a current example. Today we can already teach AI systems ethical behavior by presenting them with many human texts from which they extract our prejudices—because ethical rules are, in a certain sense, really just prejudices. A contemporary AI would therefore say that the public wearing of a mask is not accepted in Germany. However, it would not take into account that in the coronavirus pandemic, masks are a part of our everyday life. In the future, an AI could search current news and take the knowledge gained into account in its decisions.

In order to better understand the difference to existing AI systems, it is helpful to take a look at the past: during the first wave of AI from 1956 to the 1980s, the intelligent behavior of humans was pre-programmed. The computer was able to draw its conclusions from a large number of if-then relationships with the help of a programmed logic. This is how the first "expert systems" were created, which gave recommendations for action in a specific area of activity.

We are benefiting from the second wave

The second wave of AI started in the 1980s and continues to this day. Today, computers are able to learn from examples—also called "data"—and thus develop "intelligent" behavior. It is no longer necessary for the human programmers to imagine every eventuality and manually pre-program countless rules. Only the learning algorithm is still programmed. Among the best-known successes of such AI systems are the victory of the IBM chess computer Deep Blue over world champion Garry Kasparov (1996) and the victory of the AI software AlphaGo over the world-class South Korean go player Lee Sedol (2016). Today, we all benefit from the second wave of AI—for example through voice recognition in smartphones or cars that can drive to some extent without our intervention.

The third wave is just starting to take off. And it builds on what we have developed in the past two waves of AI. The new approach could be summarized roughly as follows: combining low-level perception (120 km/h) and high-level reasoning (traffic rules) and contextualizing decisions (in town) and communicating them in a human-like way (asking the passenger).

Technically, we use a combination of neural networks, probability models and logic to achieve this—as Nobel Prize winner Daniel Kahneman describes for us humans in his book *Thinking, Fast and Slow*: the fast, instinctive, and emotional system (neural networks and probability models) works together with the slower, more logical system (program logic) that thinks things through.

One of the important developments for the third wave of AI is "neural symbolic AI": while the well-known Convolutional Neural Networks (CNN) can recognize traffic signs from the pixels of a video camera, for example, they lack a special ingredient that makes us human: common sense—that intuitive sense of context that seems so natural to us. It enables people to deduce the meaning of a new word, the properties of unknown substances, or even social norms based on a few experiences. Such conclusions go far beyond the available data.

AI grasps the true meaning

The technology has not yet reached this stage. Today's neuronal networks are inclined to confuse a school bus tipped over on its side with a snowplow. Humans are different: once we have learned what a school bus is, we have no major difficulties recognizing it even in unfamiliar situations. This is because we humans can abstract, generalize solution strategies, and apply them to similar, albeit different, situations.

Thanks to neural symbolic AI, machines will soon be able to do this as well. In the future, we will use neural networks which, alone or in combination with other methods of AI, can grasp the true meaning of traffic signs, understand them as "symbols" and then apply program logic to "put two and two together"—for instance that you are not allowed to drive 120 km/h in a town.

"With the third wave of AI, machines will soon be partners with humans who think and understand like us."

Thanks to the third wave of AI, machines will soon be partners to humans who think and understand us just like we do. In climate research, for example, they will combine data and models for the atmosphere, the oceans and the cloud system with economic models and biosphere models to create a "big picture."

Future AI systems will also be much more transparent to us. This is because they will be able to put their decisions into words, abstract from unimportant details, and make it easier for us to understand how they arrive at their decisions: why does the navigation system take this particular route? Why does the financial software recommend exactly this investment? Why does an AI reject a certain applicant and give preference to another? With the third wave of AI we will solve the problem of the "black box" and make the processes transparent.

For the third wave of AI, the players are in the process of planting their flags. Companies in the US, particularly, have already recognized the potential of this development and are currently buying many start-ups in the field. We are also well positioned in Europe because there are many capable scientists and developers here—but unfortunately less venture capital sloshing about. However, the train has not yet left the station and it is up to us to help shape the future of AI. My message to politicians, industry, and science is therefore that we should create an AI that is more friendly and more useful. An AI for the benefit of all. Let's ride the third wave!

End of the off-road

Text: Jost Burger Contributor: Marc Kluge Photos: Eduard Herr

Ready for the track: The Pro-Street RZR was created as a variant of the Polaris RZR off-road vehicle. The most striking change is its low road position.

With its off-road vehicles, Polaris has gained a loyal fan base. In just a few months, Porsche Engineering built a demonstrator for the US company for a racetrack version of an off-road vehicle. In the process, engineers used their experience from sports car development.

Wyoming is a tranquil little town in the US state of Minnesota, surrounded by lakes, forests, and grassland—and is thus an ideal location for the development department of Polaris, a world-renowned manufacturer of off-road vehicles. Engineers can test four-wheeled off-road buggies like the RZR right next to their offices. The compact, high-legged two-seater with its striking front end has been a notable presence on off-road scene for years. But in the summer of 2019, there was something unexpected to marvel at during a major dealer show at the company headquarters: the road version “Pro-Street RZR”, developed and built by the experts at Porsche Engineering in just four months.

The idea for the racetrack version of the RZR came to the engineers at Porsche Engineering during a joint project to optimize the chassis and handling of a Polaris off-roader set to be launched in 2021. “We had the idea of transferring the potential of the RZR to the racetrack,” says Marc Kluge, Senior Manager Design Drivetrain at Porsche Engineering. After all, the RZR variant offered him and his employees the opportunity to demonstrate the overall vehicle know-how of Porsche Engineering while incorporating experience from sports car development. “The Pro-Street RZR shows that we always look at and understand the vehicle as whole.” This includes chassis development as well as our knowledge of the vehicle body and the finer points of the individual components,” says Kluge. “It also gave us the opportunity to show Polaris that Porsche Engineering also builds complete demo vehicles on request.”

“We sensed immediately that two very similar corporate cultures were at work here: enthusiasm for the technology, courage to try things out and think laterally, direct lines of communication in implementation.”

Brian Gillingham, Chief Engineer at Polaris

Polaris Chief Engineer Brian Gillingham, like his colleagues, was enthusiastic about working with Porsche Engineering from the very beginning. “We sensed immediately that two very similar corporate cultures were at work here: enthusiasm for the technology, courage to try things out and think laterally, direct lines of communication in implementation. It clicked right away.” Without hesitation, he says, they trusted that the idea was feasible—and gave the engineers at Porsche Engineering great freedom to achieve their goal.

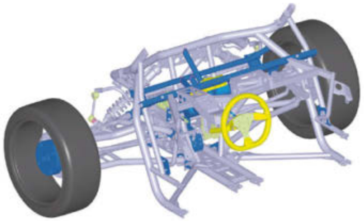
Use of many identical parts

Their self-appointed task, in turn, was clear: it was not intended to be a completely new development, but a variant based on the existing off-roader. “We wanted to use as many identical parts as possible and modify the original vehicle skeleton only minimally,” says Kluge. Vehicle parts such as the dashboard, the drivetrain and the body panels were already available as “carry-over parts” (COP). Using them was key to enabling rapid implementation of the project.

The result is impressive. “You can still see the Pro-Street RZR s origins, but at the same time its purist design makes it an absolutely track-ready race car," says Kluge. Indeed: the striking front end has remained the same. Only the bumper that normally adorns the off-road version is missing. The Porsche Engineering team also left out a large part of the paneling. This saves weight and provides a clear view of the chassis and engine. The driver's cage was also changed: the Pro-Street RZR has a new, lower rollbar. The two passengers sit in a flatter cage without a roof or windshield, made of the same material as the rollcages of Porsche race cars. This changes the overall silhouette, as does the wide and high-mounted rear spoiler.

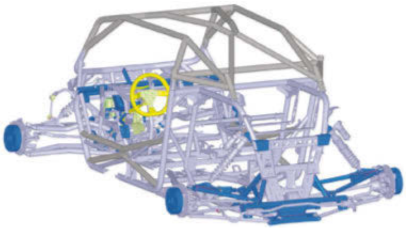
But the most striking change is the new road position. While the high-stepping original RZR offers a ground clearance of more than 30 centimeters, the road version glides only a few centimeters above the asphalt—as befits a race car. In this, among other aspects, the engineers from Porsche Engineering were able to bring their motor racing experience to bear: new suspension struts with an optimized angle bring the vehicle closer to the road. Together with specially tuned dampers, a modified wishbone geometry, new stabilizers, and 18-inch rims, they give the vehicle a wider track. This generates greater handling stability and also matches the special conditions of race tracks: less vertical forces than off-road, but higher lateral forces when cornering at speed. And of course, the Pro-Street RZR does not utilize high-profile off-road tires, but racing tires selected on the test bench. "This is another example of how we have optimized the entire vehicle for the racetrack down to the last detail," says Kluge.

The low road position did require further modification, however. Normally the tank of the RZR is mounted under the seats. Since there was no room there, it was installed on the rear frame. Carbon shell seats and high-performance brakes further heighten the sports car character of the Pro-Street RZR. "The powerful brakes are needed to cope with the higher deceleration and the associated high energy input to the brakes," explains Kluge. The steering was also adapted to racing conditions. Instead of using power steering, the driver steers purely mechanically. "This gives more direct feedback and ensures more precise handling, as is



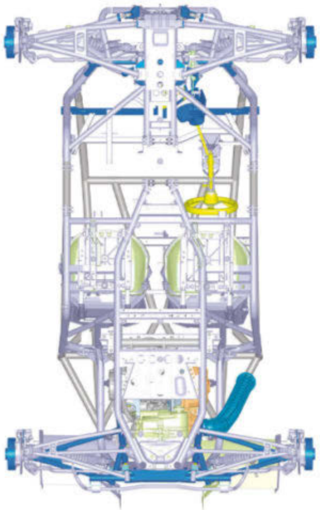
Front frame

For the Polaris road race car, the chassis was redesigned and the dashboard lowered.



Rear frame

The developers modified the rear frame, changed the axle geometry and fitted new arms.



Overall view

The view from below shows the new chassis geometry, which was adapted to the requirements of the race track.

needed on the race track," explains Kluge. The engine and automatic transmission remained unchanged, however. The two-cylinder engine with just under one liter of displacement and around 170 hp accelerates the Pro-Street RZR to around 160 km/h.

A team of eight colleagues at the Bietigheim and Mönsheim locations developed, calculated, and designed the RZR derivative over three months. After that, five Porsche Engineering employees assembled the demo vehicle in four weeks and tested it on site. In July 2019, the variant finally arrived in America by plane—and caused quite a stir there, as Gillingham recalls: "Our marketing manager personally broke open the shipping crate. And when the Pro-Street RZR was rolled out, we were all thrilled."

Big sensation in the USA

Gillingham has had the opportunity to drive the variant himself. "My first thought was: it's so low!" Of course the driving experience is completely different than the off-road version—not least because of the lower seat position, which leads to a different view of the road. A real race car feeling—for Brian Gillingham, the Pro-Street RZR is quite simply "cool."

Among the visitors at the dealer show in Wyoming, the presentation of the Pro-Street RZR caused more than just astonished looks. "People were very interested and curious," Gillingham recalls. "They found the vehicle truly fascinating." And with that, Polaris had accomplished its goal. "Although we will continue to operate primarily in the off-road sector, we have shown that there is a lot more to Polaris when it comes to exciting technology," says Gillingham. And the Pro-Street RZR will continue to be used as an attention-getter at corporate events.

Porsche Engineering is just as pleased with the result. "The Pro-Street RZR is fully track-ready and offers extremely agile and precise handling at a low weight—just as we had envisioned," says project manager Kluge. At no point in time was there any doubt as to its feasibility. "A great and highly motivated team that had a lot of fun in the project has proven unequivocally: it definitely works!"

Off-road specialist: The RZR four-wheel-drive off-road buggy has a worldwide following. The Pro Street RZR was developed on the basis of this off-roader.

170 hp
are at the disposal of the two-cylinder engine with just under a liter capacity.

160 km/h
is the top speed of the Pro-Street RZR on the road.

"The Pro-Street RZR demonstrates that we always look at and understand the vehicle as whole.

Marc Kluge, Senior Manager Design Drivetrain at Porsche Engineering

Stable road handling: The Pro-Street RZR was outfitted with new shock absorbers with an optimized angle. Together with specially tuned dampers, a modified wishbone geometry, new stabilizers, and 18-inch rims, they give the vehicle a wider track.

Intelligent, connected, Nardò.

Text: Christian Buck Contributors: Antonio Gratis, Roberto Buttazzi, Pierpaolo Positano Photos: Theodor Barth

At the Nardò Technical Center (NTC) of Porsche Engineering, the mobility solutions of tomorrow are put through their paces. The NTC itself is also preparing for the future of automotive development—with a modernized infrastructure, expanded capabilities, and a growing team of specialists.

They'll soon be off. "Test in three, two, one seconds," says the voice from the radio. As soon as the countdown ends, the silver Porsche Cayenne immediately springs into action. But Mario Toledo, Test Engineer at Porsche Engineering, has neither his hands on the wheel nor his feet on the pedals. Instead, a driving robot is in command and ensuring that the car stays safely on track.

Together with the Cayenne, a gray Panamera is also on the driving dynamics platform of the NTC in southern Italy this morning. At the Porsche Engineering proving ground, engineers are now investigating the performance of autonomous driving functions. Toledo has printed out a whole stack of test scenarios on the tray above the dashboard, including: driving in parallel lanes with sufficient distance between vehicles, changing lanes to the right or left, and avoiding an oncoming vehicle.

Such tests for autonomous driving functions at SAE Level 4 (fully automated driving) are now part of everyday life at the NTC—this is where the mobility of tomorrow is tested until it is ready for series production. But continuous development is also required of the NTC itself: "A revolution is looming in the automotive industry over the next five to ten years, caused by trends such as autonomous driving, connectivity and e-mobility," says NTC Managing Director Antonio Gratis. "We must adapt to this—with new infrastructure and new capabilities."

What this means can be seen on the circuit of the test center: the inner circular track, which in the past was used primarily for testing commercial vehicles, was given 48 kilometers of new road markings in 2020 and now part of it looks like a three-lane motorway under EU standards and part of it a three-lane US highway. "The new road markings are crucial for us," explains Davide Palermo, Manager of the ADAS Competence Center. "Without them, tests for autonomous driving functions on SAE Level 4 would not be possible." Together with his colleague Toledo and another test rider on a motorcycle, Palermo performs predefined maneuvers typical of the highway: lane changes and driving in the center lane with and without another road user ahead.

"The automotive industry is on the verge of a revolution in the next five to ten years."

Antonio Gratis,
Managing Director of the Nardò Technical Center

Efficient endurance tests with steering robots

In the future, some tests at the NTC might actually be carried out without any people at all: in February 2020, a Porsche Cayenne drove more than 600 kilometers at a maximum speed of 130 km/h on the circuit—without human intervention. During the endurance test, the steering wheel and pedals were operated by a steering robot, and a test driver was only on board for safety reasons. "This form of test automation promises higher efficiency and better reproducibility," says Palermo. "But it cannot completely replace human drivers."

In addition to the improvements to the test tracks, a further innovation is preparing the NTC circuit for the future. In the future, a fiber optic cable will act as a data backbone, connecting displays, traffic lights

Fully connected: The NTC test vehicle is equipped with four WiFi and two GPS antennas. They are used for vehicle-to-vehicle communication and precise localization.

and transmitter masts along the route, thus enabling communication between vehicles and the surrounding infrastructure (vehicle-to-infrastructure). To this end, the NTC has prepared the infrastructure for laying 91 kilometers of fiber optic cable around the circular track and the vehicle dynamics platform.

The NTC is also working on its own mobile communications infrastructure, which will enable further tests of autonomous driving functions and vehicle-to-vehicle communication. And in a few years' time, "Sim City" is supposed to be added as a new test area—a city with moving houses and traffic signs, in which different urban scenarios can be set up for testing advanced driver assistance systems (ADAS).

Antonio Leuzzi, Senior Manager Project Management, gives a practical demonstration of another upgrade of the circular track. "Do you notice any bumps?" he asks while driving around the 12.6- kilometer circular track at 297 km/h. "Last year we completely renewed the asphalt—and it is now so incredibly smooth that you don't feel any vibrations even at high speeds. This is better for drivers and leads to more accurate results, for example in vibration measurements—especially important for electric vehicles with their inherently low noise levels."

Extensive charging infrastructure

An investment in electric mobility is also located next to the workshop area of the NTC. Customers of the test center can recharge their electrically powered test vehicles in the shortest possible time at two rapid charging stations developed by Porsche Engineering. A total of six such HPC (High Power Charging) stations are distributed over the site, four of them with 920 volts and 320 kW, two with 950 volts and 350 kW. "The NTC should be like a city of the future," explains Salvatore Baldi, Senior Manager Facilities Management. "That's why we have installed all kinds of charging systems—from wall boxes with seven, 11 or 22 kW to 50 kW charging stations and HPC systems."

To put the vehicle batteries of the future through their paces, the NTC has also upgraded its fire test facilities. Tank systems have been tested here for over ten years now, but the safety of lithium-ion batteries is now increasingly coming to the fore. At the NTC, for example, they can be exposed to a flame of up to 700 degrees Celsius to put their fire resistance to the test. And should a dangerous situation arise during a test with an electric vehicle, a special container is available at the NTC fire station. "There we can put electric cars and batteries in critical condition under a kind of quarantine," says Baldi. "We pull them in with a winch and then close the container completely." When the smoke detectors sound the alarm, the sprinkler system starts

"In terms of charging infrastructure, the NTC will be like a city of the future."

Salvatore Baldi,
Senior Manager Facilities Management

"We confront new challenges in the areas of ADAS, electric drives and NVH with specialized groups of experts."

Pierpaolo Positano,
Senior Manager Engineering

700 hectares

The Nardò Technical Center of Porsche Engineering in southern Italy covers a large area.

The test tracks of the NTC are

70

kilometers long altogether.

Like the autobahn: New lane markings on the inner ring circuit enable testing of autonomous driving functions.

The picture of tranquility: Antonio Leuzzi feels no vibrations on the newly renovated NTC circuit, which facilitates more accurate results and is especially important for electric vehicles with their low noise levels.

Hands off the wheel: Davide Palermo (left) leaves the steering to a robot.

Duet on wet road: On the NTC's vehicle dynamics platform, a Porsche Panamera and a Porsche Cayenne test the performance of automated driving functions.

Extensive infrastructure: E-vehicles in critical condition can be extinguished in a special container (top). The workshop area of the NTC enables the preparation of the test vehicles.

"The asphalt is now so extremely smooth that no vibrations are felt even at high speeds."

Antonio Leuzzi,
Senior Manager Project Management

"Those who work for us are part of a great adventure: the transformation of the automotive sector."

Nildo Sestini,
Senior Manager Human Resources

to reduce the flames in the initial phase of the fire. At the same time the flooding system is activated, which pumps 800 liters of water per minute at a pressure of 6 bar into the container. During the design and construction of the system, the NTC worked together with Denios' occupational safety experts.

The NTC is also continuously working on the renovation of existing workshops and the expansion of workshop capacities. By 2022, plans envision building 20 modular workshops that can be flexibly adapted to the needs of the users. In addition to the modernized technical infrastructure, customers will also be able to benefit from more extensive engineering services for their test vehicles. "So far, we have mainly rented out our testing grounds," explains Gratis. "In the future we want to take on more turnkey projects: the customer brings their vehicle to the NTC and our team carries out all tests on site—right up to the final report and engineering recommendations. Customers benefit from reduced travel costs and greater efficiency because they get everything at the NTC from a single source."

High-quality engineering services

To implement this plan, Pierpaolo Positano, Senior Manager Engineering, is expanding his team of more than 70 engineers, mechatronics engineers, technicians and drivers, adding new skills in areas such as ADAS and e-mobility. "We have gained a lot of experience in recent years, for example with reliability tests or tests on driving dynamics," says Positano. "Now we are facing new challenges, which we are meeting with specialized groups of experts—for example for NVH, ADAS and electric drives. In the future, we will be able to offer not only kilometers on our test tracks, but also our know-how—in other words, higher-value services for our customers. A magical mix of infrastructure and expertise awaits you."

The NTC finds the necessary experts on the labor market on the one hand, and through its close cooperation with universities on the other. For example, Positano and Nildo Sestini, Senior Manager Human Resources, visited universities in southern and northern Italy and gave the students tasks they could have fun with. "We don't just want to give a presentation, we want to enter into a dialog with the young people," says Sestini. Groups from universities regularly visit the NTC as well. "This is always a good opportunity to get to know each other better and find suitable candidates for us," says Sestini. "We offer promising students an internship for a period of time designed to allow them to gain experience and competence and to contribute to our center."

Content-related collaboration with the universities in Lecce (vehicle dynamics), Bari (batteries and battery management systems), Florence (ADAS and autonomous driving) and Naples (vehicle and motorcycle dynamics) also results in regular contacts with top young talents. Sestini believes in the NTC's growing appeal to bright minds: "Those who work for us are part of a great adventure: the transformation of the automotive sector."

Participants in Formula Student are considered particularly promising talents in the automotive industry. The NTC is a sponsor of the team from the University of Lecce, but does not regard its commitment as a mere recruiting measure—rather, the test center also wants to make a contribution to development in southern Italy. "Our commitment to Formula Student and in other areas fosters the growth not only of the NTC, but of the entire region," says Sestini. "We therefore want to integrate ourselves even more strongly into the ecosystem around us. This includes schools, universities and local institutions."

"We are continuously developing our infrastructure, our expertise and our team," says Gratis, summarizing the many activities at the NTC. "We always keep an eye on the megatrends in the automotive industry. And just as new technologies will soon revolutionize the driving experience, our test center will also be moving into a new future. The NTC 2.0 is fast approaching."

40

fully equipped workshops are available to customers in the NTC.

High-power charging: There are six rapid charging stations for electric vehicles on the NTC site.

Cayenne

Fuel consumption (city): 11.5–11.2 l/100 km
Fuel consumption (highway): 8.2–8.1 l/100 km
Fuel consumption (combined): 9.4–9.2 l/100 km
CO_2 emissions (combined): 215–210 g/km
Energy efficiency class: D

Panamera

Fuel consumption (city): 11.4–11.1 l/100 km
Fuel consumption (highway): 7.5–7.0 l/100 km
Fuel consumption (combined): 8.8–8.6 l/100 km
CO_2 emissions (combined): 201–197 g/km
Energy efficiency class: D

Taycan 4S

Power consumption (combined) (Performance Battery): 26.2 kWh/100 km
Power consumption (combined) (Performance Battery Plus): 27.0 kWh/100 km
CO_2 emissions (combined): 0 g/km
Energy efficiency class: A+

Taycan Turbo

Power consumption (combined): 28.0 kWh/100 km
CO_2 emissions (combined): 0 g/km
Energy efficiency class: A+

Taycan Turbo S

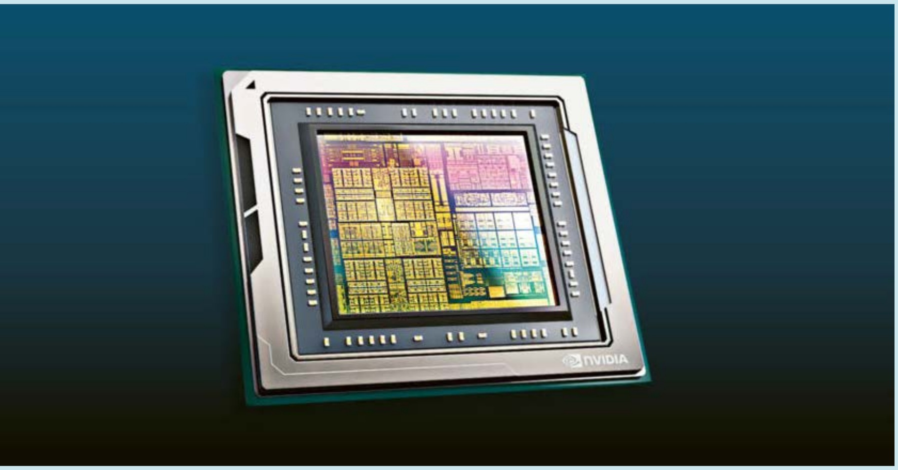
Power consumption (combined): 28.5 kWh/100 km
CO_2 emissions (combined): 0 g/km
Energy efficiency class: A+

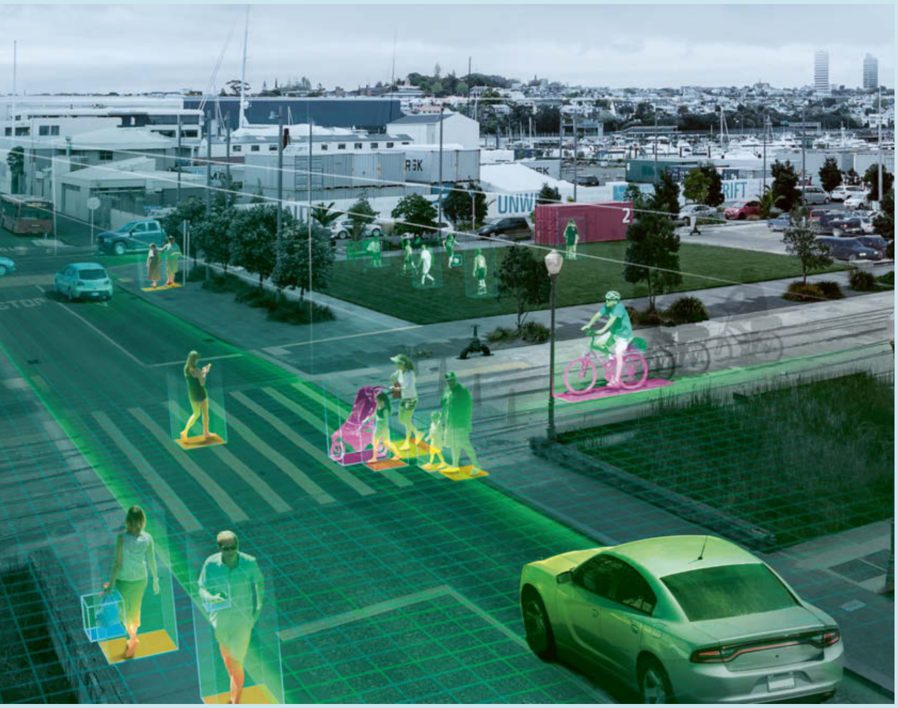
IN BRIEF

Porsche Engineering's long-established Nardò Technical Center is investing in new infrastructure and its engineering capacities. The aim is to be able to offer NTC customers a comprehensive range of services—always oriented towards automotive megatrends such as autonomous driving, connected vehicles and e-mobility.

The Nvidia headquarters in Santa Clara: Around 13,800 people work for the California-based company.

Brains for autonomous driving





Technologies for autonomous driving: Nividia's Drive-AGX Pegasus hardware (above) enables robotics, among other things. The company also trains neural networks in its own data centers.

Text: Constantin Gillies Contributor: Dr. Joachim Schaper

Nvidia made its name with graphics cards for PCs. But the US company's processors can do more—enable AI applications in vehicles, for instance. This is why the company is now an important partner of the automotive industry.

Drivers who are guided by the navigation system know the problem: if the lanes are close together, the navigation system cannot recognize which lane the vehicle is in. GPS is not precise enough for this—it can only determine the position to within two to ten meters. A system currently being developed by Porsche Engineering is much better: It uses artificial intelligence (AI) to calculate a more precise position from GPS data. "This makes it possible, for example, to identify the ideal line on a race track," says Dr. Joachim Schaper, Senior Manager of Artificial Intelligence and Big Data at Porsche Engineering. The necessary calculations can be performed in the vehicle itself, in a compact computer equipped with graphics processing units (GPUs). "This brings AI functionality to the vehicle," says Schaper.

The hardware platform is manufactured by the company Nvidia from Santa Clara, California. "When you hear the name, you don't necessarily think of the automotive sector," says Schaper. Most PC users associate Nvidia primarily with graphics cards. Or rather: especially fast graphics cards, such as those required for computer games. This reputation dates back to the early 2000s. At the time, the first games with elaborate 3D graphics came onto the market, and those who wanted to play games like *Quake 3* or *Far Cry* without screen jerking needed powerful hardware. Among gamers, a favorite quickly crystallized: the GeForce graphics card from Nvidia. It became a bestseller and catapulted the company, founded in 1993, into the top ranks of hardware manufacturers. At the turn of the millennium, the Americans already had a turnover of three billion US dollars.

AI researchers as a new customer group

In the early 2010s, Nvidia noticed that a completely new group of customers appeared on the scene who were not interested in computer games: AI researchers. After all, word had gotten around in the scientific community that GPUs were perfectly suited for complex calculations in the field of machine learning. If, for example, an AI algorithm is to be trained, GPUs that perform computing steps in a highly parallel fashion are clearly superior to conventional sequential processors (central processing units, CPUs) and can significantly reduce computing times. GPUs quickly developed into the workhorses of AI research.

Nvidia recognized the opportunity earlier than the competition and brought the first hardware optimized for AI to the market in 2015. The company immediately focused on the automotive sector: the company's first computing platform for use in cars was presented under the label Nvidia Drive. The PX 1 was able to

"The customer can put together their own solution and saves on basic development."

Ralf Herrtwich, Senior Director Automotive Software at Nvidia

THREE QUESTIONS TO RALF HERRTWICH

"The automotive sector advances AI as a whole"

1

When does artificial intelligence (AI) arrive in the car?

It's already in the cockpit, for example. Many manufacturers offer voice control based on AI. The performance of these systems has improved noticeably in recent years. In addition, the vehicle is increasingly expected to perceive its environment and react appropriately, as is the case in assistance systems. Here, too, AI is playing a growing role. Such vehicle applications are among the most demanding of all. We expect this area to advance AI as a whole.

2

When will autonomous driving become a reality?

Robotic vehicles are already being used in localized areas, especially in places where the weather is good. However, for the time being we see the main market for regular vehicles with support functions, that is autonomy levels 1 to 3. Overall, the coming years will be characterized by a competition between such systems—that is by the question of which manufacturer's system can master most situations. It is less about the aspiration of being completely self-controlled.

3

How does artificial intelligence change the automotive ecosystem?

The more important software functions become, the more the role of tier 1 suppliers changes. Their traditionally strong ties to manufacturers are weakening. In the future we can imagine a triangular constellation: OEMs work with technology companies like Nvidia on processors and software modules, and tier 1 builds the control unit. Some OEMs already attach importance to keeping software functions in their own hands.

process images from twelve connected cameras and simultaneously execute programs for collision avoidance or driver monitoring. It had the computing power of over 100 notebooks. Several manufacturers used the platform to bring the first prototypes of autonomous vehicles to the road.

Initially, Nvidia relied on a pure hardware strategy and supplied the OEMs with processors. Currently, business in the automotive sector has two pillars: cockpit graphics systems and hardware for autonomous or computer-assisted driving. Sales in the automotive sector grew steadily between 2015 and 2020, but still represent a low share of overall sales. Last year, Nvidia's sales in the automotive sector amounted to 700 million US dollars, which corresponds to a good six percent of total sales; however, sales are increasing by nine percent per year. Jensen Huang, Founder and CEO of Nvidia, sees great market opportunities here. "The cars of tomorrow are rolling AI supercomputers. Only two of the numerous control units will remain: one for autonomous driving and one for the user experience," he says.

Complete package of hardware and software

To gain an even stronger foothold in the automotive world, Nvidia has changed its strategy: the company no longer focuses solely on chips, but offers a complete package of hardware and software. "Customers can put together their own solution and save on basic development," explains Ralf Herrtwich, Senior Director Automotive Software at Nvidia. An OEM that wants to offer a semi-autonomous vehicle, for example, can obtain both the hardware for evaluating the camera images and pre-trained neural networks from Nvidia—for example, one that automatically recognizes traffic signs. Unlike other manufacturers, this modular system is open. "All interfaces can be viewed. The OEM can thus adapt the system to its own requirements," explains Herrtwich. In theory, a manufacturer can use pre-trained neural networks from Nvidia and then combine them with in-house developments.

Through this strategy of openness, the American company aims to gain as many OEMs as possible as users, which ultimately also drives the development of the products. "We can best optimize our hardware if we know how it is used," explains Herrtwich. He offers an example: most Nvidia products are System-on-a-Chip (SoC). This means that a processor is combined with other electronic components on a semiconductor.

"Tomorrow's cars will be rolling AI supercomputers."

Jensen Huang,
Founder and CEO of Nvidia

The automotive sector, for example, uses chips with built-in video inputs to which external cameras are connected. But how many inputs are needed? And how should the network connection be designed? Such questions can only be answered in close contact with the users, says Herrtwich. AI expert Schaper has a similar view: "The input from other OEMs is important." In the current phase, it is crucial to jointly accelerate the development processes.

In addition to hardware and software, Nvidia also offers closely cooperating OEMs access to its own infrastructure. For example, manufacturers can collaborate on training neural networks in Nvidia data centers, where thousands of GPUs work in parallel. After all, a self-driving algorithm must first learn to recognize a pedestrian, a tree, or another vehicle. To do this, it is fed millions of images from real traffic on which the corresponding objects have been manually marked. Through trial and error, the algorithm learns to identify them. This process requires a lot of work (such as labeling the objects) and requires high computer capacities. Nvidia handles both. Car manufacturers can thus access an artificial intelligence that has virtually been in school for several years.

Why GPUs are the better AI computers

GPUs are specialized in performing geometric calculations: rotating a body on the screen, zooming in or out. GPUs (graphics processing units) are particularly good at performing the matrix and vector calculations required for this. This is an advantage in the development of neural networks. They are similar to the human brain and consist of several layers in which data is processed and passed on to the next layer. To train them, matrix multiplications are key—in other words, exactly the specialty of GPUs. In addition, these computer architectures have a lot of memory to store intermediate results and models efficiently.
The third strength of GPUs is that they can process several data blocks simultaneously. The processors contain thousands of so-called shader units, each of which is quite simple and slow. However, these computing units can process parallelizable tasks much faster than conventional processors (central processing units, CPUs). When training neural networks, for example, graphics processors reduce the time required by up to 90 percent.

Charging master for electric vehicles

Text: Hans Oberländer Contributor: Alexander Schneider-Schaper

Porsche offers its customers a wide range of home charging options. One part of this is the Home Energy Manager (HEM) developed by Porsche Engineering. It sets new standards—for one thing, it is approved worldwide and can therefore be installed anywhere.

Coming home in the evening, parking the electric vehicle, charging the battery via your own power connection, and driving off again the next morning with sufficient range. This scenario requires intelligent charging solutions for the home that provide sufficient power and integrate seamlessly into the existing system of consumers. The Porsche Mobile Charger will be available in three versions in 2021, ensuring that there is a suitable version for all requirements.

The basic model is available with a connected load of 3.6 kW and 7.2 kW; the Mobile Charger Plus enables up to 11 kW charging power; and the Mobile Charger Connect is even capable of recharging the battery with up to 22 kW—if the vehicle is equipped accordingly and the home power supply has sufficient capacity. Intelligent charging functions also make recharging an inexpensive matter: with the "cost-optimized charging" function, users can use specific day and night periods for charging when electricity is particularly cheap.

The Mobile Charger models are connected to a home or industrial socket. The cable and a wall bracket are included in the scope of delivery. An elegant charging dock and a Porsche Charging Pedestal are also available for the Mobile Charger Connect. The special feature of the most powerful model is its five-inch touch display. It displays data such as the current battery charge level and the remaining charging time. Alternatively, with Mobile Charger Connect the data can also be displayed on a linked smartphone or tablet via the Porsche Connect App. Above all, however, the Mobile Charger Connect via PLC (Powerline Communication) and WiFi enables the use of the Porsche Home Energy Manager, which rounds out the range of Porsche charging solutions and was developed by Porsche Engineering.

Monitoring the circuits

One of the most important tasks of the Porsche Home Energy Manager is to monitor the electrical circuits in the house and thus ensure, among other things, that recharging the electric vehicle does not lead to an overload. With the introduction of environmentally friendly cars into the garages of their owners, the home connections are faced with completely new consumers: while an electric stove, for example, has a

Filling up on electricity: The charging solutions from Porsche can be adapted to personal wishes and available space constraints.

Porsche Home Energy Manager

Device dimensions

W 159.4 millimeters
H 73.2 millimeters
D 90.2 millimeters

Interfaces

2 × USB
1 × PLC

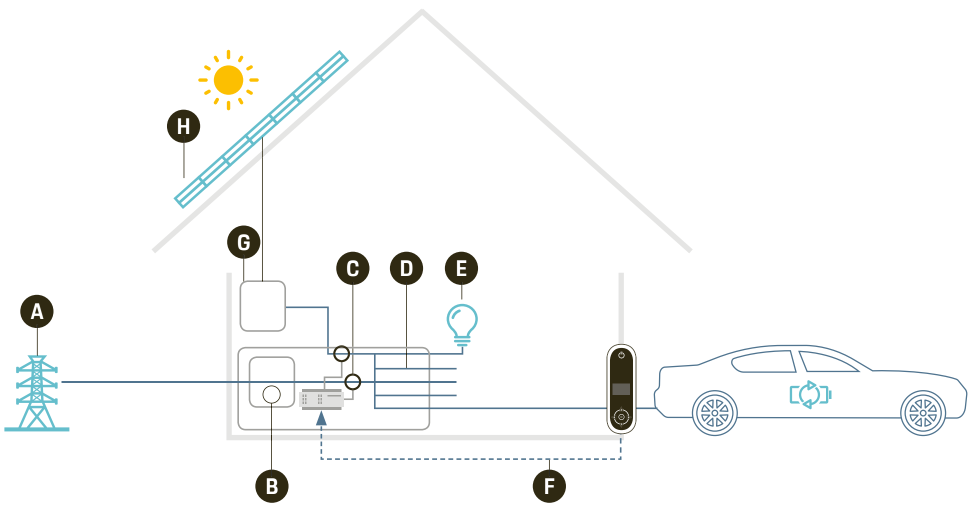
1 × WLAN
2 × Ethernet*

12 × CT input
1 × RS485/CAN**

* used 1×,
for future application/use 1×

** for future application/use

Installation variant



- A Power supply
- B Electricity meters
- C Current sensors
- D Distributor
- E In-house consumers
- F EEBUS protocol
- G Inverter
- H Photovoltaics

EEBUS: the global language for data exchange

The Internet of Things (IoT) connects more and more devices with each other. But they can only interact with each other if they all speak a common language. EEBUS ("Energy-Efficiency Bus") offers just that. As a communication interface in the smart home, EEBUS enables the exchange of data, for example from white goods such as refrigerators and washing machines and heating and ventilation systems, electric vehicles, and other equipment. In this way, EEBUS can help reduce CO_2 emissions through intelligent energy management that combines the areas of electricity, heat, and mobility. This allows energy to be distributed according to demand, which better balances consumption and generation.

Many possible applications

Porsche
Mobile Charger Connect
Battery charger with 5-inch touch display and maximum 22 kW output.

Porsche
Charging Dock
Elegant wall mount for the Porsche Mobile Charger Connect.

Porsche
Compact Charging Pedestal
This accommodates the Porsche Mobile Charger Connect in outdoor parking areas.

connected load of 3.6 to 7.5 kW, rapid recharging of the battery requires up to 22 kW. Smart energy management is therefore indispensable. On the one hand, it must make maximum use of the available power to achieve short charging times. On the other hand, it must also ensure that all other electrical consumers receive sufficient power and that an overload situation never occurs.

To this end, the Porsche Home Energy Manager continuously monitors the household's electricity requirements and compares them with the available power from the power socket. In the event of an imminent overload, it communicates with the Porsche chargers and reduces the power for the charging process. The installation of the Porsche Home Energy Manager is very easy: the device is installed by a qualified electrician in the distribution box of the house, connected to the internet, and configured. After completing the installation wizard, the technology is ready to go.

Strongly user-friendly design

The Porsche Home Energy Manager was developed by a team from Porsche Engineering—from the first sketch to the market-ready product. The requirements were extremely high when the project was launched in 2016. The Home Energy Manager, with its emphasis on user-friendly design, had to be approvable worldwide and work in any power grid. The result is that today, the Home Energy Manager is the only device of its kind that is approved and installable worldwide. However, there is also a lot of work behind this success: the approval process, which was conducted jointly with TÜV Süd, took almost two years, partly because many countries did not yet have any standards for the Home Energy Manager device class. "We have done pioneering work in many fields," says Alexander Schneider-Schaper, Project Leader at Porsche Engineering, "including with the functional properties."

This enables Porsche to set new standards with its Home Energy Manager: if the necessary communication and energy charging infrastructure is available, theoretically up to 254 vehicles can be charged simultaneously. The algorithms calculate and coordinate the maximum charging energy available for the electric vehicles—while at the same time the stove, heating, light, and the many other devices in the house continue to function perfectly. Using the web interface, users can define what happens if several electric vehicles are to be charged. A list of priorities can be drawn up according to requirements and different charging strategies can be defined, for instance

"We have done pioneering work in many fields, including with the functional properties."

Alexander Schneider-Schaper, Project Leader for the Home Energy Manager at Porsche Engineering

Taycan Turbo S

Power consumption (combined): 28.5 kWh/100 km
CO_2 emissions (combined): 0 g/km
Energy efficiency class: A+

according to the principle of first come, first served. Or the available charging energy can be distributed equally among all vehicles.

Whether it's a photovoltaic system, air conditioning and heating, pool, stove, refrigerator, or other devices, up to twelve circuits can be monitored in real time with the Porsche Home Energy Manager—three circuits are common in the industry. Communication with the Porsche Mobile Charger Plus and Connect for the electric vehicle goes via the EEBUS communication interface. It provides a standardized language for data exchange and energy management on the Internet of Things (see box). In the next step, heating, ventilation, air conditioning, and household appliances will also communicate with the Home Energy Manager via EEBUS. This provides a precise overview of the energy flows in the house and forms the basis for demand-oriented energy distribution. The heating, stove, and so forth are prioritized: should there ever be a bottleneck in the power supply because many devices are in operation, the charging capacity of the electric vehicle will be reduced.

Many users supply their electric vehicles with their own green electricity, for example via the photovoltaic system on the roof. The Porsche Home Energy Manager helps to optimize energy costs in the long term—for example by ensuring that as much energy as possible is consumed from the home's own photovoltaic system. In many countries, customers also have electricity rates that are less expensive at certain times. When the user enters their electricity rate, the Home Energy Manager optimizes the charging process depending on these rates and the desired charge level of the vehicle.

Up to now, the focus of the Porsche Home Energy Manager has been on the charging process for electric vehicles. But the Porsche Engineering team has long been planning to expand it in such a way that it will also make the operation of heating, air conditioning, and household appliances more energy- and cost-efficient. The goal: comprehensive energy management for the entire house—from Porsche. The Home Energy Manager could become a kind of energy marketplace: heating, refrigerator, electric vehicle, and other consumers compete for the electricity supplied by the home's photovoltaic system or the grid connection. Preference is given to the device with the highest defined priority. Improvements to the user interface are also forthcoming: the Home Energy Manager will soon be integrated into the Porsche Connect app, and installation at home will become a simple plug-and-play experience.

A unique symbiosis of contrasts: the new Porsche Panamera now covers an even wider range. It combines the performance of a sports car with the comfort of an exclusive sedan. With the 463 kW (630 hp) Panamera Turbo S in particular, the sports car manufacturer underscores its high standards of best-in-class performance. The new top model clearly surpasses the performance figures of the previous Panamera Turbo. Porsche is also consistently pursuing its E-Performance strategy. The Panamera 4S E-Hybrid complements the plug-in hybrid range with a completely new drive system with 412 kW (560 hp) of system output. The purely electric range has been increased by up to 30 percent compared to previous hybrid models. Comfort and sportiness benefit in equal measure from enhanced chassis components, control systems, and a new generation of steering control and tires.

Improved driving performance

With 463 kW (630 hp) and 820 Nm of torque, the new Panamera Turbo S offers 59 kW (80 hp) more power and 50 Nm more torque than the previous top-of-the-line combustion engine, the Turbo. This significantly improves driving performance: in Sport Plus mode, the standard sprint takes just 3.1 seconds. The maximum speed is 315 km/h. The familiar four-liter

Panamera 4S E-Hybrid

Fuel consumption (combined): 2.2–2.0 l/100 km
CO_2 emissions (combined): 51–47 g/km
Power consumption (combined): 18.1–17.4 kWh/100 km
Energy efficiency class: A+

Panamera Turbo S

Fuel consumption (city): 14.9–14.8 l/100 km
Fuel consumption (highway): 8.5–8.4 l/100 km
Fuel consumption (combined): 10.8–10.7 l/100 km
CO_2 emissions (combined): 247–245 g/km
Energy efficiency class: E

Panamera GTS

Fuel consumption (city): 15.4–15.4 l/100 km
Fuel consumption (highway): 8.2–8.0 l/100 km
Fuel consumption (combined): 10.9–10.7 l/100 km
CO_2 emissions (combined): 249–244 g/km
Energy efficiency class: F

Panamera

Fuel consumption (city): 11.4–11.1 l/100 km
Fuel consumption (highway): 7.5–7.0 l/100 km
Fuel consumption (combined): 8.8–8.6 l/100 km
CO_2 emissions (combined): 201–197 g/km
Energy efficiency class: D

Panamera 4

Fuel consumption (city): 11.6–11.4 l/100 km
Fuel consumption (highway): 7.3–7.1 l/100 km
Fuel consumption (combined): 8.8–8.7 l/100 km
CO_2 emissions (combined): 202–199 g/km
Energy efficiency class: D

Best in class with performance plus

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

The new Porsche Panamera is living up to its role as a four-door sports car with powerful and efficient drives more than ever before. New models such as the Panamera Turbo S also underline the claim to best-in-class performance. With the equally new Panamera 4S E-Hybrid, Porsche is presenting another powerful plug-in hybrid.

V8 biturbo engine—developed in Weissach, built in Zuffenhausen—has been fundamentally revised for this purpose. In order to transfer the enormous power to the road in a controlled manner and to maximize cornering performance, the three-chamber air suspension, Porsche Active Suspension Management (PASM), and the Porsche Dynamic Chassis Control Sport (PDCC Sport) roll stabilization system—including Porsche Torque Vectoring Plus (PTV Plus)—have been customized to each specific model and optimized accordingly.

The V8 biturbo engine in the Panamera GTS has been optimized above all in terms of its power delivery. With 353 kW (480 hp) and 620 Nm, the new Panamera GTS delivers 15 kW (20 hp) more power than its predecessor model. This power increases continuously until close to the engine speed limit. The power delivery is thus equal to that of a classic naturally aspirated sports car. In addition, the new standard sports exhaust system uses asymmetrically designed rear silencers to emphasize the classic V8 sound characteristics even more than before. In the new Panamera and Panamera 4, the familiar 2.9-liter V6 biturbo engine is now being used in all markets worldwide. The output figures remain unchanged at 243 kW (330 hp) and 450 Nm.

For all new Panamera models, the suspension and control systems have been trimmed for sportiness and comfort and in some cases completely re-applied. The revised Porsche Active Suspension Management (PASM), for example, provides a noticeable improvement in damping comfort, while the control of the Porsche Dynamic Chassis Control Sport (PDCC Sport) electric roll stabilization system ensures more body rest. In addition, a new generation of steering and tires is being used.

New high-performance hybrid model

With the new Panamera 4S E-Hybrid, Porsche is presenting another performance-oriented plug-in hybrid model. The intelligent interaction of the 100 kW (136 hp) electric motor integrated into the eight-speed PDK dual-clutch transmission and the 2.9-liter V6 biturbo unit with 324 kW (440 hp) produces a system output of 412 kW (560 hp) and a maximum system torque of 750 Nm. The driving performance is correspondingly impressive: in combination with the standard Sport Chrono Package, the sprint from 0 to 100 km/h takes just 3.7 seconds. It tops out at 298 km/h. The gross capacity of the battery has been increased by means of optimized cells from 14.1 to 17.9 kWh compared to the previous hybrid models, and the driving modes have been optimized with a view to even more effective energy use. The Panamera 4S E-Hybrid now has a purely electric range of up to 54 kilometers (NEDC: up to 64 kilometers) in the WLTP EAER City.

Model maintenance: The light strip now runs seamlessly across the tailgate (top). The Porsche Communication Management (PCM) system includes additional digital functions and services (below).

630 hp
of power is delivered by the new Panamera Turbo S, with 820 Nm of torque.

3.1 seconds
is all it takes from 0 to 100 km/h in Sport Plus mode.

The new Panamera models now come ex-works with the previously optional Sport Design front with distinctive air intake grilles and large lateral cooling air vents as well as the single-bar front light module. The completely new front end of the Panamera Turbo S is differentiated by the larger side air intakes and newly designed elements in the exterior color, which are connected horizontally and thus emphasize the width of the vehicle. The light modules of the dual Turbo front lights are now set much further apart.

The revamped light strip at the rear now runs seamlessly over the luggage compartment lid with an adapted contour. It thus provides a continuous and flowing connection between the two newly designed

Moving fast: The record-breaking Panamera was equipped with a racing seat and a safety cage to protect the driver.

7:29.81

on the clock

for a lap on the Nordschleife of the Nürburgring: optimizations to the chassis and drive system of the new Panamera made the record possible.

LED tail light clusters. GTS models sport the new darkened Exclusive Design tail light clusters as standard with dynamic coming/leaving home function. Three new 20- and 21-inch wheels have been added to the wheel range, so that a total of ten different designs are now available.

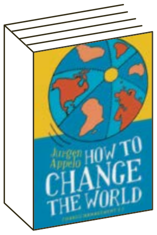
The Porsche Communication Management (PCM) includes additional digital functions and services such as the improved Voice Pilot online voice control, Risk Radar for up-to-date road sign and hazard information, wireless Apple® CarPlay, and many other Connect services. The Panamera also offers an extensive range of innovative light and assistance systems, such as the now standard Lane Keeping Assist system with road sign recognition, as well as Porsche InnoDrive including Adaptive Cruise Control, Night Vision Assist, Lane Change Assist, LED matrix headlights including PDLS Plus, Park Assist including Surround View, and head-up display.

Nürburgring: record time in the luxury class

Even before its world premiere, the new Porsche Panamera impressively demonstrated its exceptional performance: on July 24, 2020, test driver Lars Kern completed a full lap of 20.832 kilometers on the legendary Nordschleife of the Nürburgring in exactly 7:29.81 minutes. In the official ranking list of Nürburgring GmbH, this time, certified by a notary, is listed as a new record in the category “luxury class.” The record time underlines the extensive further development of the second Panamera generation: As early as 2016, Lars Kern had already conquered the Eifel circuit in 7:38.46 minutes with a 550 hp Panamera Turbo—over the 20.6 kilometers that was customary for record attempts at the time, that is without the approximately 200-meter-long section of the track at grandstand number 13. In accordance with the new statutes of Nürburgring GmbH, this time the complete Nordschleife distance of 20.832 kilometers was measured. By comparison: Lars Kern and the new Panamera had already passed the 20.6-kilometer mark at 7:25.04 minutes. The record team was some 13 seconds faster than four years ago.

Top time: Lars Kern holds the record in the “luxury class” category

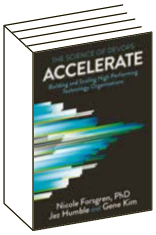
Deeper knowledge



Change Management 3.0

Although it is by no means easy to reshape organizations, anyone can become an effective actor for change—with knowledge of change management and the agile mindset.

How to Change the World
Jurgen Appelo
Jojo Ventures BV



Measuring the performance of software teams

Nicole Forsgren, Jez Humble and Gene Kim have found a way to measure the performance of software development teams using statistical methods. This book presents the results and the science behind the research.

Accelerate—The Science of Lean Software and DevOps
Nicole Forsgren, Jez Humble, Gene Kim
IT Revolution Press

When everything is automated

In this podcast, host Jennifer Strong and the MIT Technology Review team discuss topics related to artificial intelligence such as autonomous driving, face recognition, and possible algorithmic errors.

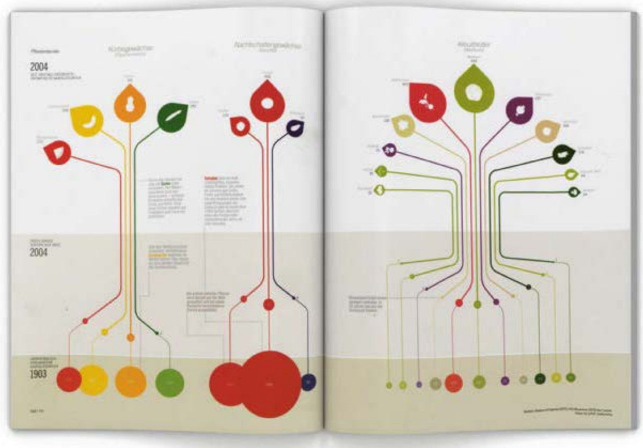
***In Machines We Trust* (podcast)**

"The world through the lens of software"

Thus the motto of the *Software Engineering Daily* website. Articles and podcasts address current topics such as "robotic process automation" or "hyperparameter tuning" as well as megatrends such as block chain technology.

Software Engineering Daily
softwareengineeringdaily.com/

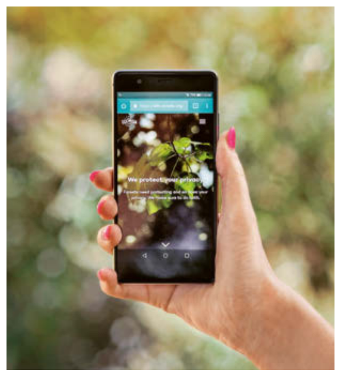
The big picture



Grand connections with ingenious simplicity

With colorful graphics, this book explains both simple and complex relationships in a playful way. Among them: the most common causes of air crashes in the last 20 years and the number of different types of stars that make up the Milky Way.

Knowledge is beautiful
David McCandless
Harper Collins



Search and plant trees

Everyone knows Google. One alternative to the popular search engine is Ecosia. The company uses its advertising revenue to plant trees—already more than 110 million worldwide.

www.ecosia.com

For the child in all of us

Programming a robot is child's play

Using the set, children seven and older can learn the basics of programming, mechanical engineering, and robotics. All they have to do is choose one of the five models and download the free app.

LEGO Boost 17101
Programmable robotics set
www.lego.com

Self-built telescope

Stargazing at a bargain price: With this kit you can build yourself a 72-centimeter telescope. Aside from the lenses and the mirror, the kit consists entirely of cardboard and is designed to be able to be put together without the use of adhesives.

buildyourownkits.com

Intelligent entertainment

Dangerous investigations

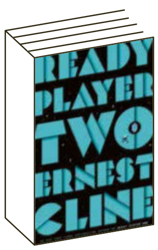
The young software engineer Lily Chan (played by Sonoya Mizuno) is investigating in the secret development department of her employer, the high-tech company Amaya based near San Francisco. She believes that the company is behind the murder of a friend and wants to find out the truth.

***Devs* (TV series)**

Critical appraisal

Big data, feminism, data capitalism, inclusion, and data discrimination: this book deals with each of these current issues—in the form of explanations, black and white illustrations and cats.

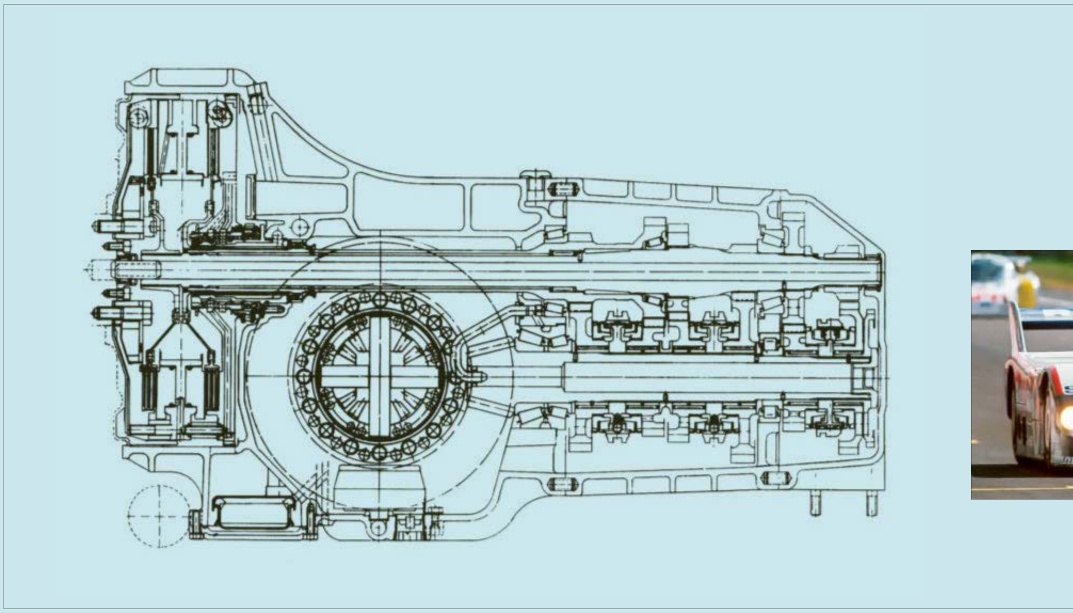
We Need to Talk, AI
Julia Schneider, Lena Kadriye Ziyal
epubli



Search for the digital Easter egg

This science fiction novel by US author Ernest Cline continues his 2011 award-winning debut *Ready Player One*, in which the protagonist Wade Watts searches for an "Easter egg" in a virtual reality game. The story continues in November 2020.

Ready Player Two
Ernest Cline
Ballantine Books



New concept: The ancestor of the PDK from 1981 (left) and a Porsche 956 with dual-clutch transmission from 1984.

1983

After decades of preparatory work, the Porsche dual-clutch transmission (PDK) was developed at the beginning of the 1980s, tested in the Porsche 956 from 1983 and used in races from 1984 onwards. After the turn of the millennium, the PDK entered series production, where it was able to fully exploit its advantages—including gear changes without loss of traction and reduced fuel consumption.

718 GTS 4.0 (with PDK)

Fuel consumption (city): 13.0 l/100 km
Fuel consumption (highway): 7.6 l/100 km
Fuel consumption (combined): 9.6 l/100 km
CO_2 emissions (combined): 219 g/km
Energy efficiency class: G

718 Spyder (with PDK)

Fuel consumption (city): 13.7 l/100 km
Fuel consumption (highway): 8.1 l/100 km
Fuel consumption (combined): 10.2 l/100 km
CO_2 emissions (combined): 232 g/km
Energy efficiency class: G

718 Cayman GT4 (with PDK)

Fuel consumption (city): 13.7 l/100 km
Fuel consumption (highway): 8.1 l/100 km
Fuel consumption (combined): 10.2 l/100 km
CO_2 emissions (combined): 232 g/km
Energy efficiency class: G

More than 50 years ago Porsche engineers were already looking for a transmission concept that would have the advantages of a manual transmission while avoiding the disadvantages of an automatic. As early as 1964, a five-speed racing transmission with a powershift dual-clutch was developed, followed in 1968 by an automatic four-speed transmission with electrohydraulic control. In 1979, for the 995 concept sports car of the future, the developers again designed a dual-clutch transmission, which later became the basis of the Porsche dual-clutch transmission (PDK). The PDK was developed from 1981 onwards, was first tested in 1983 in the Porsche 956, and was used in racing from 1984—in what is probably one of the most successful race cars of all times. The PDK played a major role in that success: by shifting gears without interrupting traction, the vehicle accelerated faster and at the same time consumed less fuel. However, the PDK was too far ahead of its time for series use—the electronics and the computing power of the control units are not yet capable of meeting the high comfort requirements for operation in a road vehicle.

This changed after the turn of the millennium. Porsche took up the PDK development again and presented the first dual-clutch transmission for production sports cars in the 997 generation of the 911 Carrera. It is ideally tailored to sports cars: The PDK combines the driving dynamics and excellent mechanical efficiency of a manual transmission with the high shifting and driving comfort of an automatic transmission. The gears of the PDK are distributed over two sub-transmissions, which are connected to the engine via two parallel powershift clutches. The odd-numbered gears and reverse are connected to clutch I, the first sub-transmission. The even gears are connected to clutch II, the second sub-transmission. In principle, the individual gears are selected via shift forks, as in a mechanical manual transmission, but in the PDK they are operated electrohydraulically.

Even at its debut, the dual-clutch transmission completed shifting operations up to 60 percent faster than an automatic transmission. It also allows gear changes without interrupting tractive force and reduces fuel consumption. To this day, the PDK continues to exploit these advantages. In numerous Porsche vehicles, it ensures breathtaking shifting times and acceleration values while also reducing fuel consumption and enabling functions such as predictive driving and shifting. Since September 2020, the Porsche models 718 GTS 4.0, 718 Spyder and 718 Cayman GT4 have also been offered with a PDK. Compared to the vehicles with manual transmissions, they complete the sprint to 100km/h roughly half a second faster.

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