Porsche Engineering Magazine

Issue
2/2021

20 YEARS OF FUTURE PORSCHE ENGINEERING

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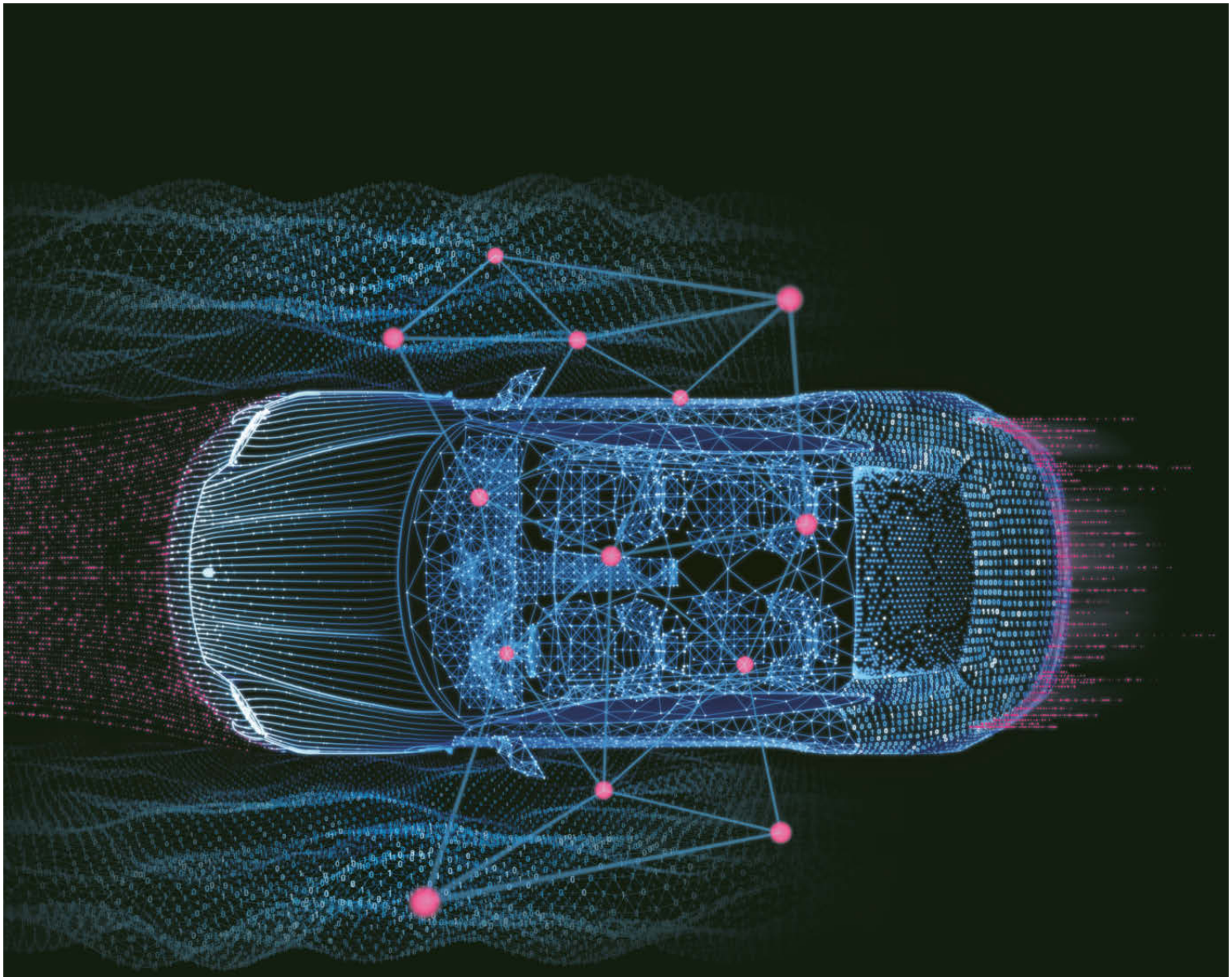
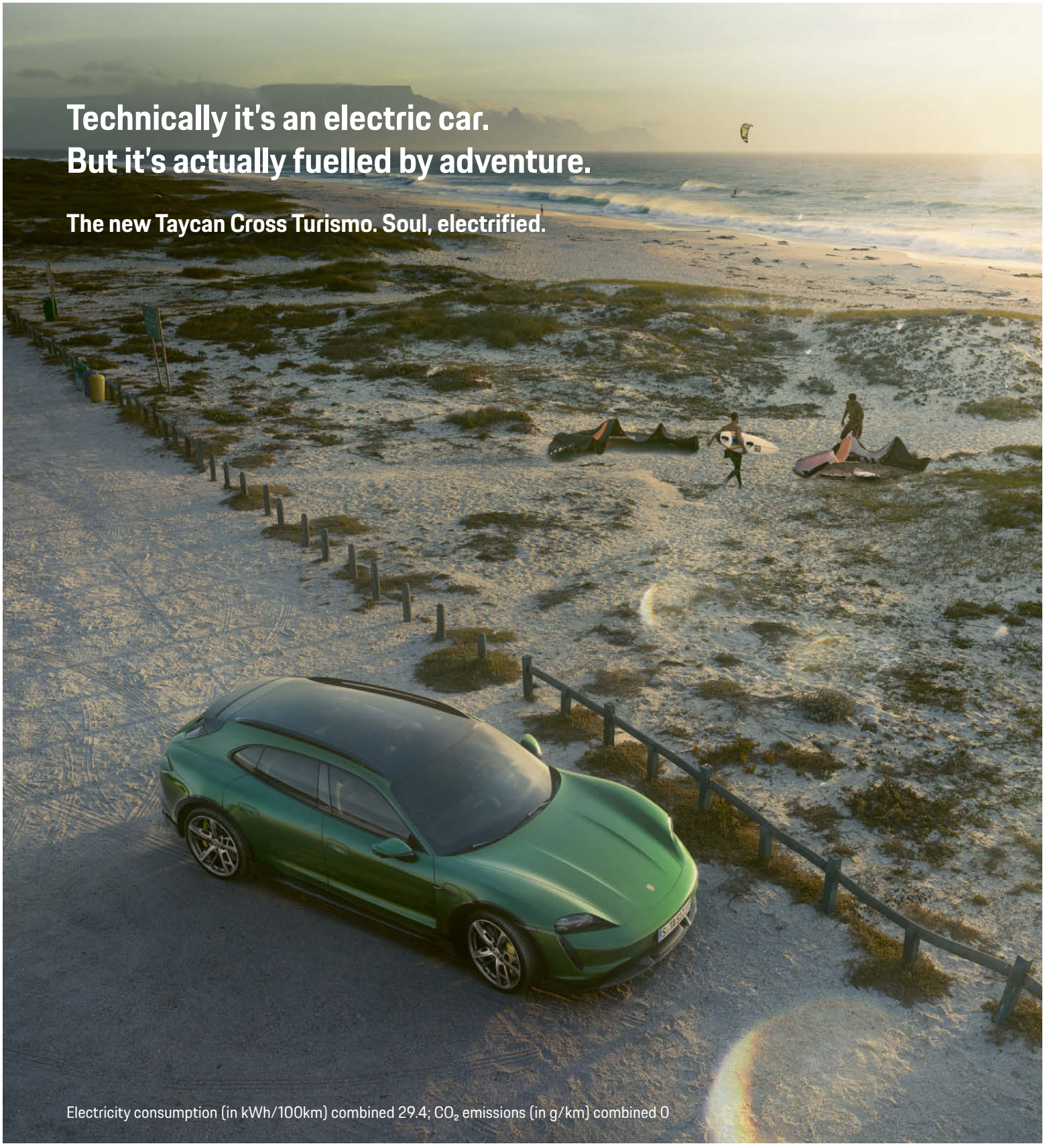


THE PATH TO THE AUTOMOTIVE FUTURE

Intelligent. Connected. Digital


Technically it's an electric car.
But it's actually fuelled by adventure.
The new Taycan Cross Turismo. Soul, electrified.
Electricity consumption (in kWh/100km) combined 29.4; CO_2 emissions (in g/km) combined 0

PORSCHE

Dr. Peter Schäfer
Managing Director of Porsche Engineering

Dear Reader,

A pioneering spirit has shaped Porsche's history from its very inception. This is just as true for engineering services by Porsche as it is for the sports car manufacturer Porsche. Since the founding of the Porsche engineering office 90 years ago, we have dedicated ourselves to technical challenges with passion and inventiveness. Our aim is always to develop the innovations of tomorrow.

What Ferdinand Porsche began with pioneering work such as the Volkswagen, we are carrying forward today with the development of technologies for the intelligent and connected vehicle of the future. In the process, we pay close attention to specific market requirements for digital functions. Hence the theme of the current issue of our magazine: "Intelligent. Connected. Digital".

Our report on the Big Data Loop shows the potential that artificial intelligence holds in store for new driving functions. Learning in the cloud will make it possible to optimize driving functions largely automatically even after a vehicle has been delivered, thus offering customers added value. What we were able to demonstrate in the proof of concept using the example of adaptive cruise control will be of interest for many other driving functions as well. The Big Data Loop is also a good example of the increasing importance of connectivity. We use data from all the vehicles in a fleet to optimize each of them individually.

We are taking a connected and local approach to automotive development in China. Here, on the one hand—as in other markets—we need to connect vehicles as seamlessly as possible with the digital ecosystem of their users. On the other hand, it is also important to take into account the special features of the local infrastructure and the services of domestic technology companies such as Tencent or Alibaba. As Porsche Engineering has been active in China for more than 20 years, we are ideally positioned to make these connections a reality.

The combination of intelligent and local approaches is also the focus of the AI Delta Learning project. Here, the goal is to selectively teach intelligent driving functions something new. This is particularly important if we want to adapt vehicles to local conditions with as little effort as possible.

"Intelligent. Connected. Digital": And we will continue to dedicate ourselves to the technologies of tomorrow, and our tradition of innovation, in the future as well.

I hope you enjoy reading this issue of the magazine.

Best regards,
Peter Schäfer

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

16 **China expert:** Dr. Jens Puttfarcken (pictured) talks with Dr. Peter Schäfer and Kurt Schwaiger about China's role in automotive development

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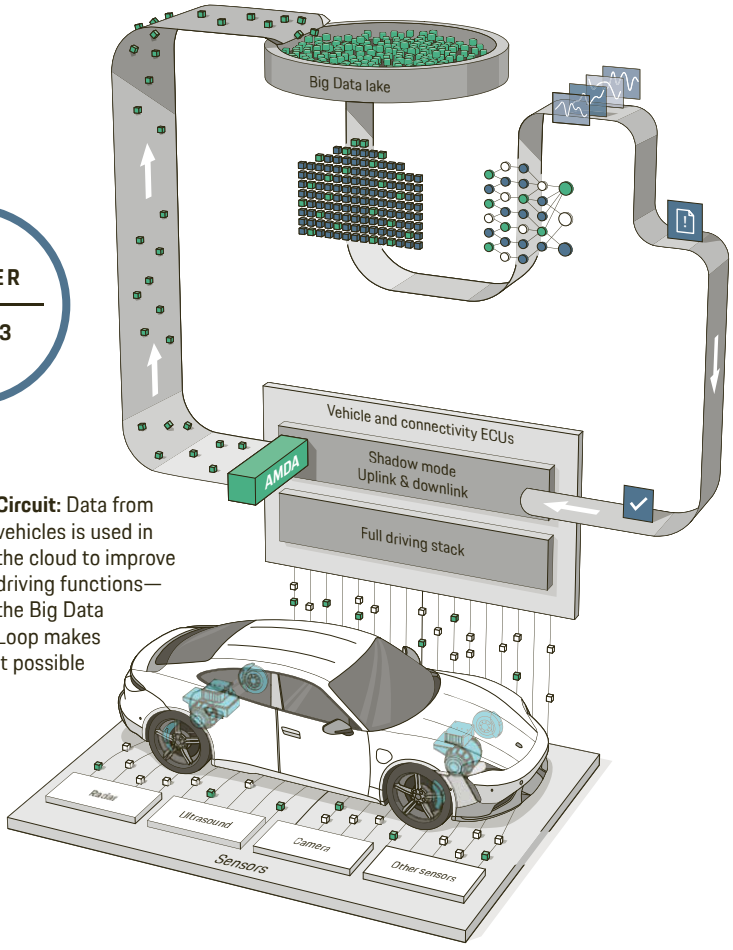

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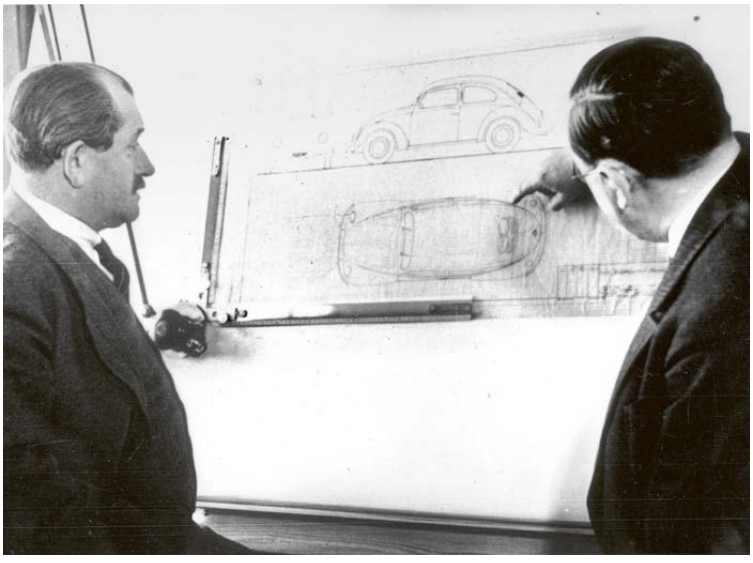

40 **Pioneer:** Ferdinand Porsche (left) has had a decisive influence on the development of automotive technology for decades

Porsche Engineering Magazine

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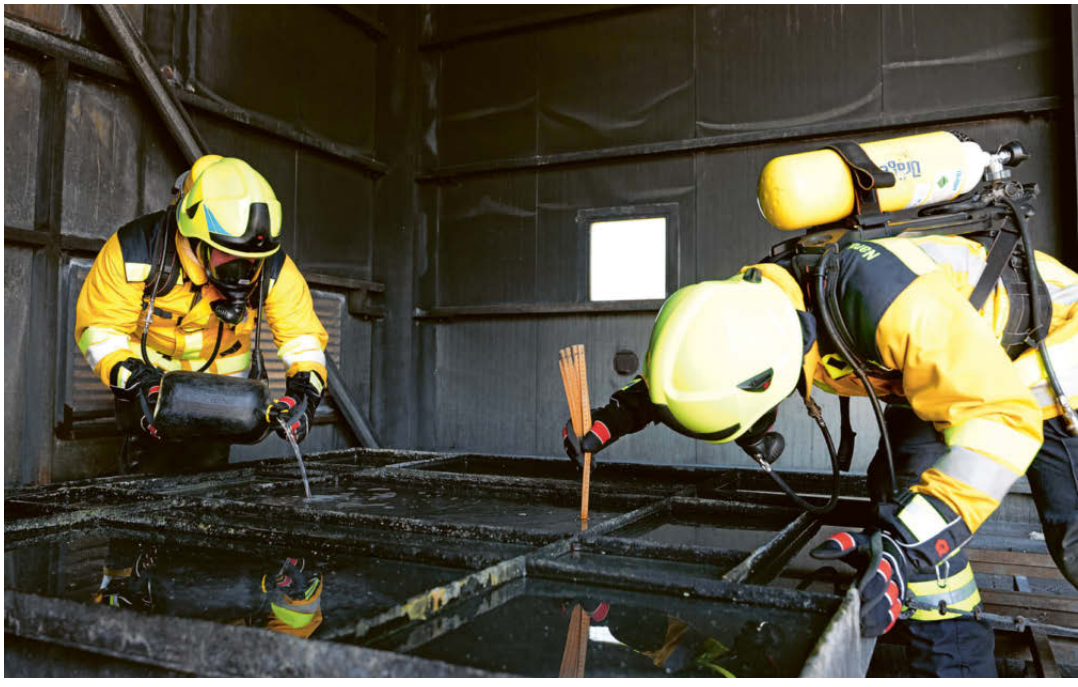
NTC Academy and misuse tests of batteries

The Nardò Technical Center expands its services

The Nardò Technical Center (NTC) Academy, founded at the beginning of the year, offers premium quality driving training to drivers and technicians from the automotive industry. At the wheel of high-performance sports cars, they can improve their skills and driving capabilities at the proving ground. In various training levels, they are taught comprehensive driving knowledge—from the basics of vehicle control to high-performance and super sports training. Participants benefit from the NTC's extensive testing experience and driving dynamics expertise, as well as unique and tailored training sessions by a qualified team of instructors and engineers. For those who wish to further improve their professional driving skills, the NTC Driving Academy offers the complete package of training courses. They are conducted on the Lorry Dynamic Platform while advanced trainings are held on one of the most challenging tracks at the proving ground, the Handling Track.

In addition, the NTC has expanded its portfolio of expertise and services to include misuse testing of batteries. The fire resistance tests according to UNECE100 are carried out at the Fire Test Site at temperatures of up to 700 degrees Celsius and monitored in real time by cameras. A quarantine container is available for batteries or e-vehicles in a critical state. On request, the devices to be tested can be equipped with temperature and pressure sensors. The NTC engineering department offers pre-test simulations. Post-processing of the data is automatic and fast thanks to analysis routines developed in-house. At the end, customers receive a report with test results, including photographic and high-resolution video documentation.



Driving Academy (above): Performing driving maneuvers during the training session.

Battery tests: NTC firefighters fill a tub with the amount of fuel required by UNECE100 standards.

Up to

700

degrees Celsius are applied during the battery tests in Nardò.

Load test under extreme conditions

MAY sunshades in the wind tunnel

Due to their large contact surfaces, sunshades are subject to strong forces even at low wind loads. In addition, dynamic excitations due to turbulence cause the structure to vibrate, which can lead to failure. Above all, the dynamic behavior can often only be determined inadequately by calculation. In order to ensure the stability of the individual components and the overall construction, Porsche Engineering subjected the MAY sunshades to load testing under extreme conditions in the wind tunnel for quality assurance purposes. MAY has been supplying premium sun protection systems "Made in Germany" for the commercial and private sectors since 1983. As part of the aerodynamics testing, it was analyzed, for example, whether outriggers and suspensions could bend or even break and whether the fabric covering was at risk of tearing.

Solid growth despite the coronavirus crisis

Porsche Engineering Romania continues to expand

Porsche Engineering's Romanian subsidiary has grown in 2020 and is hiring new skilled workers. The company is primarily looking for specialists and engineers in the field of software development. The goal is to reach 280 employees by the end of 2021. Porsche Engineering Romania expects demand for its services and technologies to continue growing, particularly in the areas of virtual testing, software and function development, and automated driving. To protect its employees, the company relies on working-from-home models and preventive health measures. "We reacted immediately to the new situation in March 2020 and made all the necessary arrangements to enable our employees to work from home," says Marius Mihailovici, Managing Director of Porsche Engineering Romania. "This involved investments in technology as well as training." In making the switch to working from home, the site benefited from the experience of its employees. "One of the main advantages of our young and tech-savvy team is that they were already used to working offline and online," says Mihailovici. "Our previous online experiences with other Porsche Engineering offices around the world helped us a lot in the transition." In addition, a package of measures has been implemented at the Cluj office for employees who need to be in the office due to the nature of their work. These include Plexiglas partitions, limiting the number of employees in the office, marked areas to ensure a safe distance, disinfectants, masks, and medical thermometers.

"We reacted immediately to the new situation in March 2020 and made all the necessary arrangements."

Marius Mihailovici,
Managing Director of Porsche Engineering Romania

Donation by Porsche Engineering

Support for the local community

Porsche Engineering has made a donation to the Habila workshop for the disabled in Markgröningen and the Theo Lorch Workshops in Bietigheim-Bissingen. In addition, the Porsche Engineering Works Council is donating to the Sterneninsel children's and young people's hospice and to the Schlupfwinkel facility, a drop-in and counseling center for children and young adults aged 12 to 25. "We are very pleased to be able to give back and support the local community," said Michael Merklinger, Director Human Resources, Corporate Communications & Strategy, as he presented a check to the Habila workshops. The facility provides disabled people in Baden-Württemberg with individual assistance for social participation and self-determination.

The Big Loop

Text: Constantin Gillies
Contributors: Philipp Wustmann, Dr. Joachim Schaper
Illustrations: Florian Müller

The vehicles of the future will feature many systems that are constantly improving themselves. In the "Big Data Loop" proof of concept, Porsche Engineering has successfully demonstrated the principle using the example of an adaptive cruise control system. However, automatic feedback loops are also interesting for other functions. CARIAD is actively advancing the development of the Big Data Loop for a wide variety of complex application purposes.

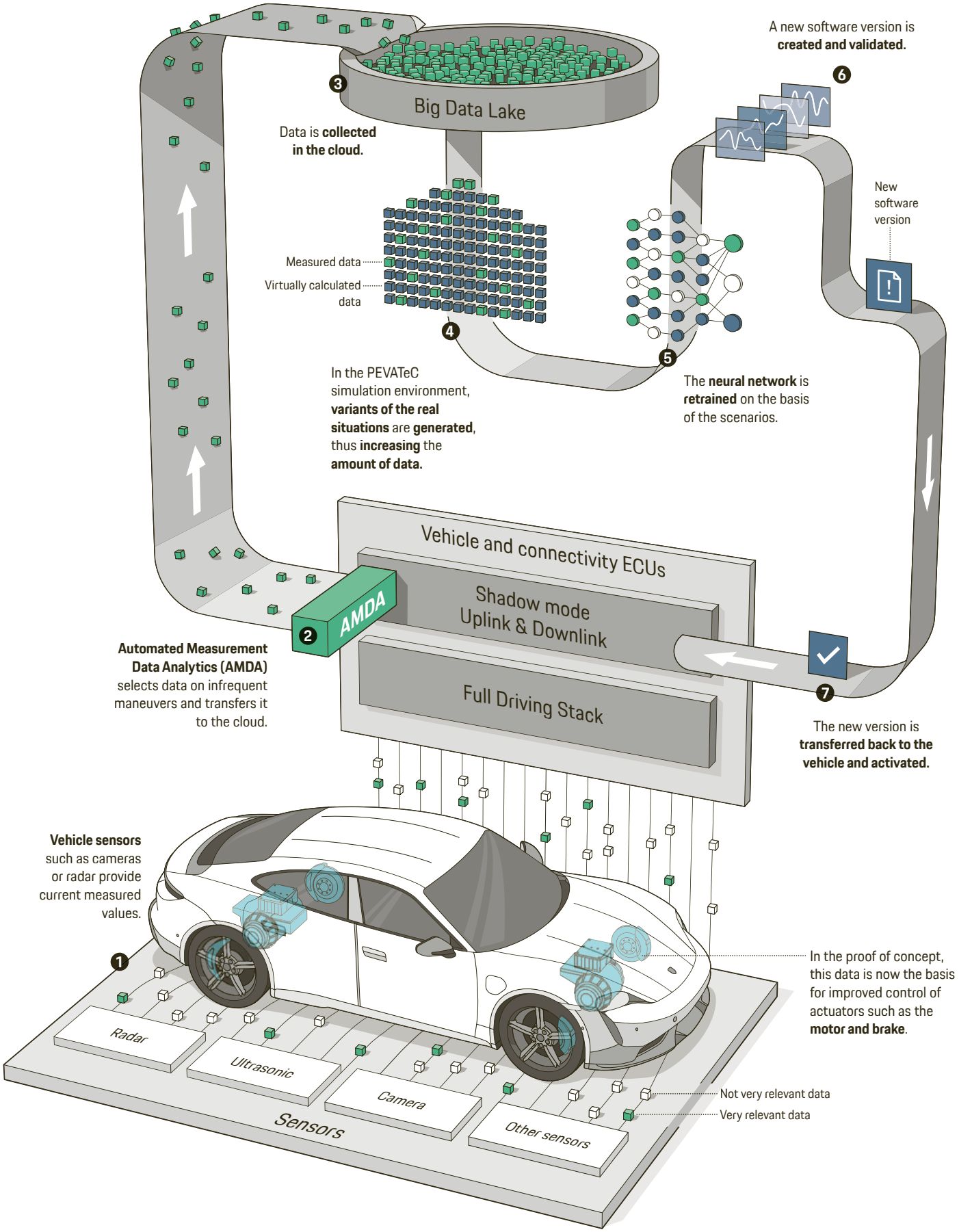
A driver is constantly learning and develops a kind of intuition over time. For example, if you are driving in the fast lane and see a car ahead in the right lane slowly pulling to the left, you will automatically let off the gas—even if the other car has not yet put on its turn signal. Any experienced driver suspects that the other car is about to change lanes.

How can an autonomous vehicle learn from experience in the same way and also react intuitively? Porsche Engineering addressed this question together with Porsche AG and CARIAD, a software and technology company of the VW Group, as part of a Big Data Loop proof of concept. The software specialists at CARIAD are now pushing ahead with series development within the Group. The proof of concept was intended to demonstrate how all functions based on artificial intelligence (AI) can be continuously developed in the future. The solution resembles a circuit: Data from the vehicle is transmitted wirelessly to the cloud, where it is used to further train the AI. Afterwards, the improved algorithm is tested and fed back again.

Detecting lane changes at an earlier stage

The test object in the project is a vehicle equipped with an enhanced Adaptive Cruise Control (ACC) system. The regular series-production driver assistance system ensures that a safe distance to the vehicle in front is always maintained. To do this, the ACC must detect early when other road users are cutting in. The aim is now to use AI to detect precisely this behavior at an earlier stage: In the test vehicle, a neural network developed in-house takes over this task, which is continuously further trained with real scenes from the test drives. This creates an endless cycle of observation and learning that continuously improves the performance of the

Big Data Loop proof of concept



ACC. "A likely lane change is detected half a second to a second earlier—the equivalent of 30 meters of driving on the motorway," reports Dr. Joachim Schaper, Senior Manager AI and Big Data at Porsche Engineering.

Every modern vehicle with assistance systems produces enormous amounts of data (Big Data), including evaluated camera signals or information from radar sensors—so there is plenty of material to train a neural network. What appears to be a simple idea at first glance, however, turns out to be a real challenge when it comes to implementation. "For example, we only want to record the data that really helps the system move forward," says project manager Philipp Wustmann, an expert in longitudinal and lateral control at Porsche Engineering. "That's no easy task, because radar sensors and cameras generate an immense amount of data, most of which is not relevant to the function under consideration." Driving on an empty highway, for example, offers no learning opportunities for a distance controller. Moreover, evaluating all the data would be far too time-consuming.

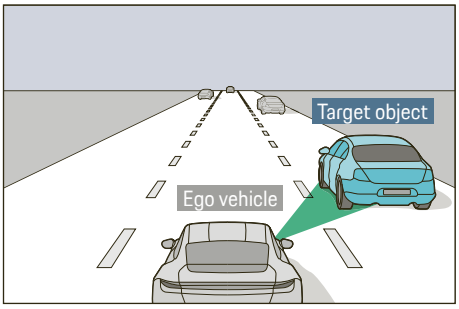
That's why we select specific scenes from which the AI can learn something. This task is performed by something called a SceneDetector in the Taycan test vehicle: This algorithm uses the interpreted camera signals on the vehicle bus. These are not raw video images, but information about which objects are at what distance from the vehicle. The SceneDetector filters out those scenes from the current traffic situation in which the ACC is not yet reacting optimally—for example, when the vehicle cutting in is detected too late or incorrectly. In addition, it is technically possible to have the program record what are known as corner cases, meaning borderline cases that rarely occur in everyday driving. For example, if a vehicle in front swerves in its lane without actually changing it, the algorithm could mark this scene. The same applies to a situation in which the camera does not detect the lane markings. This detection of specific scenes is handled by special software called Automated Measurement Data Analytics (AMDA).

Propagation of data by simulation

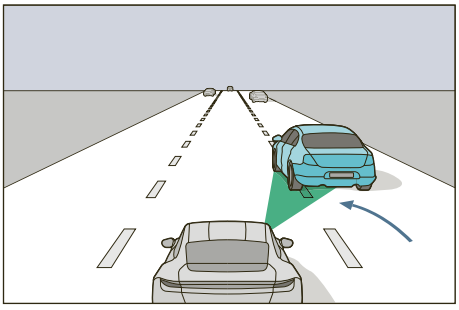
Once the SceneDetector has found five potentially instructive cut-in events, it transmits the associated data to a server via mobile radio. In the cloud, the amount of illustrative material is increased: To do this, the data is first fed into a simulation that uses a game engine, the same technology that computer games use to generate their images. With the help of the Porsche Engineering Virtual ADAS Testing Center (PEVATeC), virtual test drives can be produced in which the vehicles in the

Case example: true positive

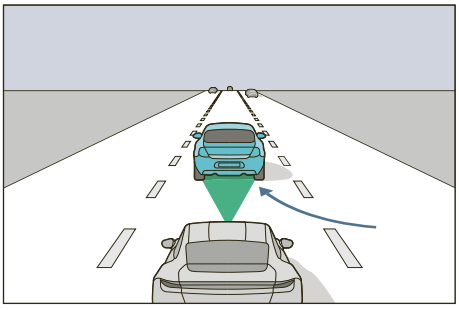
The cut-in detection system should correctly predict whether another vehicle is about to change lanes. If so, the Adaptive Cruise Control (ACC) can brake gently and early.



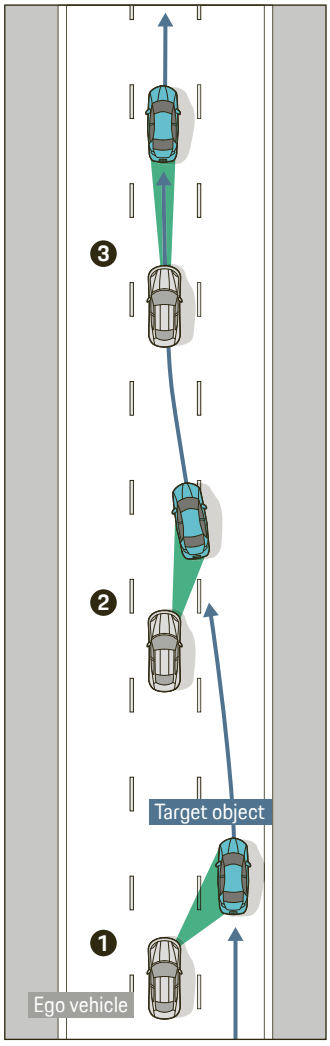
❶ The scene detection module detects an object change.



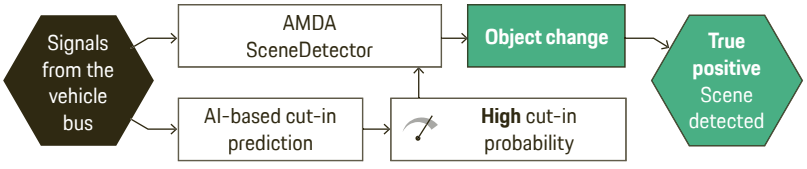
❷ The cut-in module calculates a high cut-in probability.



❸ The ACC system adjusts the desired distance to the new object at an early stage.

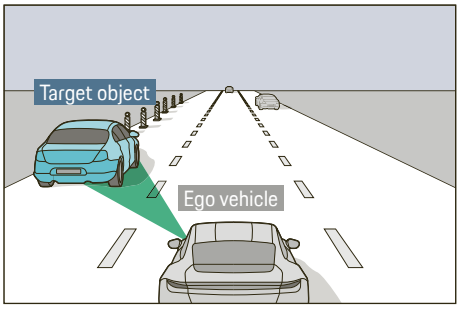


In this example, the cut-in detection functioned correctly. This case occurs very often and is therefore less relevant for the Big Data Loop.

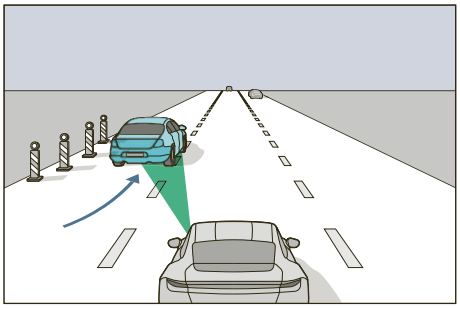


Case example: false positive

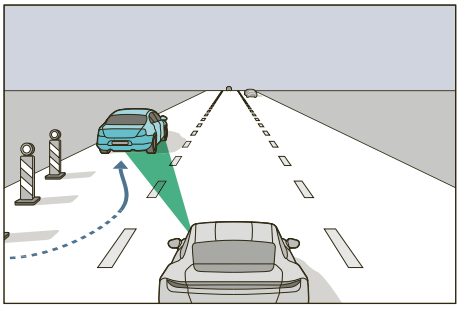
Cut-in detection should also detect that a vehicle is drifting to the right, but will still not cut in. This helps to avoid unnecessary braking maneuvers.



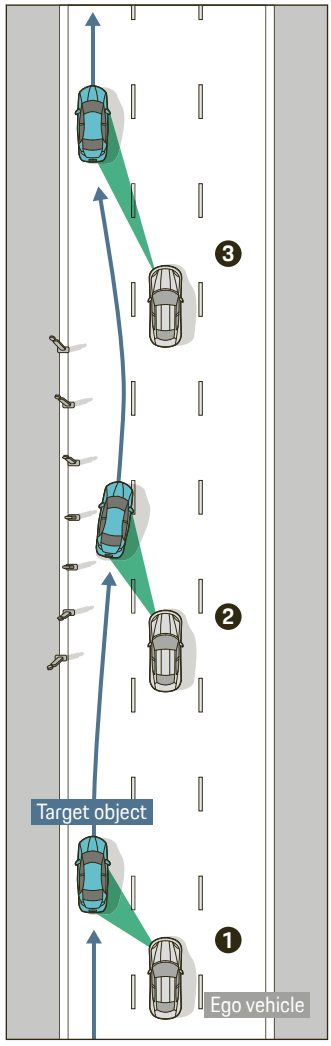
1 The scene detection module does not detect an object change.



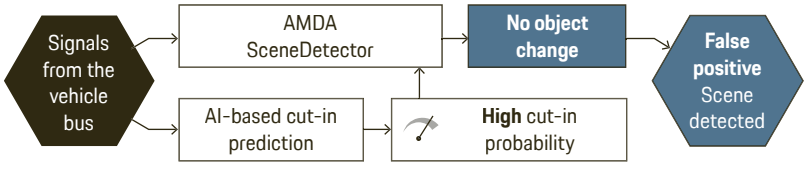
2 The cut-in module nevertheless calculates a high cut-in probability.



3 However, the vehicle does not cut in. The ACC system brakes unnecessarily.



In this example the cut-in detection did not work correctly. This case is rare and therefore very relevant for optimization in the Big Data Loop.



computer physically behave like their real counterparts on the asphalt. The simulation results in measurements that correspond to those of the real vehicle bus.

In the PEVATeC simulation environment, different variants of the recorded cut-in process are created, again automatically, on the basis of the real measurements—in other words, a re-simulation of the real situation takes place. In each case, the simulated cut-in processes differ only minimally: In one version the other road user pulls to the left more quickly, in another he is traveling at a greater distance. These variations generate more training data within a very short time without additional test drives. It also improves the generalizability of the AI model. It recognizes not only standard situations, but also those that occur less frequently. That's essentially the nature of the technology: Neural networks acquire new skills exclusively through observation. The more examples they see, the better they become. The simulation environment also allows critical or atypical situations to be recreated to broaden the range of training data.

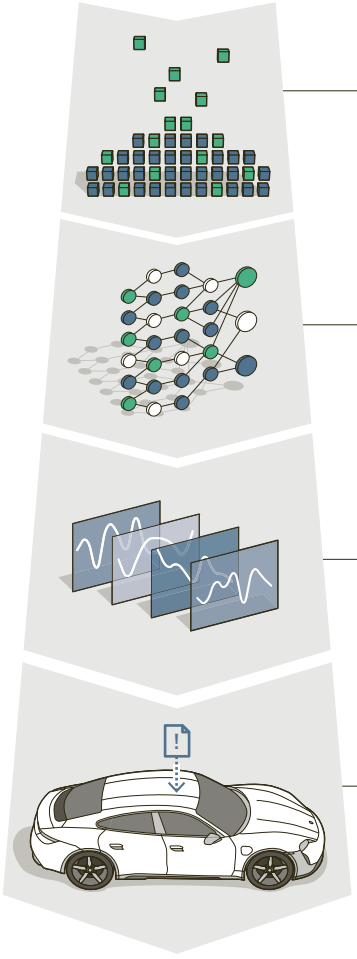
After all the visual scenarios have been created, the actual learning begins: All the real and simulated cut-in events are used to train a neural network in the cloud. By observing, it learns to recognize the signs of an approaching lane change in a similar way to a human driver. This allows the ACC to brake smoothly, almost exactly like a human driver. Or as the expert Schaper puts it: "We are replicating intuition in AI." In the long run, the vehicle could literally develop a sense for the behavior of other road users and, for example, recognize an aggressive driving style that suggests risky lane changes. Porsche Engineering uses the Volkswagen Group's cloud platform GroupMDM (MDM stands for Measured Data Management) to store and process the data.

"A likely lane change is detected half a second to a second earlier—equivalent to 30 meters of travel on the motorway."

Dr. Joachim Schaper, Senior Manager AI and Big Data at Porsche Engineering

Training and validation of new AI models

The new AI model is automatically trained with an improved dataset and validated with an existing validation dataset. If it is better than the previous model, it is used for further testing in the vehicle.



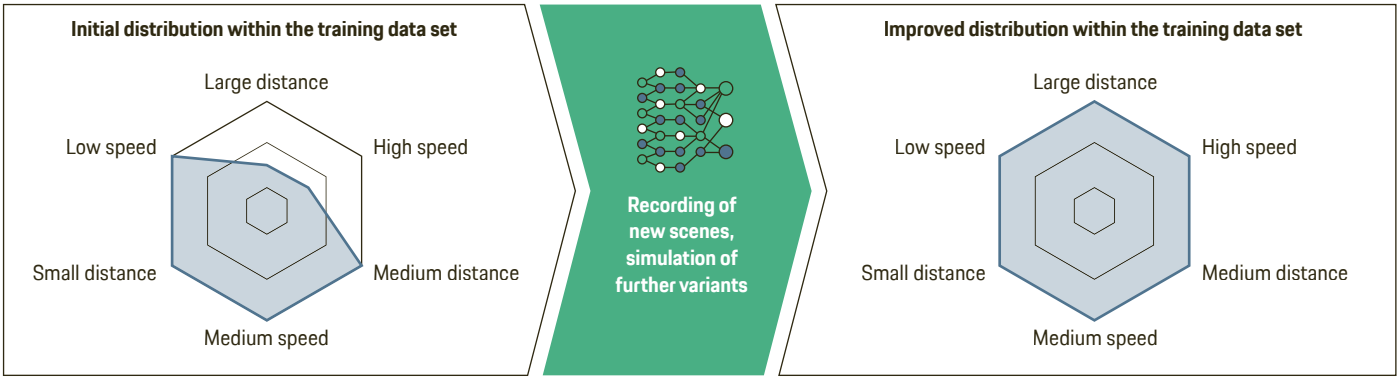
Data acquisition and propagation: The SceneDetector uses the interpreted camera signals on the vehicle bus and filters out those scenes from the traffic events in which the ACC does not yet react optimally. In the PEVATeC simulation environment, different variations of the recorded cut-in event are automatically generated on the basis of the real measurements. These variations generate more training data within a very short time without additional test drives.

Training a new model: All real and simulated cut-in events are used to train a neural network in the cloud. By observing, it learns to recognize the signs of an approaching lane change in a similar way to a human driver. In the long run, the vehicle could develop a sense of the behavior of other road users, allowing it to detect, for example, an aggressive driving style that experience has shown to indicate a propensity for risky lane changes.

Validation of the new model: At the end of the training in the cloud, new software for the adaptive cruise control system is automatically created and validated. The software is only transferred to the vehicle if it proves itself unequivocally.

Rolling out the new model: After validation, the new model is transferred to the vehicle. The driver then sees a dialog box and can activate the new release. As soon as he has done so, the enhanced vehicle function starts working.

For the Big Data Loop, new scenarios are continuously recorded and simulated to expand the size of the training dataset.



The driver can activate a new release

Once training is complete, new software for the adaptive cruise control system is automatically created and validated. What that means is that it must be able to reliably recognize cut-ins in a large number of unknown test scenarios. Only if the software proves itself unequivocally is it transferred to the vehicle. Then the driver sees a dialog box with the text: "A new release is available. Do you want to activate it?" If the driver then presses "OK," the enhanced adaptive cruise control starts working.

It would also be possible to test the new ACC module in the background (ShadowMode) in the vehicle first: While driving, the enhanced model receives the same sensor data as the existing on-board system and must react accordingly. However, the old ACC continues to control the accelerator and brake. Meanwhile, software monitors the quality of the predictions. If, for example, the "advanced" AI predicts a cut-in process that does not take place ("false positive"), it would be disqualified. Only when it becomes clear that the neural network trained in the cloud is really superior in its predictions does it go into live operation.

In this proof of concept, the push of a button by which the driver activates the new version of ACC represents the only manual step in the learning cycle. "What's new is that everything is automated," Schaper emphasizes. The recognition of the relevant scenes in the vehicle happens without human intervention, as does the propagation of the learning scenes in the simulation environment. A computer also controls the training of the neural network in the cloud and the update back to the vehicle. The developers only check things. "The vehicle optimizes itself," Wustmann summarizes.

Proof of concept in just four months

Porsche Engineering was able to implement the self-learning adaptive cruise control system in just four months. A patent application was filed for part of the technology. The proof of concept demonstrated that the technical approach works. The architecture used here is already being used in other development projects, for example to test and validate a new sensor generation as a replacement for existing sensors. The next step will be to bring the Big Data Loop into series production. There are still a few challenges to be met here, for example corner case detection or fully automated function optimization. CARIAD is currently working on a series application of the Big Data Loop in the overall context of automated driving for the brands of the VW Group. This proof of concept will provide valuable insights.

"The technology could also be interesting for lateral guidance, for example for the lane keeping system."

Philipp Wustmann, Project Manager for Longitudinal and Lateral Control at Porsche Engineering

Once the necessary technology is standard in all delivered vehicles, learning will also be faster—because there will be more digital visual material: After all, while today a single test vehicle is on the highway collecting cut-in maneuvers, in the future every vehicle will be able to send data back to the manufacturer if the customer agrees. Project manager Wustmann is excited by this prospect: "Getting direct feedback from customer fleets in different countries would save an immense amount of time, money and testing."

Cut-in recognition represents only one part of the road to a lifelong learning vehicle. In the future, neural networks will be used in many places in the vehicle, and they could all be improved by automatic feedback loops. "The technology could also be interesting for lateral guidance, for example for the lane keeping system," Wustmann reports.

IN BRIEF

The Big Data Loop allows AI-based vehicle functions to be continuously developed. The approach has proven itself in a proof of concept and is already being used in other development projects. It could be an important step towards the lifelong learning vehicle.

“Becoming more agile during development”

Text: Christian Buck Photo: Martin Wagenhan

In this interview, Joachim Bischoff, Director Intelligent Connected Vehicle at Porsche Engineering, explains what role the Big Data Loop plays for the automotive industry and the customer experience in the vehicle.

Why is the Big Data Loop so important for the entire automotive industry?

— **JOACHIM BISCHOFF:** All manufacturers are facing the same challenge: Ever shorter development cycles and the desire of customers to always have up-to-date and individualized functions in their vehicles. If you want to be a technological pioneer and successful in the market, you have to focus on customer satisfaction and, in particular, on individualization. This is where the Big Data Loop helps us: It can be used to personalize the customer experience even more. The other brands in the Volkswagen Group also benefit from these developments.

What else are you using the Big Data Loop for?

— **BISCHOFF:** Among other things, to become more agile during development. Our customers expect the latest functions to always be available to them in the vehicle—just as they are used to from their smartphones. Until now, however, the development cycles of the automotive industry and consumer electronics have been very different. The Big Data Loop helps us to become faster. It allows us to transfer data from the vehicles to the cloud, optimize a function using artificial intelligence (AI), and transfer the new status back to the vehicle for validation in just a few minutes. This noticeably reduces the time to market.

What role does this approach play after the vehicles are delivered?

— **BISCHOFF:** Here, the Big Data Loop enables us to continuously optimize vehicle functions even while our customers are using them. They benefit from regular software updates, for example. But one thing is very important to me: We will not turn our customers into beta testers. Before any new software is installed in the vehicle, it will continue to be extensively validated. This is how we ensure high quality and avoid undesirable side effects in other vehicle systems. However, we can reduce the duration and number of tests through the high level of automation in the Big Data Loop.

What are the biggest challenges with the Big Data Loop?

— **BISCHOFF:** The consistency and context of data collection plays a crucial role: With them, in

"With the Big Data Loop, the customer experience can be personalized even more."

Joachim Bischoff worked at Nokia and Harman Becker after studying communications engineering. In 2010, he joined Porsche Engineering as Senior Manager Systems Development and currently heads the Intelligent Connected Vehicle department.

addition to the actual measured values from the vehicle sensors, the boundary conditions such as weather, geography, road conditions, and day and night situations are also important. The evaluation of the data not only makes it possible to improve driver assistance functions, but also to continuously optimize the powertrain or high-voltage battery system, for example.

What role does artificial intelligence play in the Big Data Loop?

— **BISCHOFF:** A central role: It helps us select data and optimize vehicle functions—especially for non-deterministic functions such as cut-in detection. And of course it is the basis of numerous driver assistance systems as well as highly automated driving in general.

What are Porsche Engineering's unique selling points?

— **BISCHOFF:** As a wholly owned subsidiary of an automobile manufacturer, we understand the complete vehicle. This distinguishes us from many Tier 1 suppliers, who are skilled in their dedicated areas. Equally important are our strong software expertise and skills in the latest AI methods. Today, digital topics and e-mobility account for more than half of all activities at Porsche Engineering. This means we can do both: Vehicle and software. We also have tools developed in-house that we use to accelerate development. With our Car Data Box based on an NVIDIA architecture, we can test new features—based on AI methods, for example—in the vehicle. And in all our activities, we make sure that data protection is "Made in Germany."

New functions have to be adapted to local conditions. Are they trained differently from region to region?

— **BISCHOFF:** In principle, the technologies used should be the same globally. But it is true: We also have to take local peculiarities into account, such as right-hand or left-hand traffic. That's why we use a cloud for the Big Data Loop and train the functions for different markets with different data.

Finally, a personal question: Would you feel comfortable in a vehicle that is continuously optimized even after delivery?

— **BISCHOFF:** Since a final test will take place before every update for the foreseeable future, I'm not worried in terms of quality and safety. On the contrary: Through the Big Data Loop, my car will be able to benefit from the experiences of the entire fleet in the future. This makes my own product progressively safer and safer. That's why my clear answer is: I would feel absolutely comfortable in such a vehicle.

Futuristic: Porsche China's headquarters in Shanghai. Today, China is setting the pace in many development topics.

"Keeping a close eye on current developments and implementing them quickly"

Text: Jost Burger Photos: Yolanda vom Hagen, Martin Stollberg

China is on track to take a leading role in many developments. In this interview, Dr. Jens Puttfarcken (President & CEO of Porsche China), Dr. Peter Schäfer (Managing Director of Porsche Engineering), and Kurt Schwaiger (Managing Director of the Porsche Engineering branch in Shanghai) report on the latest trends and their collaboration in the country.

Expert panel: Dr. Jens Puttfarcken, Dr. Peter Schäfer, and Kurt Schwaiger (from left).

In China, the smartphone plays a key role in daily life. Which Chinese app is particularly important for you?

— **DR. JENS PUTTFARCKEN:** My two most important apps are WeChat and Alipay. I use Alipay to pay for things and to gain access to buildings. But I can also use the app to book a bike or call a taxi.

— **KURT SCHWAIGER:** I've been leaving my wallet at home for a long time. Beyond WeChat and Alipay, the navigation app on my phone is very important to me. It tells me exactly where I am allowed to go with my license plate and has never let me down.

— **DR. PETER SCHÄFER:** A translation app helps me communicate with people on location in China. It's fascinating and enriching to use it to engage in direct communication with people.

Apps represent only a small sample of technological developments in China. What else is going on at the moment?

— **PUTTFARCKEN:** The expanding connectivity, for one thing. The major cities have all been fully equipped with 5G since last fall. For example, facial recognition is becoming increasingly important for unlocking vehicles. Finally, the advancement of artificial intelligence should make existing technologies and applications even more user-friendly.

— **SCHWAIGER:** In terms of vehicle development, 5G in particular plays a very important role, for example for autonomous driving. Many start-ups here are working on solutions such as robot taxis and self-driving vehicles. Porsche Engineering is located in Jiading, where there is a 30-square-kilometer test area. It is fully equipped with 5G infrastructure. Autonomous driving is allowed in public and tests with the technology take place daily.

— **SCHÄFER:** It's important to note that in China the communication between vehicles and the infrastructure will be crucial. The aforementioned technologies therefore lead to new possibilities, for example in driver assistance systems or automated driving. China is enabling incredibly fast development in this area, while at the same time customers here are also demanding new solutions of this type.

5G

is already available in all major cities in China. The new mobile communications technology plays an important role in autonomous driving.

Digital on the move: Dr. Jens Puttfarcken and Kurt Schwaiger pay in China only by app, such as with Alipay.

— **PUTTFARCKEN:** Another major topic is electronic components. There is currently an acute shortage of chips, which is why China wants to become more independent from the outside world, for example by producing its own chips. It may therefore be the case that in a few years the country has built up its own technology and then makes technological demands on chips that are geared to the domestic market and cannot easily be met by the Western world.

What role does government play in this?

— **PUTTFARCKEN:** It sets the framework with its five-year plans. It's important to understand that today, a five-year plan is something like a corporate strategy. It defines strategic goals, the implementation of which is entrusted to individual government agencies, but also to provinces or companies. The implementation of these targets flows into the evaluation of Senior Executives of SOEs (State-owned enterprises) or party secretaries, and is therefore an important factor in their careers. Against this backdrop, you can understand the speed with which things are implemented here. In the latest five-year plan, three issues are important to us. First, China wants to strengthen domestic purchasing power and increase demand in the premium sector in particular. At the same time, it wants to open up to foreign investment and increase exports. All of this goes hand in hand with the tendency to decouple from Western technologies and rely increasingly on domestic developments. Second, China aims to stop the rise in carbon dioxide emissions by 2030 and be CO_2-neutral by 2060. Third, the government wants to promote technologies such as artificial intelligence more strongly in order to become the market leader in this area.

— **SCHWAIGER:** We can see the detachment from Western standards in e-mobility, for example with China-specific standards for charging technology. And the strong promotion of domestic e-cars is also clear, for example through the support by the state of start-ups in this field. At the same time, China is creating major incentives for consumers to buy an electric vehicle—financially, but also by the fact that in the future you may only be allowed to drive in the inner cities with an electric vehicle.

35

years old are Chinese Porsche customers on average—and almost half of them are women.

Chinese society is also changing. In what ways does that manifest itself?

— **PUTTFARCKEN:** On average, our customers are 35 years old and almost half of them are women. If this continues, in five to ten years most Porsche buyers will be members of Generation Z, i.e. born between 1995 and 2010. Like everywhere else in the world, this generation has grown up with digitalization. Constant networking is completely normal for these young Chinese. What is specific to China, however, is that this generation has never known bad times. Rising prosperity is a matter of course for them, and consumption in the premium and luxury segment in particular is viewed positively. Strong economic growth and certainly also the successful handling of the coronavirus pandemic confirm this generation in its belief that it lives in the world's best system, which will also guarantee growth and consumption in the future.

What are the implications for the automotive industry?

— **SCHÄFER:** Young customers expect digital functions in their vehicles that they are also used to from their smartphones. In addition, we are generally experiencing a rapid change in trends and technologies: Generation Z will change their requirements at ever shorter intervals. Our challenge here is to be flexible and fast—and to go with these trends. For this reason, we need short innovation cycles. Being

"We get first-hand information here in China and this flows into development and testing that we carry out locally together with Porsche Engineering."

Dr. Jens Puttfarcken

Dr. Jens Puttfarcken has headed Porsche China and Porsche Hong Kong since July 2018. He was previously Chairman of the Executive Board of Porsche Deutschland GmbH and Vice Preseident of After Sales and Customer Relations at Porsche AG.

Dr. Peter Schäfer has been Chairman of the Executive Board of Porsche Engineering since 2019. The mechanical engineer has worked for the Porsche Group since 2003 and was, among other things, Vice President of Complete Vehicle Development.

Kurt Schwaiger has lived in China for eleven years and has been Managing Director of Porsche Engineering's Shanghai branch since 2015. Previously, he worked as Director E/E at Qoros Auto (Shanghai). He has also worked for BMW and Siemens.

here on the ground is also an essential requirement. This is the only way the industry can understand Chinese customers and develop and test new technologies. We are well positioned for this with our location in Shanghai. We are developing the digital vehicle technologies of the intelligent and connected vehicle of the future there.

— **PUTTFARCKEN:** We have to remain relevant to our Generation Z customers. That means keeping a close eye on current developments and implementing them quickly. That's why the collaboration with Porsche Engineering and Porsche Digital is so important. Because it is precisely in the digital area that we see the greatest demands from the market.

Three megatrends are e-mobility, connectivity, and autonomous driving. What's happening in these areas?

— **PUTTFARCKEN:** China is the largest market for battery electric vehicles: more than 1.5 million e-cars are on the roads here. Roughly 50 percent of them are basically scooters with four wheels and a slightly larger passenger compartment. But here, too, the trend is now towards larger models from the C and E segments (medium and executive cars, respectively). What the newer vehicles in particular have in common is a high degree of standard digitalization: they offer, for example, facial recognition and autonomous parking, as well as features that are not necessary from a Western perspective, such as light concerts visible from afar on the radiator and rear, or individual color and lighting concepts in the interior.

— **SCHWAIGER:** In the past ten years, China has learned to build cars of high quality. OEMs now develop their own standard components. The next stage involves intelligent electronic systems that are very highly connected with the infrastructure. The trend in China is clearly moving in the direction of internet-based cars.

Building bridges: Porsche Engineering sees itself as a link between the development center in Weissach and the activities in China.

How is Porsche addressing these trends and challenges?

— **PUTTFARCKEN:** In the future, we will integrate the requirements from the Chinese market into our processes even more extensively and at an even earlier stage. We get first-hand information here in China and this flows into the development and testing that we carry out locally together with Porsche Engineering. We cannot develop products for the Chinese transport infrastructure in Germany.

What approach is Porsche Engineering taking in China?

— **SCHÄFER:** We have a long tradition of collabora-

"We know the Chinese market very well and can combine this knowledge with our specific expertise in automotive and software development."

Dr. Peter Schäfer

Long-standing partnership: Porsche China intends to intensify its cooperation with Porsche Engineering in the future.

tion with Chinese customers. As we have been active locally for more than 20 years, we know the Chinese market very well and can combine this knowledge with our specific expertise in automotive and software development. In order to meet the requirements of innovation drivers such as connected driving and intelligent software solutions, we are continuously expanding our collaboration with our Chinese partners and also with Porsche AG locally. We see ourselves as a link between the development center in Weissach and the activities in China. In this way, we play a significant role in the China-specific features and functions that go into a Porsche vehicle.

— **SCHWAIGER:** Porsche Engineering Shanghai develops solutions for Chinese OEMs and the VW Group, including Porsche. There are currently around 100 engineers working at Anting in all areas of automotive mobility. In the future, we will develop

"Porsche Engineering in Shanghai plays an important role in the development and validation of functions for the Chinese market."

Kurt Schwaiger

Intercontinental: The interview took place digitally at the Bietigheim-Bissingen and Shanghai sites.

Local peculiarities of the Chinese market require a local presence. Porsche Engineering has been in China for more than 20 years and can look back on a long tradition of cooperation with Chinese customers.

even more China-specific digital functions. The idea is to integrate the functions of mobile devices into the vehicle, such as WeChat or Alipay. We are also working intensively on highly automated driving. This can only be developed and tested in the transport infrastructure available here.

— **PUTTFARCKEN:** For us, this is an ideal setup. Porsche China has the task of bringing our vehicles to market. To do this, however, we also need the technical expertise of Porsche Engineering in China. The collaboration offers us an excellent opportunity to implement wishes from the market locally. We intend to intensify this fruitful cooperation in the future.

So local development and testing in China is essential?

— **PUTTFARCKEN:** Yes, because different traffic rules apply here, and there are also big differences in driving. Think of the elevated roads or the fact that you sometimes have to drive all the way to the right to turn left. You can only test that here in China.

— **SCHWAIGER:** It is also not allowed to bring geo-based data or video data outside the country. Porsche Engineering in Shanghai therefore plays an important role in the development and validation of functions for the Chinese market.

What will the Chinese automotive market look like in 2030?

— **PUTTFARCKEN:** The entire automobile market will continue to grow at considerable rates, with the number of new registrations rising to 30 million in the coming years. The premium and luxury segment is likely to perform even better than the market as a whole. At the same time, we will see a significant push with battery electric vehicles because they make it easier to get started with digital networking and digital services. This is the best way for carmakers to connect their products with the reality of their customers' lives, which is heavily influenced by networking.

How important are collaborations with the scientific community in your work?

— **SCHWAIGER:** Very important. Porsche Engineering has a long-standing collaboration with Tongji University. In 2018, we launched the Tongji Porsche Engineering Symposium, which brought together top managers from the Chinese automotive industry and unfortunately had to be postponed in 2020 due to the coronavirus. We also support Tongji University's DIAN student racing team with our knowledge in the development of their e-vehicle for Formula Student Electric. Our experts also hold lectures there to teach students about the latest developments. And finally, we support the Intelligent and Connected Vehicles professorship. Together with Porsche China, a first-class collaboration has been established in which both sides share their respective experience, promote science and education, and advance technologies.

30 million

new registrations are expected in China over the next few years. The premium and luxury segments are expected to grow even faster than the overall market.

Finally, a personal question: What is your favorite food in China?

— **PUTTFARCKEN:** Food is almost like a religion in China. Everything is of high quality and tastes great. Here in Shanghai, I especially like the dumplings. As for China as a whole, my favorite is Szechuan cuisine with its spiciness and sophistication.

— **SCHÄFER:** I am fascinated by the incredible variety of Chinese cuisine. My favorite is vegetables of all kinds. It's a special treat for me every time.

— **SCHWAIGER:** What appeals to me most is the Chinese culture of sharing. Food is always understood as communal. I really appreciate this open way of eating—it encourages exchange and dialog.

Integrated: Connected vehicles must be seamlessly connected to the customers' reality of life.

Perfect replica

Text: Andreas Burkert

With hardware-in-the-loop (HiL), developers can use electronic control units (ECUs) almost as they would in a vehicle. This can reduce the number of prototypes in early development phases, and functions can be developed more efficiently and tested earlier. Porsche Engineering uses HiL systems at various locations worldwide—including to adapt vehicle functions to local requirements. In the future, the cloud and artificial intelligence will play an important role in this.

The development of a new automobile involves extensive test drives totaling several million kilometers with prototypes in the various stages of development. This is the only way to put all systems through their paces. In practice, such tests are still an integral part of the overall development process, but advances in modern driver assistance systems call for different strategies. After all, just to test a semi-autonomous driving function, engineers would have to test it on the road for several years. That's why computer simulations are increasingly coming into focus. Including at Porsche Engineering. In many projects, experts there use hardware-in-the-loop (HiL), a method that has proven itself in component tests and is increasingly being used for highly complex systems as well.

Roughly
100
HiL test benches are in use by Porsche Engineering worldwide, including 60 at the international locations in Shanghai, Prague, Ostrava, and Cluj.

Hardware-in-the-loop is the link between software and the target hardware in the vehicle. The HiL test bench acts as a replica of the real environment of an ECU or an ECU network. The electronics of the connected ECU are supplied with electrical control signals, while the signals of the bus systems are

Proven technology: Hardware-in-the-loop is increasingly being used for highly complex systems in addition to component tests.

supplied by a residual bus simulation. For the ECU, this state cannot be distinguished from operation in the vehicle. For test purposes, it is also possible to selectively apply incorrect information to the vehicle's sensor interfaces and data buses, for instance to simulate the effects of a defective crankshaft or the complete failure of another vehicle system, as a means of validating the ECU's diagnostics.

Library with simulation models

The basis for the HiL simulations is detailed mathematical software models, which are created with Matlab/Simulink and reproduce the physical processes in the vehicle. They are stored in libraries from which the modelers can extract suitable modules—for example based on the engine variant or chassis type—and combine them to form an overall simulation model. Among other things, the library contains models for the behavior of an intake system or the combustion chamber, but also complex models of various chassis with or without adaptive air suspension, anti-roll stabilization, and a wide variety of wheels. Access to the libraries means that not every HiL simulation model has to be reprogrammed. Instead, it is sufficient to configure and parameterize the existing modules. However, replicating the physical processes in the vehicle is very computationally intensive and requires an appropriate infrastructure. "We have installed several very powerful computers in the HiL test benches and can thus now easily reproduce individual submodels physically correctly in real time. There are also models of the entire vehicle network, the driver, and the environment. But in some complex processes, such as the entire combustion cycle in the engine, we currently still have to find a workaround," says Jörg Turowski, who is the specialist project manager at Porsche Engineering responsible for powertrain HiL systems.

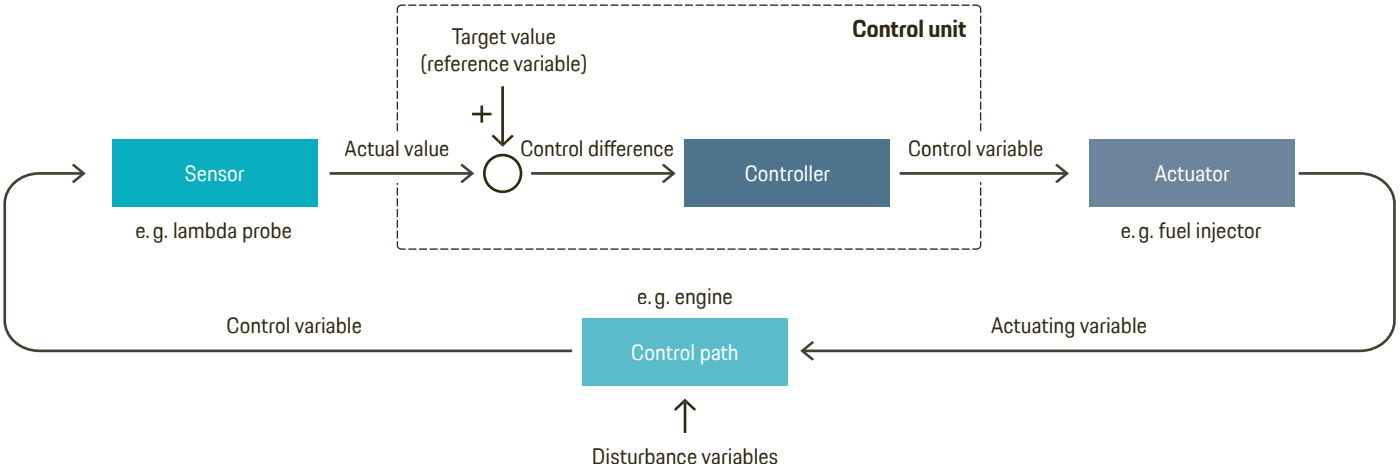
"Some of our HiL tests would be associated with a high risk of personal injury and property damage in the vehicle."

Jörg Turowski, Specialist Project Manager for powertrain HiL systems

That's why the HiL experts use neural networks, which require significantly less computing power than physical models. Among other things, they are used to simplify physical models. In a simulation model of an engine, for example, the sequence of the combustion process is calculated from the control signals of the engine control unit. The simulation provides values such as the generated torques and sensor signals as output variables, which are fed back into the engine control unit. By using a neural network, these output values do not have to be calculated using a physically correct formula. Instead, the neural network provides them in real time. To do this, however, it must first be trained with the data from a

Measurement and control

Sensors supply the input for the electronic control unit, which then compares the measured actual values with target values. If the actual values deviate from the target values, the control unit initiates corrections via actuators.



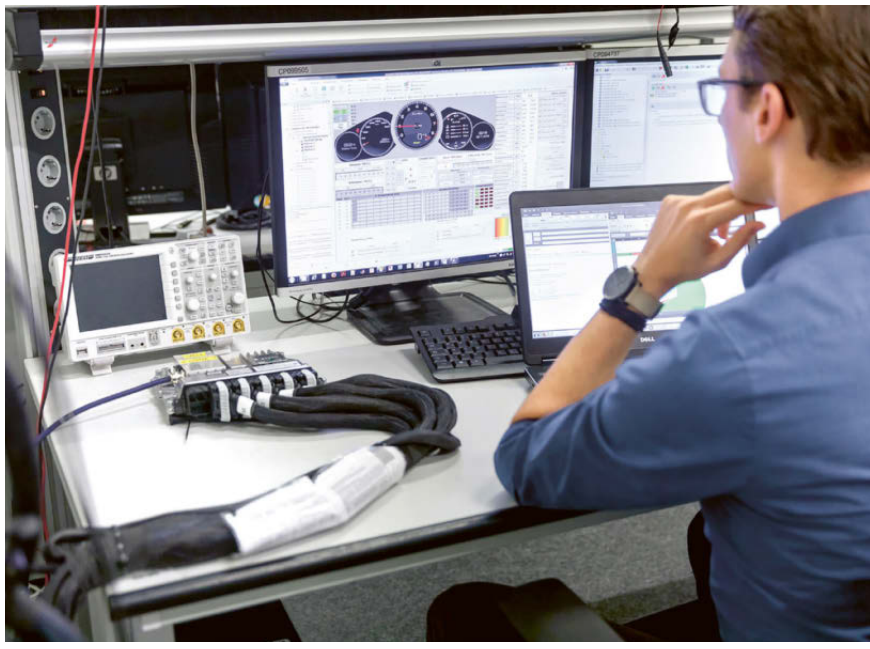
real prototype engine or a physical model that is not capable of real-time execution. Porsche Engineering has been using neural networks very successfully in its simulation models for years.

The possibilities for validating software are almost unlimited thanks to HiL test benches. “With hardware-in-the-loop, even test cases that are very difficult to examine on the road or in field tests can be analyzed,” explains Heiko Junker, Senior Manager Powertrain Electronics at Porsche Engineering. This applies in particular to the study of extreme situations. "Some of these tests would involve a high risk of personal injury and property damage in the vehicle," adds Turowski. “With hardware-in-the-loop, on the other hand, they can be repeated as often and exactly as desired.” As examples, he cites tests at high speeds, deliberately exceeding limits, and testing software responses to signals that are only triggered in the event of an accident. “This is important, for example, to validate protective functions,” says Turowski.

When using hardware-in-the-loop, Porsche Engineering benefits from its many years of experience in the field of simulation. In addition, the identical simulation models are used in the complete validation and integration process. “This allows us to exploit many synergies,” says Junker. “We are also aided by fully automated processes, from the specifications to the test result. We use test specification generators and test case generators for this.” Customers benefit from a one-stop service: Porsche Engineering offers them a complete package—from the concept to design and commissioning to residual bus simulation and physical modeling. Added to this is a detailed analysis of the test results, including recommendations on possible remedial measures.

Intercontinental cooperation based on the same processes, techniques and methods

Several Porsche Engineering locations work closely together on HiL projects. This intercontinental cooperation on the basis of the same processes, techniques, and methods gives Junker and Turowski the opportunity to distribute tasks worldwide according to the availability of resources and expertise and with due regard for the special features of the markets. For example, while the site in Mönsheim provides the hardware-in-the-loop test benches on site for component and function developers and develops the concepts for future HiL systems, the tools for automated test case implementation and evaluation are continuously optimized in Prague, as well as in-house HiL systems for test case execution. Shanghai, on the other hand, specializes in the creation of physical simulation models and the integration and teaching of neural networks.



Expertise: When using HiL, Porsche Engineering benefits from its many years of experience with simulations.

“We are continuously expanding our HiL capacities.”

Heiko Junker,
Senior Manager
Powertrain Electronics

“We can also take advantage of the time difference between Germany and China,” Junker says. “If we find an error in the simulation model here during HiL tests, it can be analyzed overnight in Shanghai.” There, as well as at the other international locations in Cluj, Prague, and Ostrava, Porsche Engineering maintains laboratory space with a total of more than 60 HiL test benches. In addition, there are another 40 or so test benches in Germany, making it possible to meet the steadily increasing demand for testing. In the future, the use of hardware-in-the-loop technology will continue to increase, as the trend toward fewer and fewer real prototypes will continue. "This is why we are continuously expanding our HiL capacities," says Junker.

The computing power required for highly complex simulation models is available, as it can be increased almost indefinitely by moving parts of the model to the cloud. “Moreover, the ECUs at the test benches are already connected to the backend today,” says Turowski. “So cloud functions can also be validated at an early stage.” Even the complete replacement of prototypes seems conceivable: “We are working on connecting several component HiL systems in the cloud to form a virtual complete vehicle,” says Junker.

Stop twice: Different road markings, such as in the UK (left) and South Korea, currently make it difficult to train AI systems.

The little difference

Text: Constantin Gillies

New situations are challenging for autonomous vehicles. As things stand today, if traffic signs or rules change the vehicles have to be completely retrained. The AI Delta Learning research project funded by the German Federal Ministry for Economic Affairs and Energy aims to solve this problem and thereby reduce the effort involved substantially.

Stop signs look similar in many countries—red, octagonal, with the word "STOP" in the middle. There are exceptions, however: In Japan the signs are triangular; in China the word "STOP" is replaced by a character; in Algeria by a raised hand. Non-local drivers have no problem with these little differences. After the first intersection at the latest, they know what the local stop sign looks like. The artificial intelligence (AI) in an autonomous vehicle, on the other hand, needs to be completely retrained to be able to process the small difference.

These ever-changing lessons take a lot of time, generate high costs, and slow down the development of autonomous driving as a whole. So the automotive industry is now taking a joint step forward: The AI Delta Learning project aims to find ways to selectively teach autonomous vehicles something new. Or to stick with our example: In the future, all you want to have to do is tell the autopilot: "Everything remains the same except the stop sign."

70,000
graphics processor hours are needed to train an autopilot.

100
experts from 18 partners are working on the AI Delta Learning project to find methods for knowledge transfer.

50%
less effort: AI Delta Learning could halve human labor input.

"The objective is to reduce the effort required to be able to infer things from one driving situation to another without having to train each thing specifically."

Dr. Joachim Schaper, Senior Manager AI and Big Data at Porsche Engineering

The importance of the task is demonstrated by the list of participants in the project, which is being funded by the German Federal Ministry for Economic Affairs and Energy: In addition to Porsche Engineering, partners in the project include BMW, CARIAD, and Mercedes-Benz, major suppliers such as Bosch, and nine universities, including the Technical University of Munich and the University of Stuttgart. "The objective is to reduce the effort required to be able to infer things from one driving situation to another without having to train each thing specifically," explains Dr. Joachim Schaper, Senior Manager AI and Big Data at Porsche Engineering. "The cooperation is necessary because currently no provider can meet this challenge alone." The project is part of the *AI family*, a flagship initiative of the German Association of the Automotive Industry aimed at advancing connected and autonomous driving.

Roughly 100 people at a total of 18 partners have been working on AI Delta Learning since January 2020. Workshops are held at which experts exchange views on which approaches are promising—and which have proved to be dead ends. "In the end, we hope to be able to deliver a catalog of methods that can be used to enable knowledge transfer in artificial intelligence," says Mohsen Sefati, an expert in autonomous driving at Mercedes-Benz and head of the project.

In fact, the stop sign example conceals a fundamental weakness of all neural networks that interpret traffic events in autonomous vehicles. They are similar in structure to the human brain, but they differ in a number of crucial points. For example, neural networks can only acquire their abilities all at once, typically in a single large training session.

Domain changes demand huge efforts

Even trivial changes can require massive efforts in the development of autopilots. Here's an example: In many autonomous test vehicles, cameras with a resolution of two megapixels were previously installed. If they are now replaced by better models with eight megapixels, in principle hardly anything changes. A tree still looks like a tree, only that it is represented by more pixels. Yet the AI still needs millions of snapshots from traffic again to recognize the objects at the higher resolution.

The same is true if a camera or radar sensor on the vehicle is positioned just slightly differently. After that, a complete retraining is once again necessary.

Experts call this a domain change: Instead of driving on the right, you drive on the left; instead of bright sunshine, a snowstorm is raging. Human drivers usually find it easy to adapt. They intuitively recognize what is changing and transfer their knowledge to the changed situation. Neural networks are not yet able to do this. A system that has been trained on fair-weather drives, for example, is confused when it rains because it no longer recognizes its environment due to the reflections. The same applies to unknown weather conditions, to the change from left- to right-hand traffic or to different traffic light shapes. And if completely new objects such as e-scooters appear in traffic, the autopilot must first be familiarized with them.

Aim of the project: learning only the "delta"

In all these cases, it has so far not been possible to teach the algorithm only the change, that is what in science is called the "delta." In order to become familiar with the new domain, it again needs a complete dataset in which the modification occurs. It's like a student having to go through the entire dictionary every time they learn a new word.

This kind of learning gobbles up enormous resources. "Today, it takes 70,000 graphics processor hours to train an autopilot," explains Tobias Kalb, a doctoral student involved in the AI Delta Learning project for Porsche Engineering. In practice, numerous graphics processing units (GPUs) are used in parallel to train neural networks, but the effort is still considerable. In addition, a neural network needs annotated images, that is images from real traffic events in which important elements are marked, such as other vehicles, lane markings, or crash barriers. If a human performs this work manually, it takes an hour or more to annotate a snapshot from city traffic. Every pedestrian, every single zebra crossing, every construction site cone must be marked in the image. This labeling, as it is known, can be partially automated, but it requires large computing capacities.

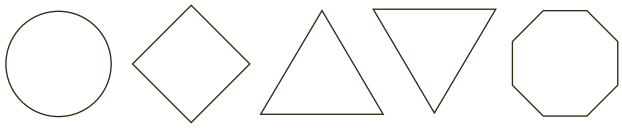
In addition, a neural network sometimes forgets what it has learned when it has to adapt to a new domain. "It lacks a real memory," explains Kalb. He himself experienced this effect when using an AI module trained with US traffic scenes. It had seen many images of empty highways and vast horizons and could reliably identify the sky. When Kalb additionally trained the model with a German dataset, a problem arose. After the second run, the neural network had trouble identifying the sky in the American images. In the German images, it was it was often cloudy or buildings blocked the view.

Continual Learning

In Continual Learning, neural networks are gradually expanded to include new knowledge. In the process, they retain in memory what they have already learned. This means that they do not have to be trained again with the entire dataset each time.

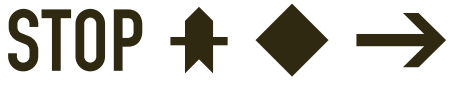
First training run

❶ The neural network learns to distinguish shapes.



❷ The neural network can correctly classify colors.

❸ The neural network distinguishes different labels and characters.



❹ With these skills, it can now recognize a German stop sign.

Additional knowledge is learned

With the help of the previously learned knowledge about the shapes, colors, and fonts of the German signs, the neural network only has to learn the new characters after delta learning in order to reliably recognize a Japanese stop sign.

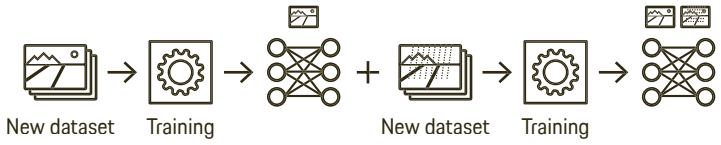
Five approaches to AI Delta Learning

❶ In **continual learning**, algorithms are developed that can be extended with new knowledge without loss of knowledge—without the need to retrain the entire dataset. Unlike traditional methods, not all data needs to be available at training time. Instead, additional data can be added to the training step by step at a later time. For example, a neural network can learn to recognize a Japanese stop sign without forgetting the German stop sign.

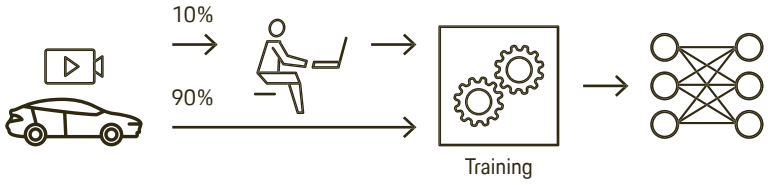
❷ In **semi-supervised learning**, labels are available for only a small portion of the data, which can be used to classify it into a category. Therefore, the algorithm trains with both unlabeled and labeled data. For example, a model trained with labeled data can be used to make predictions for some of the unlabeled data. These predictions can then be incorporated into the training data to train another model using this augmented dataset.

❸ **Unsupervised learning** is where an AI learns using data that has not previously been manually categorized. This allows data to be clustered, features to be extracted from it, or a new compressed representation of the input data to be learned without human assistance. In the AI Delta Learning project, unsupervised learning is used on to initialize neural networks and reduce the volume of annotated training data. It can also be used to adapt an already trained network to a new domain by trying to learn a unified representation of the data. For example, when making a domain switch from daytime to nighttime images, the features that the model learned for a car during the day should be equally applicable at night. So ideally they should be domain invariant.

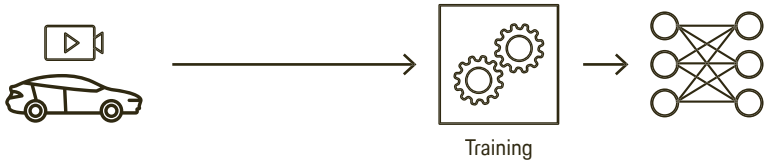
❶ **Continual learning**



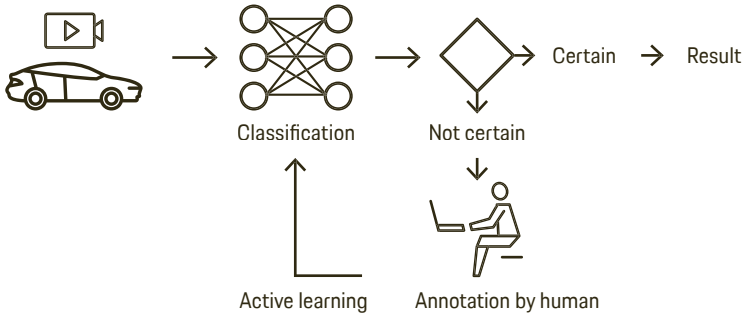
❷ **Semi-supervised learning**



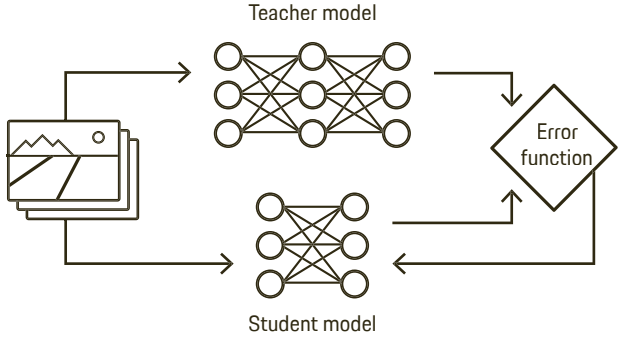
❸ **Unsupervised learning**



❹ **Active learning**



❺ **Knowledge transfer**



❹ In **active learning**, algorithms self-select the training data for a neural network during training time—for example, those situations that have not occurred before. The selection is based, among other things, on degrees of uncertainty that estimate how certain a prediction of the neural network is. Through active learning, one can, for example reduce the effort required for the manual annotation of video images because only the training data that is essential for learning later on has to be processed.

❺ **Knowledge transfer** (knowledge distillation) is the transfer of knowledge between neural networks—usually from a more complex model (teacher) to a smaller model (student). More complex models usually have a larger knowledge capacity and thus achieve higher prediction accuracies. Knowledge distillation compresses the knowledge contained in the complex network into a smaller network, with little loss of accuracy. Knowledge distillation is also used in Continual Learning to reduce knowledge loss.

"Until now, the model has been retrained with both datasets in such cases," Kalb explains. But this is time-consuming and reaches its limits at some point, for example when the datasets become too large to store. Kalb found a better solution through experimentation: "Sometimes very representative images are enough to refresh the knowledge." For example, instead of showing the model all American and German road scenes again, he selected a few dozen pictures with particularly typical highway distant views. That was enough to remind the algorithm what the sky looked like.

Two AIs train each other

It is precisely such optimization possibilities that AI Delta Learning aims to find. For a total of six application areas, the project partners are looking for methods to quickly and easily train the respective AI. This includes, among other things, a change in sensor technology or the adaptation to unknown weather conditions. Proven solutions are shared among the organizations involved in the project.

Another promising approach is for two perception AIs to train each other. First, a teacher model is built for this purpose: It receives training data in which a class of objects, for example signs, is marked. A second AI, the student model, also receives a dataset, but one in which other things are marked—trees, vehicles, roads. Then the teaching begins: The teacher system imparts its knowledge to the student as it learns new concepts. So it helps it recognize signs. After that, the student in turn becomes the teacher for the next system. This method, "knowledge distillation," could save OEMs a lot of time in localizing their vehicles. If a model is to be introduced in a new market, all that needs to be done when training the autopilot is to use a different teacher model for the regional signs—everything else can stay the same.

Much of what the researchers are currently testing is still experimental. It is not yet possible to predict which method will ultimately allow a neural network to best adapt to new domains. "The solution will lie in a clever combination of several methods," expects expert Kalb. After a year of project work, those involved are optimistic. "We have made good progress," says project manager Sefati from Mercedes-Benz. He expects to be able to show the first methods for AI Delta Learning when the project ends at the end of 2022. That could yield huge benefits for the entire automotive industry. "There is high potential for savings while increasing quality if the training chain is highly automated," explains AI expert Schaper. He estimates that human labor input in the development of autonomous vehicles can be halved through AI delta learning.

The AI project family

AI Knowledge
Developing methods for incorporating knowledge into machine learning.

AI Delta Learning
Developing methods and tools to efficiently extend and transform existing AI modules of autonomous vehicles to meet the challenges of new domains or more complex scenarios.

AI Validation
Methods and measures for validating AI-based perceptual functions for automated driving.

AI Data Tooling
Processes, methods, and tools for efficient and systematic generation and refinement of training, testing, and validation data for AI.

IN BRIEF

When changing the environment or the sensor technology, neural networks in vehicles today have to be trained again and again from scratch. The AI Delta Learning project aims to teach them only the differences after such a domain change, thus significantly reducing the effort involved.

A country electrified

Text: Eric Røkeberg Photos: Ilja C. Hendel

Norway is one of the world's pioneers in the field of e-mobility. More than half of the new vehicles registered there in 2020 had an all-electric powertrain. In addition to modern design and innovative technology, Norwegian customers also want vehicles that offer a long range and sufficient space for the family. Ideal conditions for the Porsche Taycan and the new Porsche Taycan Cross Turismo.

Sparsely populated: Norway is about the size of Germany, but has only around 5.4 million inhabitants.

Best seller: The Taycan has allowed Porsche to double its sales in Norway.

Norwegian Erling Henningstad loves fast and dynamic cars with good handling. And he has known for many years that you don't necessarily need an internal combustion engine to achieve it. The IT entrepreneur from the Oslo area bought his first electric car back in 2012, and some 250,000 km later he knows the new powertrain system inside out. Talking to Henningstad, it becomes clear: the Norwegian Porsche customer is passionate about technology and meticulously researches every aspect of his car.

So when Porsche opened the reservation list in 2018 for what was then still called the "Mission E," he didn't have to think twice—and was one of the first customers in Norway to sign the order for a car of which he had only seen a sketch and the basic technical data. "I've always dreamed of owning a Porsche," Henningstad says. "And when an electric model became available, that dream could finally come true. I knew: This will be my car."

Erling Henningstad has been the owner of a Porsche Taycan 4S Performance Plus since July 2020. "The Taycan 4S offers a lot for the money," says the 59-year-old software expert. For the equipment package, he opted for a large battery with 93 kWh of capacity, a 150 kW DC charger, a heat pump, Adaptive Cruise Control (ACC), and Surround View . His favorite feature is the battery temperature gauge, which is important for both charging and performance. "Few cars offer that," he says. "But the display is very useful with varying usage and changing seasons."

Impressive charging speed

Henningstad was positively surprised by the range of his electrically powered Porsche: "It was absolutely sufficient in both summer and winter—and I drove my Taycan in temperatures as low as minus 30 degrees," says Henningstad. Range anxiety—*rekkeviddeangst* in Norwegian—is certainly not an issue for him. "The dreaded battery drain is also no problem with the Taycan—unlike other electric cars, which noticeably lose charge when stationary for a long period," he says.

The Porsche fan was also impressed by the charging speed: at a rapid charging station with a capacity of 350 kW, the battery was half-charged in just ten minutes. "It's almost on-par with fossil fuel cars in terms of fueling time," Henningstad comments cheerfully.

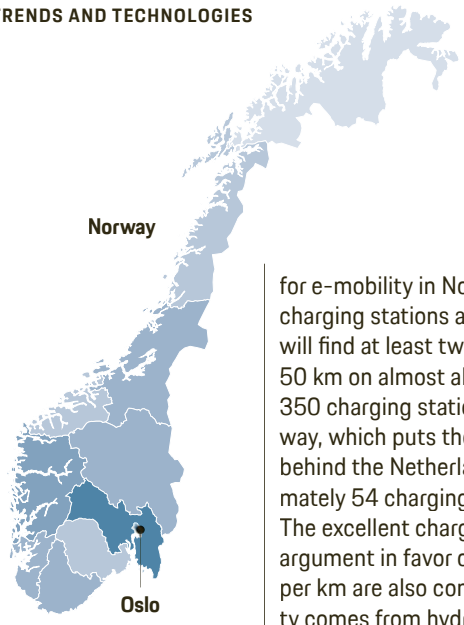
The fact that Henningstad can hardly tell the difference between his Taycan and a conventionally powered vehicle is due in no small part to the extensive support for e-mobility in Norway. There are almost 19,000 charging stations around the country, so e-car drivers will find at least two rapid charging stations every 50 km on almost all major roads. There are more than 350 charging stations per 100,000 inhabitants in Norway, which puts the country in second place in Europe behind the Netherlands (386). Germany has approximately 54 charging stations per 100,000 inhabitants. The excellent charging infrastructure is not the only argument in favor of switching to e-mobility; the costs per km are also compelling: Most of Norway's electricity comes from hydroelectric power, which is why green electricity is cheaper there than fossil fuels such as gasoline and diesel.

In addition to a nationwide charging infrastructure and low electricity prices, drivers of e-cars in Norway also benefit from various government incentives. For example, the 25 percent value-added tax is waived if a customer decides on an electric vehicle. In addition, no extra taxes are levied based on emissions and weight, as is the case with fossil-fuel cars. Beyond the financial advantages, there are further benefits on the road: e-vehicles are allowed to use city bus lanes, for example—an invaluable advantage during rush hour. And they get to park for free in many places.

Only zero-emission new cars from 2025

The enthusiasm for electrically powered cars goes back a long way in Norway. As early as the 1970s, the Strømmens Verksted company began experimenting with electric vehicles. Later, ABB Battery Drives developed a powertrain that was used on a trial basis in the VW Golf Citystromer in 1989. A series of road tests followed from 1990 to 1999, including the Ford Think. Intensive government support for e-mobility in Norway began just over 30 years ago. At that time, the environmental group The Bellona Foundation and the pop stars of a-ha launched an initiative to abolish the fees for electric cars, which gained majority support in 1990. Since then, e-vehicles have become an ever-more-frequent sight on Norway's roadways. Meanwhile, the country is fully committed to sustainable drive technologies: starting in 2025, only zero-emission cars are to be registered in Norway.

It's no wonder, then, that the majority of Norwegian customers are already opting for electric vehicles: nearly 77,000 electric vehicles were sold there in 2020, representing some 54 percent of all newly registered vehicles—not including plug-in hybrids, which actually put the share of electrified cars at nearly 75 percent. And the boom has continued this year as well: in March,



Number of charging stations in Norway's eleven counties.
SOURCE: STATISTA

- 4,000 – 5,000
- 2,500 – 4,000
- 1,500 – 2,500
- 1,000 – 1,500
- 500 – 1,000
- 250 – 500

Almost

19,000

public charging stations can be found in Norway. Relative to the number of inhabitants, this puts the country in second place in Europe.

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+

Adventurous: Erling Henningstad is on the road a lot and likes to spend weekends in the countryside. A long range is particularly important to him.

In 2020, approximately

77,000

electric vehicles were sold.

That was approximately

54%

of all newly registered vehicles.

By the end of 2021, there should be roughly

400,000

electric vehicles in Norway.

Roughly

1,600

hydroelectric power plants exist in Norway.

They generate roughly

95%

of Norway's electricity.

Cheap energy: Thanks to hydroelectric power, green electricity is cheaper in Norway than gasoline and diesel.

Extensive network: Drivers of electric cars will find plenty of charging stations in Norway, even in the countryside.

Taycan 4 Cross Turismo:
Power consumption (combined): 28.1 kWh/100 km;
CO_2 emissions (combined): 0 g/km;
Energy efficiency class: A+

Taycan 4S Cross Turismo:
Power consumption (combined): 28.1 kWh/100 km;
CO_2 emissions (combined): 0 g/km;
Energy efficiency class: A+

Taycan Turbo Cross Turismo:
Power consumption (combined): 28.7 kWh/100 km;
CO_2 emissions (combined): 0 g/km;
Energy efficiency class: A+

Taycan Turbo S Cross Turismo:
Power consumption (combined): 29.4 kWh/100 km;
CO_2 emissions (combined): 0 g/km;
Energy efficiency class: A+

56 percent of all new cars sold were electric models. Despite its population of roughly 5.4 million, this puts Norway in fourth place in the world for electric vehicle sales, and nowhere in Europe are there more electric cars per capita.

Thanks to high demand, the total number of electric vehicles sold in Norway will be approximately 400,000 by the end of 2021. The Taycan is also benefiting from the electric euphoria: launched on the Norwegian market in January 2020, the thousandth Taycan customer was able to take delivery of their vehicle at the beginning of November 2020. The sales launch of the all-electric sports car ensured that Porsche sales in Norway doubled over the same period of the previous year.

Perfect for a wide range of conditions

Erling Henningstad has not regretted his choice for a second and is completely satisfied after his first months as a Taycan owner. "The interior of the car is stylish and feels solid," he says approvingly. "And the driving characteristics are phenomenal: with its low center of gravity, the Taycan is well balanced and offers full control regardless of the conditions." He's particularly pleased that he can change many of the electric sports car's characteristics, such as engine response, suspension settings, and electronic stabilization, to suit his tastes, mood, or the current ambient conditions. This enables it to cope perfectly with a wide range of conditions. "The Taycan can handle everything from race tracks to gravel roads," says Henningstad, summing up his experience so far.

Being able to handle roads of all kinds with confidence is particularly important in Norway, where almost all families own a weekend home by the sea or in the mountains. A car that can also cope well with dirt roads is therefore indispensable. Customers also want sufficient space for several passengers, including sports equipment. This makes the new Porsche Taycan Cross Turismo particularly suitable for the Norwegian market. "All indications are that it will be a perfect fit for adventurous people like me who appreciate back roads and extra space," says Henningstad. "I also expect it to drive as superbly as you'd expect from a Porsche. And if it really does handle better on rough roads with the raised ride height, the Taycan Cross Turismo could put the perfect car for me within reach."

Questions to Thomas May, Director Area Northern Europe at Porsche AG

"Norway is five years ahead of many countries with regard to e-mobility"

What are the specific requirements of customers in Norway?

They focus on top quality and are very design-savvy. Many Norwegians also have a hytte, a small house in the mountains or on a fjord. They spend almost every weekend there. They want cars with four-wheel drive that offer enough space for the family and luggage. And they need vehicles that function reliably even in sub-zero temperatures.

What new target group could the Taycan Cross Turismo tap into?

It is particularly interesting for customers with high space requirements, such as families with children. The press, in any case, have dubbed it "a dream car" and "a Porsche made for Norway"—at least these are two of many recent headlines. We expect that the Taycan Cross Turismo will have a large market share. So far we have more than 1,700 prospective buyers and have received over 700 orders. A good start!

What can other countries learn from the e-car boom in Norway?

Norway is about five years ahead of many countries, and e-mobility is completely commonplace there. Drivers of e-cars also benefit from other advantages in addition to government support, such as an e-car-only parking garage in Oslo. Range is also no longer a problem, with nearly 1,000 new rapid charging stations installed in 2020 alone. This is how you make e-mobility attractive and convenient for customers. That makes all the difference.

In other words, with the right incentives, everywhere could be like Norway in a few years' time?

All the basic questions regarding e-mobility—range anxiety, the installation of charging stations at home—are no longer an issue in Norway. People have total confidence in electric vehicles and have grown to love them. While they were initially only used as a second or third vehicle, they have now become the car for daily use. In a few years, this could also be the case here, if the right conditions are created.

What can be learned from Norway with regard to sales?

Today, "depositor programs" are standard there: even before the official start of sales, you can register online as a prospective buyer and make a deposit. So communication with interested parties begins very early and in a targeted manner. The customers themselves also talk to each other. In the private Facebook group "Porsche Taycan Norway," which they initiated and which has more than 5,000 members, they report on their experiences, give each other tips on operation, or get information on equipment before placing the final order.

Thomas May, Director Area Northern Europe at Porsche AG

Years of future

Text: Richard Backhaus

In 1931, Ferdinand Porsche founded his engineering office in Stuttgart. Since then, the Porsche name has been closely associated with engineering services projects. A journey through nine decades of automotive history.

When Ferdinand Porsche founded an engineering office in Stuttgart under the name 'Dr. Ing. h.c. F. Porsche Gesellschaft mit beschränkter Haftung, Konstruktion und Beratung für Motoren- und Fahrzeugbau' and had it entered in the commercial register on April 25, 1931, he could already look back on a successful career as a chief designer for renowned automobile manufacturers. Although his decision, coming at the height of the world economic crisis, was a risky one, it soon became clear that the engineering office could hold its own against the international competition. In the 1930s, it advanced to become one of the most important centers of automobile development.

The engineering office received its first official order from the automobile manufacturer Wanderer in the spring of 1931. Under the internal designation Type 7, Porsche designed a 1.5-liter, six-cylinder engine as

1931

Ferdinand Porsche takes the plunge into independence. He has already made a name for himself as a designer.

Visionary: Ferdinand Porsche and engine expert Josef Kales in the Porsche engineering office at Kronenstrasse 24 (1937).

Legendary: The Auto Union Type C race car in the pits (1936).


4
4

well as the chassis (see the article on page 64). The first complete vehicle, which followed the same year, was the Porsche Type 8 with an eight-cylinder engine, although this did not actually enter series production. In the spring of 1933, Ferdinand Porsche was commissioned by Auto Union to develop a 16-cylinder race car. The first test drives of the Auto Union race car took place in November 1933, and during its first season in 1934, it set three world records and won several hillclimb races as well as three international Grands Prix.

The office had also been working on building an inexpensive small car since 1933. Soon after, it received an order to design prototypes for "Volkswagen" (People's Car). In 1936, the government of the German Reich decided to build the Volkswagen its very own factory, which Ferdinand Porsche was also commissioned to plan. At the same time, the engineering office was at work on any number of other orders. For example, the Type 110 small agricultural tractor with an air-cooled two-cylinder engine became the basis for the later "Volkstraktor" (People's Tractor), as well as the tractor series produced after the Second World War.

New start with Ferry Porsche

With the increase in the number of air raids on Stuttgart, the engineering office was relocated to Gmünd in Carinthia, Austria, in 1944. After the end of the war, it found itself in a difficult economic situation. In April 1947, Ferdinand Porsche's son Ferry struck out to venture a new start and, together with his sister Louise Piëch, founded Porsche Konstruktionsbüro GmbH, which was also based in Gmünd in Carinthia. The first large order in the post-war period came from the Italian company Cisitalia. The result, the Type 360 "Cisitalia" race car completed in 1947, featured a state-of-the-art chassis with double longitudinal control arms at the front and a double-joint swing axle at the rear, as well as all-wheel drive.

In the spring of 1947, Ferry Porsche formulated his first ideas for building a sports car, which was given the design number 356. In February 1948, a road-ready chassis was produced, for which a sleek aluminum roadster body was subsequently produced. The Porsche 356 "No. 1" Roadster mid-engine sports car received the official blessing of the authorities on June 8, 1948, when the Carinthian provincial government issued its general operating permit. This marked the birth of the Porsche sports car brand. Production of the rear-engine Porsche 356/2 began in the second half of 1948.

1933

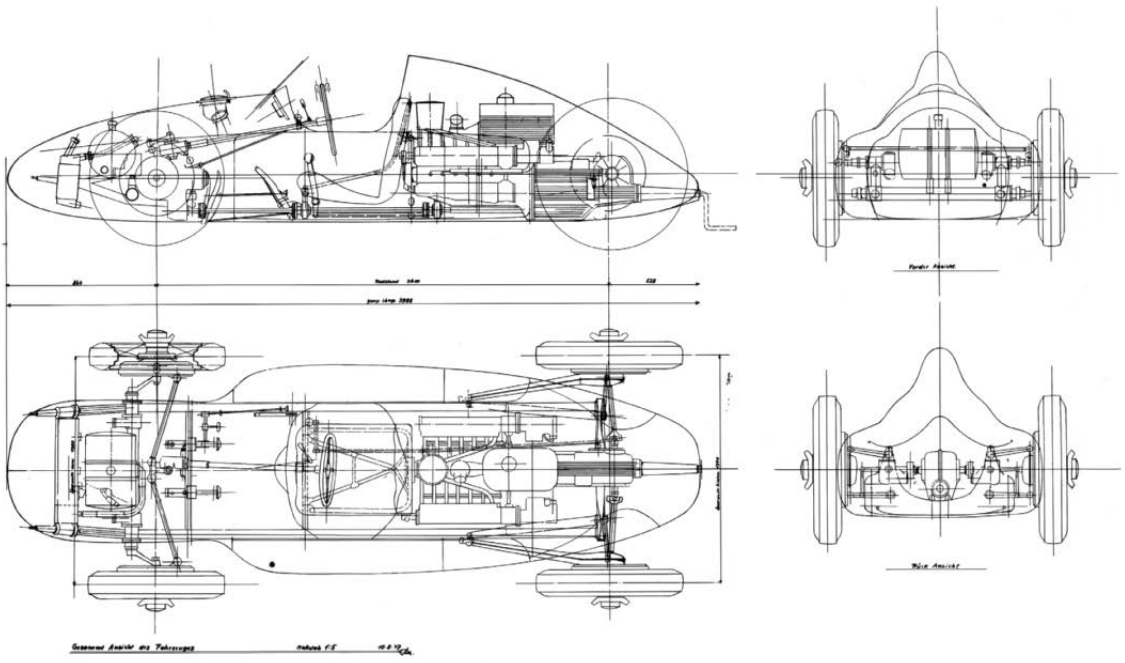
Sees the start of the development of a **16-cylinder race car** for Auto Union. In 1934, the car sets three world records and wins several races.

1936

Ferdinand Porsche is commissioned to plan a dedicated **factory for the "Volkswagen" (People's Car)**.

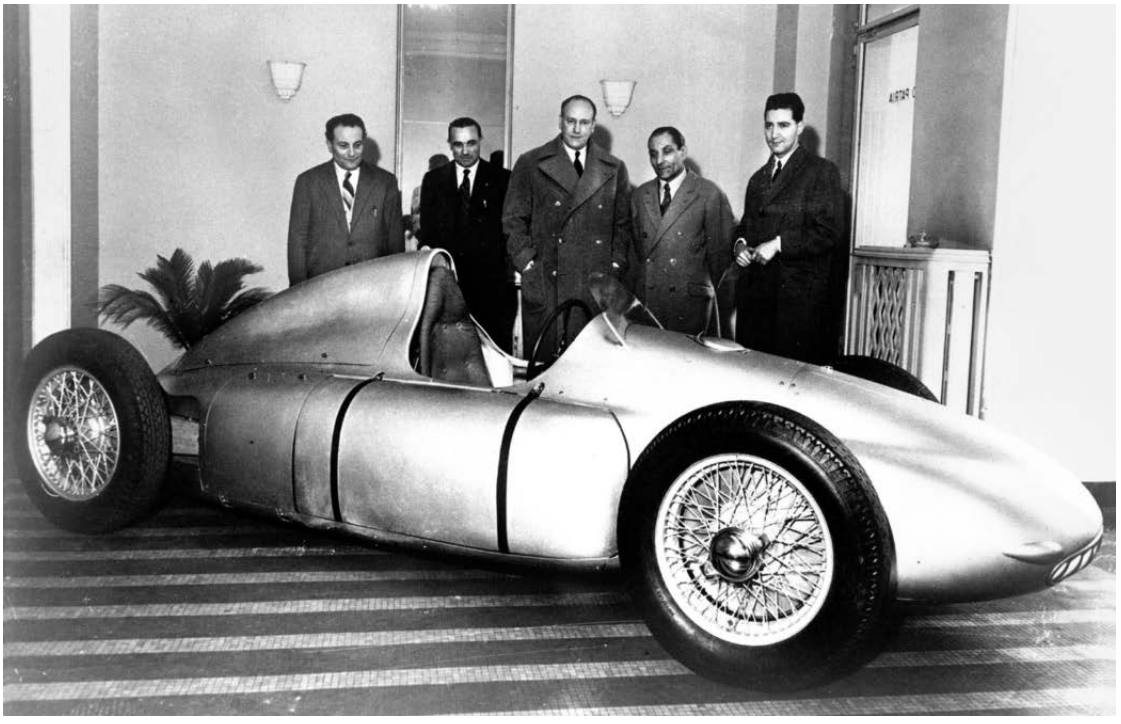
The Ur-Beetle: Porsche Type 60 (V3) during the test drives in 1936 at the Porsche villa in the north of Stuttgart.

Birth of the sports car brand: Ferry Porsche (center), his father Ferdinand Porsche (right), and Erwin Komenda with the 356 "No. 1" Roadster—the first car to bear the name Porsche (1948).



Technologically well ahead of its time:
Drawing of the Type 360 "Cisitalia" from 1947

First order after the war: Porsche Type 360 "Cisitalia".



1944

Due to the increasing air raids, the engineering office is relocated to the **Austrian town of Gmünd in Carinthia**.

1947

Ferry Porsche formulates initial ideas for the **construction of a sports car** with the design number 356.

1948

Birth of the **Porsche sports car brand.**

Order from overseas: Porsche Type 542 "Studebaker" in front of the Solitude Palace (1953).

Early proving grounds: Driving tests on Malmsheim airfield (1953/54).

1952

Porsche starts development of a **four-door sedan** for the US automobile manufacturer Studebaker Corporation.

Circular track for testing: Construction of the skid pad in 1962.

"How is it possible (...) that I create fundamentals and then leave. It would be better I found my own office and work for everybody."

Ferdinand Porsche

Perfect working environment: Aerial view of the development center in Weissach (1975).

1961

Ground is broken on the construction of a **dedicated test track** in the Weissach and Flacht districts.

1971

The entire **engineering department, including design**, was moved from Zuffenhausen to Weissach.

The engineering office started out with

12

employees.

Today there are more than

1,500

employees at Porsche Engineering.

Despite the successful start as a vehicle manufacturer, engineering services remained an integral part of Porsche's range of services. Overseas customers such as the Studebaker Corporation also placed their trust in the office: Between 1952 and 1954, Porsche developed a four-door sedan with a self-supporting body in a modern pontoon design for the US car manufacturer.

The think tank

One of the secrets of Porsche's success was the extensive testing of its designs. From 1953 onwards, a small airfield near Malmsheim, some 30 km from Stuttgart, was available for certain types of tests. However, the increasingly complex vehicle development process led to the decision to build a dedicated test track, which was to be designed according to the needs and preferences of the testing departments. On October 16, 1961, ground was broken for the construction of the facilities in the Weissach and Flacht districts, 25 km west of Stuttgart. A circular track called a skid pad was built to test driving performance and lateral acceleration, as well as two circuits. Other special sections were also built, including pothole and rough pavement sections.

Porsche was growing apace in the 1960s, and in addition to the market launch of the Porsche 901 in 1963—renamed the 911 a year later—and its increasing involvement in motor racing, a large number of customer orders kept the development team busy. Over time, it became increasingly apparent that additional test benches and workshops were needed for vehicle testing. By the end of the 1960s, plans for the Porsche Development Center Weissach (EZW) had begun to take their final shape. In the fall of 1971, the entire development department, including design, was relocated from Zuffenhausen to Weissach. From 1974 onwards, a building in the shape of a standard hexagon was constructed, which ensured perfect opportunities for working and collaboration. The innovative idea behind the concept: The EZW was to be comprised of many small think tanks, which would endow the central 'brain' with a high rate of response and development through short neural pathways.

The following years saw the successive expansion of the EZW. The Measuring Center for Environmental Technology (MZU) was equipped with six exhaust gas test benches in 1982. Construction of the test building for engines and units (PMA) began in 1983. In May 1986, Porsche opened what was then the world's most modern wind tunnel. The third construction phase was completed on September 29, 1986 with an extensive crash facility. The new facility offered modern testing capabilities with test conditions that remained unaffected by the weather, and which had the flexibility to adapt to new testing techniques.

Engineering services on a growth trajectory

Since the 1990s, development trends such as reducing fuel consumption and emissions, improving active and passive safety, or replacing mechanical components with electronics have meant that more and more factors had to be taken into account in customer orders. This increased the amount of coordination required within the EZW, and with the developer teams. In addition, the expansion of the Porsche sports car model range and its entry into the luxury SUV segment with the Cayenne required that a keen focus be directed at managing the company's own projects. In order to meet the new demands in terms of project management, Porsche placed the EZW engineering services unit on a new footing in 2001 with the founding of Porsche Engineering Group GmbH. Since then, the work on all Porsche customer projects has been pooled there, with work also continuing on internal sports car developments for Porsche. One of the first projects was a water-cooled V2 motorcycle engine, the "Revolution Engine" developed for Harley-Davidson in 2002.

Successively expanded: Aerial view of the Porsche Development Center in Weissach (2011).

World-renowned: The Nardò Technical Center in Apulia.

Three-time winner: The winning 919 Hybrid at the 24 Hours of Le Mans, driven by Nico Hülkenberg, Earl Bamber and Nick Tandy (2015).

Internationally active

Porsche Engineering took the first step on its international growth path in 2001 when it opened its location in Prague, which specializes in complex technical calculations and simulations. Since 2012, the company has also been operating one of the world's best-known automotive test sites: the Nardò Technical Center in Apulia, southern Italy. More than 20 test tracks and test facilities extend over an area amounting to 700 hectares, and Porsche Engineering also offers engineering services such as acoustic testing and the testing of driver assistance systems.

The year 2014 was decisive for the ongoing development of Porsche Engineering for two reasons. On the one hand, Porsche returned to the endurance race at Le Mans after an absence of 16 years, and took overall victory three consecutive years with the 919 Hybrid starting in 2015. Porsche Engineering developed the complete energy storage system for the innovative drive concept—from the mechanical structure to the complete system control and testing. Also in 2014, the company founded a subsidiary in China. Since then, the Shanghai location has formed the interface to local companies, as well as being a strategic partner for Porsche developments for the Chinese market. It specializes in chassis, electronic components and systems, test automation, rapid charging and technology scouting. In 2016, Porsche Engineering rounded off its expertise in the areas of function and software development with its subsidiary in Cluj-Napoca, Romania. An office in Ostrava in the Czech Republic has boosted Porsche Engineering's expertise in the field of software development even further since 2018. The engineers at Porsche Engineering are therefore in a position to develop electronics solutions for a wide range of requirements—including ones for the vehicles of the future.

The international network also enables the engineers to implement complete vehicle developments and present their customers with turnkey results. Porsche Engineering proved this with the Porsche Cayenne Coupé: As general contractor, the service provider was responsible for the entire process chain, from the concept and testing to monitoring the start of production in 2019.

Porsche Engineering has a clear vision for the future of the automobile: It has a perceptive ability, processes the impressions, keeps learning and therefore adapts increasingly well to customer requirements. It forwards information to the back end, where all fleet data is validated and optimized in the cloud. It then receives new software packages with improved and enhanced features "over the air" (OTA). This creates the basis for seamless integration of the vehicle into the customer's digital ecosystem and for efficient electric drive units. Autopilot functions will also only be feasible when there are new electronics architectures and connectivity concepts. As the overall vehicle developer, Porsche Engineering is implementing these new functions in their entirety, including software, hardware and the connectivity they require.

2001

Founding of **Porsche Engineering Group GmbH.** Since then, all Porsche customer projects have been handled there.

2014

The **subsidiary in Shanghai** is founded by Porsche Engineering.

2016

In Cluj-Napoca, the office of the **Romanian subsidiary of** Porsche Engineering is opened.

2018

Expansion of engineering activities in the Czech Republic: The **office in Ostrava** commences operations.

2019

As general contractor, Porsche Engineering was responsible for the **development of the Porsche Cayenne Coupé**.

Clear vision: As an international technology partner, Porsche Engineering is developing the intelligent and connected vehicle of the future—including functions and software.

Taycan Turbo S

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

Full responsibility: For the Cayenne Coupé, Porsche Engineering acted as general contractor for complete vehicle development. Equipment features such as the panoramic glass roof create a unique feeling of spaciousness.

Cayenne Coupé

Fuel consumption (combined): 9.5 - 9.4 l/100 km
CO_2 emissions (combined): 217 - 214 g/km
Energy efficiency class: D

Cayenne S Coupé

Fuel consumption (combined): 9.9 - 9.7 l/100 km
CO_2 emissions (combined): 225 - 222 g/km
Energy efficiency class: D

Cayenne Turbo Coupé

Fuel consumption (combined): 11.6 l/100 km
CO_2 emissions (combined): 264 g/km
Energy efficiency class: F

Cayenne E-Hybrid Coupé

Fuel consumption (combined): 2.6-2.5 l/100 km
Power consumption (combined): 22.4-22.0 kWh/100 km;
CO_2 emissions (combined): 60-58 g/km
Energy efficiency class: A+

Cayenne GTS Coupé

Fuel consumption (combined): 11.4 - 11.2 l/100 km
CO_2 emissions (combined): 260 - 256 g/km
Energy efficiency class: F-E

Cayenne Turbo S E-Hybrid Coupé

Fuel consumption (combined): 3.3-3.2 l/100 km
Power consumption (combined): 23.5-23.0 kWh/100 km;
CO_2 emissions (combined): 76-73 g/km
Energy efficiency class: A+

Sports machine: An outstanding feature of the Cayago Seabob was its innovative impeller drive with battery technology from Porsche Engineering.

More than just automotive development

Engineering services by Porsche have not traditionally been limited to the vehicle sector. The company developed a sled for luger Georg Hackl in which he could change the damping while driving, thereby achieving a higher cornering speed. The result: A silver medal at the 2002 Winter Olympics in Salt Lake City (USA). In 2007, the engineers developed three electronic components for the Seabob sports watercraft made by the manufacturer Cayago: The battery manager, the motor control unit and the control panel with graphic display.

From coal mining to data mining

Text: Christian Buck Photos: Aleš Král

In Ostrava, Czech Republic, three Porsche Engineering teams are working on the interface between the vehicle and its electronics. Software development, vehicle integration, and HiL testing are among the specialties of the location, which has just significantly expanded its capacities.

Center of innovation: Since June 2020, the branch has been located near the University of Ostrava.

Location manager: Michal Petřek benefits from the traditional automotive ecosystem in Ostrava.

Wide-ranging capabilities: David Muzika (above) and his Model-based Development Team specialize in model-based software development.

Much to offer: In addition to restored industrial facilities (bottom center), Ostrava offers an old town with cafés and shops (top) as well as modern commercial and office buildings (bottom right).

Twenty years ago, Porsche Engineering took the first step on its path of international growth by opening its location in Prague, Czech Republic. This was followed in 2018 by the expansion of the Czech subsidiary with the opening of an office in Ostrava.

If you ask Michal Petřek what makes Ostrava so special as a location for the development of new vehicle technologies, he doesn't have to think long. "The automotive industry has a long tradition here," explains the Director of the Porsche Engineering location in the Czech Republic's third-largest city. "The headquarters of Tatra, for example, are quite nearby in the town of Kopřivnice. It's the third-oldest company in the world continuously manufacturing vehicles." In addition to car manufacturing, a second industry here can also look back on decades of history: Semiconductors, the basic building blocks of modern electronics and information technology, have been developed and manufactured in the Moravian-Silesian region for more than 70 years.

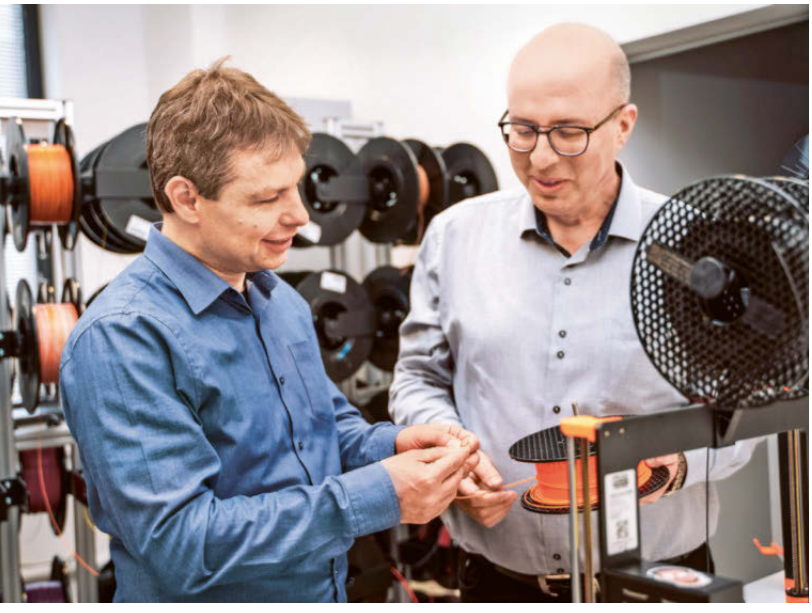
"We are now the most important center of the automotive industry in the Czech Republic and at the same time a hotspot for the IT industry."

Michal Petřek, Director of the Porsche Engineering location in Ostrava

Taycan
Power consumption (combined): 28.7-28.0 kWh/100 km
CO_2 emissions (combined): 0 g/km
Energy efficiency class: A+

"Partly because of our history, we are now the most important center of the automotive industry in the Czech Republic and at the same time a hotspot for the IT industry," Petřek says. "There are numerous research and production facilities of OEMs and suppliers here, and many software companies are also based in the area." These are ideal conditions for Porsche Engineering's activities: At the Ostrava site, some 80 employees in three teams are working on the interface between vehicles on the one hand and electronics and software on the other. For their work, they have to have a good command of both traditional automotive engineering and the latest IT technologies.

The employees in the Car Transition Team are primarily focused on software development. For example, they are working on diagnostic systems for the new electronics architecture and on a real-time emulation of the vehicle battery with which to test the battery management system during the development phase. "For our work, we need comprehensive system know-how," says Dr. Jiří Kotzian, who heads the Car Transition Team, "because we bring different things together, such as electric vehicles and the infrastructure that surrounds them." His employees therefore include both software and hardware experts who focus mainly on high-voltage issues.



System and vehicle expertise: Dr. Kotzian (left) heads the Car Transition Team, which focuses primarily on software development. The Vehicle Integration Team led by Zdeněk Kolba integrates subsystems such as electronic control units into vehicles.

Focus on e-mobility

The Model-based Development Team is also working intensively on e-mobility. In the Porsche Taycan, for example, battery management software from Ostrava and Prague calculates the remaining charge of the battery and its "state of health." But the team's

Talent factory: Working students and doctoral candidates from the nearby Technical University of Ostrava are involved in individual projects at the location.

Tourist magnet: Steel production in Ostrava ended in 1998. Today, visitors flock to the former plant.

solutions can also be found in chassis control units, performing such tasks as regulating chassis height and allowing drivers to adjust the suspension settings according to their preferences. "Our software contributes to the high-quality, sporty driving experience of a Porsche," says team leader David Muzika. In addition, the experts contributed the Automated Measurement Data Analytics (AMDA) tool for the Big Data Loop project (see article on page 8), which enables automatic data evaluation in the cloud.

The capabilities within the team are as broad-based as the team's projects: "We have experts in control engineering, data processing and artificial intelligence working for us, and we always cooperate closely with our colleagues at the Cluj-Napoca site in Romania," says Muzika. While Kotzian's team develops software manually in programming languages such as C, C++, or Python, Muzika and his employees specialize in model-based software development. New solutions are created here using the Matlab/Simulink tool, initially as combinations of abstract function blocks. "This allows us to quickly implement and test our customers' requirements," explains Muzika. "Only when the new function is running properly do we automatically generate the corresponding software code.

Close cooperation with their colleagues in Ostrava and other locations is crucial for the Vehicle Integration Team. The employees are responsible for integrating subsystems such as electronic control units from other development groups into vehicles and ensuring that they interact optimally. Technical progress constantly presents Zdeněk Kolba and his team with new challenges: "The number of electronic components in modern vehicles and the complexity of the systems continue to increase," Kolba said. "As such, integration and validation need to be as fast and effective as possible."

289,000

people live in Ostrava. It is the third largest city in the Czech Republic.

Roughly

80

employees work at the Ostrava site. They work at the interface between vehicles and electronics and software, respectively.

200

employees could work at the site. This number should be reached in two to three years.

Today, simulations on HiL test benches (Hardware in the Loop; see article on page 24) play a central role in function development and validation. For example, to check the data exchange between a control unit and the other systems, the experts use HiL to create the impression that it is already installed in the vehicle. All signals are supplied by the test bench, whose values and timing correspond exactly to the later production model—long before the first prototype is available. This approach is suitable for the integration of all kinds of components, from small subsystems to more complicated functions. The development of such HiL test benches is another specialty of the Vehicle Integration Team in Ostrava. "Our colleagues in Prague started HiL activities many years ago," Kolba says. "We are now continuing that tradition in Ostrava."

Constant learning required

"The number of control units will decrease, but the remaining components will be more complex," says Kolba. "We are already preparing for this, with new

Roughly

260

employees work at the Prague site. They work on software, control engineering, and the design and simulation of the chassis, body, and complete vehicle.

Two decades: Porsche Engineering has been active in Prague since 2001.

capabilities and new tools, for example for the future data buses in vehicles." But other trends such as connected vehicles, autonomous driving, and e-mobility also require a continuous learning process. With his team of experts in software, electronics, and mechatronics, he believes he is ideally prepared for the task: "Experience and fresh thinking"—these are the words Kolba uses to describe what makes his colleagues special. Experience because many of them had previously worked for years at one of the other suppliers or OEMs in the region. And fresh thinking because other employees joined Porsche Engineering directly after graduating from one of the region's universities.

Proximity to the academic world

In order to benefit from the latest research results, the site intends to expand its cooperation with the Technical University of Ostrava. "It's been involved in automotive research for a long time," says location manager Petřek. Working students and doctoral candidates from the technical university are already collaborating on individual projects, and the exchange is set to become much more intensive in the future. An important start has been made: Since June 2020, the location has been situated in an innovation center near the university campus. In addition to its proximity to academia, it also offers room for further growth.

Modern working environment: In addition to the latest technical infrastructure, the Prague location offers a contemporary working atmosphere in one of the most attractive cities in Europe.

"We can employ up to 200 people here—a number we hope to reach in two to three years," Petřek says. "We also have two laboratories in the new building for HiL testing and two more for building HiL test benches and electronics. In addition, there are several workshops where we can modify prototypes in secrecy."

Proximity to technical talent and a modern infrastructure are important prerequisites for staying at the forefront of development in the fast-paced automotive world. Flexibility is another indispensable quality—something the people of Ostrava have demonstrated in the past: After the demise of the local heavy industry, the city turned into a center of knowledge. "From coal mining to data mining," was the slogan. Or as Zdeněk Kolba puts it: "We're ready for the next challenge."

Expanding capabilities: Miloš Polášek focuses on digital skills.

IN BRIEF

The approximately 80 employees in Ostrava are as proficient in traditional automotive engineering as they are in the latest IT technologies. A modern infrastructure and close collaboration with the academic world ensure that the three teams can meet all customer requirements in the fields of electronics and software.

Miloš Polášek, Managing Director of Porsche Engineering in the Czech Republic, on the development work in Prague and Ostrava

"Both locations will grow"

In addition to Ostrava, Porsche Engineering is also active in Prague. How do the two locations differ, and in what areas do they work together?

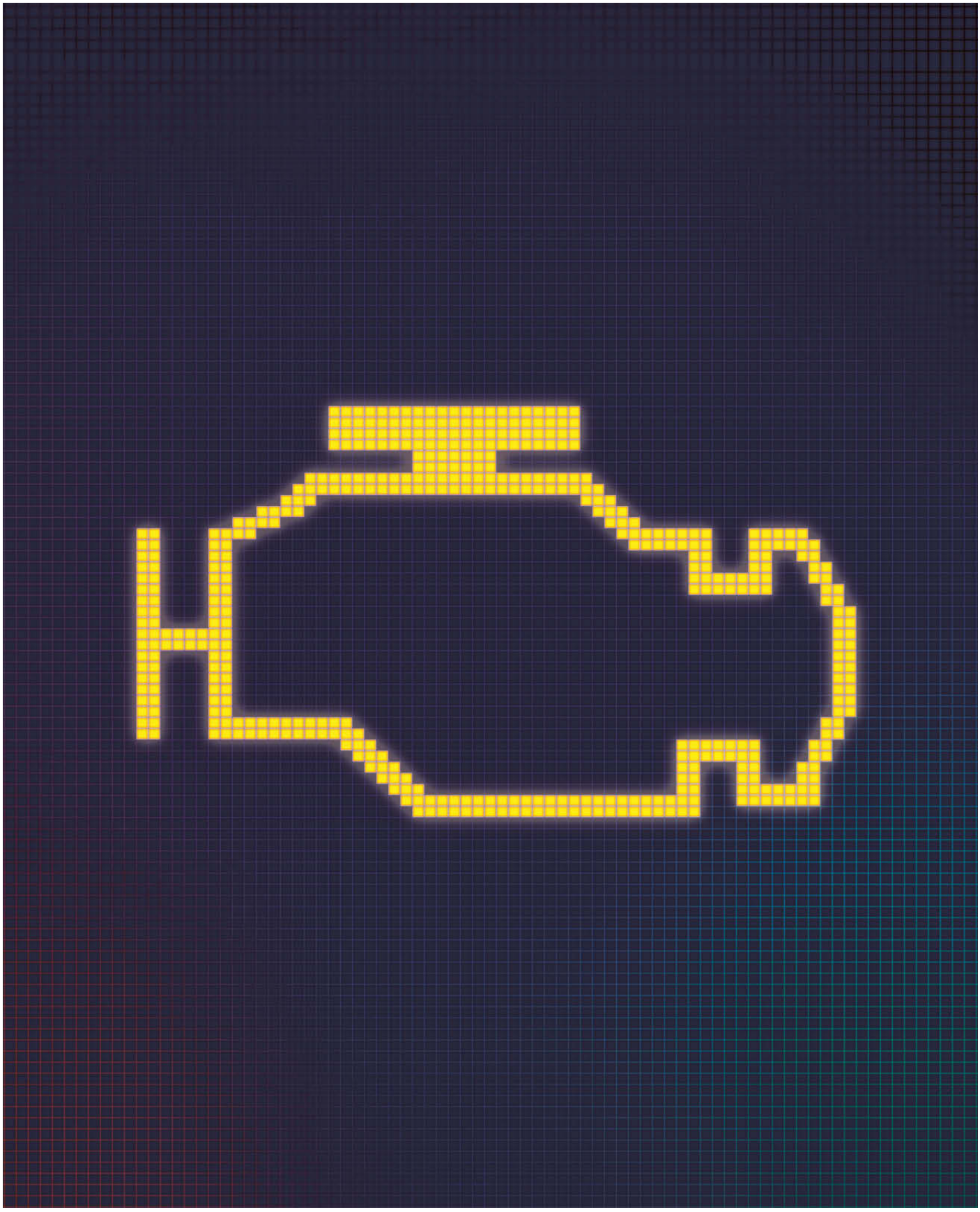
In Ostrava we work on purely digital projects. In Prague, in addition to software developers and our control engineering group, we also have engineers who work on the design and simulation of the chassis, body, and complete vehicle. However, there is close collaboration between the two locations, for instance in the development of battery-management systems.

What automotive trends are shaping your work at the moment?

The big megatrend is the transformation of our industry—from traditional vehicle development to digital capabilities. We need to supplement our existing know-how with new skills in software development, for example. Other important trends are artificial intelligence and e-mobility.

The locations in Prague and Ostrava are expected to grow further in the future. What are your plans exactly?

Both locations will grow. In Prague, we focus on software development and control engineering—a discipline in which we are among the best. In Ostrava, the focus will be more on electronics integration and testing of complete electronic systems. And just as in Prague, we want to work closely with the local universities there.



Engine malfunction indicator light: If the malfunction indicator light (MIL) comes on, the OBD has detected an emissions-related fault.

Everything at a glance

Text: Richard Backhaus

The on-board diagnostics system detects whether the emissions-related systems in the vehicle are working properly. Compliance with legal requirements is checked before the start of production and later verified during ongoing series production. In the process, Porsche Engineering increases efficiency with testing and simulation tools developed in-house.

On-board diagnostics (OBD) monitors the functionality of exhaust-related components over the life of the vehicle. To do this, test routines are implemented in all relevant control units of the vehicle and run while the vehicle is in motion. If an electronic control unit (ECU) returns implausible feedback, a corresponding code is stored in the OBD error memory of the ECU—for example if AFR sensor no longer correctly detects the oxygen content in the exhaust gas and the engine control unit then changes the combustion parameters. At the same time, the yellow malfunction indicator light in the cockpit flashes.

OBD originated in the United States: It was introduced in California in 1988 and throughout the US in 1994. Two years later, stricter emissions limits led to the more powerful OBD II system still in use today, which monitors emissions more precisely, includes other components in the check, and offers more detailed diagnostic options for workshops. OBD became mandatory in Europe in 2001, but with partly different requirements than in the US. In particular, emissions limits and measurement cycles differ significantly. Other regions such as China followed suit in subsequent years.

OBD

was first introduced in California in 1988 and throughout the US in 1994. It has also been mandatory in Europe since 2001. China and other regions followed suit in subsequent years.

At Porsche, the checking of the OBD system for a new vehicle model is divided into three steps: firstly, quality assurance tests while the vehicle is still being calibrated; secondly, type approval tests in the so-called OBD demo phase as a compulsory prerequisite for approval; and thirdly, after the start of series production, a comprehensive examination of all potential OBD fault memory entries on vehicles from current production. Throughout all phases, Porsche Engineering and Porsche AG draw on the partnership that has grown over many years. “As a rule, we start checking the OBD calibration about six months before the start of production. If the tests reveal any abnormalities, we analyze the causes and suggest possible corrective measures,” says Dr. Matthias Bach, Senior Manager Engine Calibration and Mechanics at Porsche Engineering, under whose purview on-board diagnostics falls.

Coordination with certification authorities

In the OBD demo phase that follows, it is demonstrated that the vehicle’s OBD system complies with legal requirements. To this end, Porsche AG coordinates test series with the certification authorities in the individual

regions around the world, which the experts in Porsche Engineering's testing department then work their way through. "We cover 145 markets, ten of which have individual certification procedures," says Thomas Rauner, Director of the Homologation Powertrain Department at Porsche AG. The different emissions laws, test cycles, and OBD requirements make development and testing extremely complex. A recent example is China, where the China 6b standard, which will be adoped in 2023, stipulates demanding OBD test conditions. "Unlike in the rest of the world, a positive test report will then no longer be sufficient in China to certify a new vehicle model. Rather, the OBD test must be carried out on site and under the supervision of the authorities," explains Dr. Sebastian Rüger, who is responsible for OBD certification at Porsche AG, among other roles.

As Porsche China's exclusive strategic partner, Porsche Engineering supports on-site certification by providing technical services such as conducting the test series. Porsche AG is responsible for coordinating the test results with the respective certification authorities. "Thanks to close cooperative relationships and continuous exchange of information between the colleagues of Porsche Engineering in China and Germany as well as Porsche AG, we are able to implement the approval of the vehicle model on a tight timeframe in the process," says Rauner.

3,500

possible fault codes from the chassis and powertrain areas exist in hybrid vehicles.

911 Targa 4S

Fuel consumption (city): 15.0 l/100 km
Fuel consumption (highway): 7.6 l/100 km
Fuel consumption (combined): 10.3 l/100 km
CO_2 emissions (combined): 235 g/km
Energy efficiency class: G

For the OBD type approval tests of a new vehicle model, Porsche Engineering carries out up to 80 test runs on the dynamometer, recreating various emissions-relevant events such as a damaged lambda sensor line. For example, the engineers install specially prepared components in the vehicle or simulate predefined fault cases. To simulate the wear and tear of many years, they also use components such as catalytic converters that have been subjected to an artificial aging process.

In addition to legal requirements, the ever-increasing number of electronic systems in the vehicle is also leading to greater OBD complexity. OBD not only

Investigation of emissions-related events: For the type approval tests of a new vehicle model, Porsche Engineering carries out up to 80 test runs on the dynamometer.

monitors individual components, but also checks entire functional sequences, including potential cross-influences from other vehicle systems. This also includes control units that could indirectly influence emissions in the event of a defect, for example for Adaptive Cruise Control (ACC), Porsche Stability Management (PSM), and the Remote Park Assistant, which automatically parks the vehicle. "As part of the OBD verification tests required by the authorities, the Product Vehicle Evaluation, we have to prove that the emissions-neutral compensation measure is carried out correctly—in other words, that it no longer has any influence on the vehicle's emissions behavior," says Rüger. "Experts refer to this as an Emissions Neutral Default Action, or ENDA for short." The resulting testing effort is correspondingly high: "In modern hybrid vehicles, we have up to 14 ECUs from the powertrain and chassis areas with around 3,500 possible error codes," says Bach.

Simulation of errors

These have to be verified within a period of up to six months after a vehicle goes into production. To save time and costs, Porsche Engineering relies almost exclusively on the simulation of faults. "Instead of installing and removing defective components for test bench examinations or road tests at great expense, we modify the respective sensor signals or messages in the vehicle's electronic data system," explains Bach. This requires an in-depth understanding of the component and its function in the overall system, which

"We cover 145 markets, ten of which have individual approval procedures."

Thomas Rauner, Director of the Homologation Powertrain Department at Porsche AG

95%

of defects in the OBD system can be reproduced by Porsche Engineering with its own testing and simulation tools.

Porsche Engineering, as an OBD service provider from the very beginning, has gained in countless development projects. "Our strength is our expertise in the areas of complete vehicles and testing. On this basis, we have developed our own testing and simulation tools, which can be used to reproduce around 95 percent of the defects in the OBD system," explains Bach. For example, the function of the throttle valve actuator is simulated externally during engine operation, so the throttle valve installed in the vehicle can be tested separately. In order to display the desired fault memory entries for the injectors, specially developed software is used to change the injection quantity of the injectors within a very fine range. "When it comes to simulating networking faults in the electronics architecture, we are always up to date thanks to our strong cooperation with colleagues in development and can therefore present the appropriate test procedure as soon as new diagnostic functions are introduced," says Bach.

The result is an extremely fast and efficient OBD process. It is foreseeable that the resulting advantages will become even more important in the future, as stricter emissions standards, such as the Euro 7 standard currently under discussion, further reduce the permissible exhaust gas limits worldwide. Thus the spiral of OBD development continues to turn: New systems and functions enable lower emissions values, which are then tested again via the improved OBD. In addition, there are diagnostic tasks arising from the use of synthetic fuels known as e-fuels. "It can be assumed that electric cars will also have to pass an OBD test in the future," says Bach with a view to the future. "It would then be about the condition of the powertrain and battery rather than nitrogen oxide or particulate emissions."

"Our strength is our expertise in the areas of complete vehicles and testing."

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

The all-rounder among e-sports cars

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

The new Porsche Taycan Cross Turismo features all the strengths of the Taycan, such as superior performance and long range. Added to this, there is more headroom for rear-seat passengers and a maximum luggage compartment capacity of over 1,200 liters behind the large tailgate. And the chassis is height-adjustable with standard all-wheel drive and air suspension.

Taycan 4 Cross Turismo

Power consumption (combined): 28.1 kWh/100 km;
CO_2 emissions (combined): 0 g/km;
Energy efficiency class: A+

Taycan 4S Cross Turismo

Power consumption (combined): 28.1 kWh/100 km;
CO_2 emissions (combined): 0 g/km;
Energy efficiency class: A+

Taycan Turbo Cross Turismo

Power consumption (combined): 28.7 kWh/100 km;
CO_2 emissions (combined): 0 g/km;
Energy efficiency class: A+

Taycan Turbo S Cross Turismo

Power consumption (combined): 29.4 kWh/100 km;
CO_2 emissions (combined): 0 g/km;
Energy efficiency class: A+

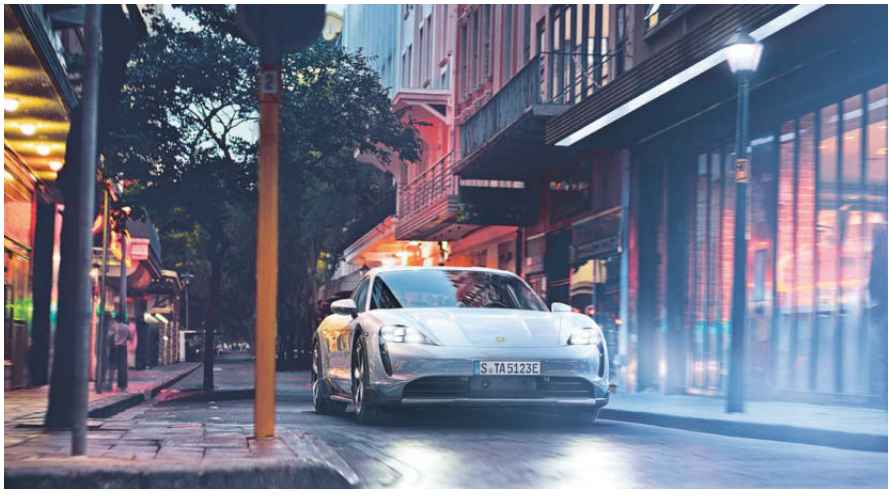
The new Porsche Taycan Cross Turismo has been on the market since summer 2021. The anticipated five largest markets for this Taycan version are the US, the UK, Norway, Sweden, and Germany. Visually, it is closely based on the Mission E Cross Turismo concept study presented at the Geneva International Motor Show in 2018: The silhouette is defined by the sporty, falling roofline towards the rear—dubbed the "flyline" by Porsche designers. The off-road design elements include wheel arch trim, unique lower aprons at the front and rear, and the side sills. In combination with the Off-Road Design package, the Cross Turismo has special flaps at the corners of the front and rear bumpers and at the ends of the sills. These provide a striking exterior while also protecting against stone impacts. Like the Taycan sports saloon, the new Cross Turismo features innovative elements such as the glass-effect Porsche lettering in the light bar.

The integrated Porsche 4D Chassis Control analyzes and synchronizes all chassis systems in real time. Porsche uses a centrally networked control system for the chassis of the Taycan Cross Turismo. Adaptive air suspension with three-chamber technology including PASM (Porsche Active Suspension Management) electronic damper control system is fitted as standard to all Taycan Cross Turismo models. The air suspension includes a Smartlift function as standard. This allows the customer to easily specify that the vehicle level should be raised automatically at certain recurring points such as road humps or garage driveways. One press of the chassis button is all it takes to save such positions.

Gravel Mode driving program

The Taycan Cross Turismo comes with the additional Gravel mode driving program as standard for driving on light terrain, for example on gravel tracks or a muddy road. The vehicle level is raised by 30 millimeters compared to the saloon. Gravel Mode also influences the Porsche Active Suspension Management (PASM),

View of the sky: The Taycan Cross Turismo is available with an optional panoramic glass roof (above). Another stylistic highlight is the standard matrix LED headlights (below).



Porsche Traction Management (PTM), Porsche Torque Vectoring Plus (PTV+), Porsche Stability Management (PSM), as well as the rear-axle transmission. The latter shifts in a traction-optimized manner. The car's throttle characteristics have also been specially designed for off-road use in terms of power delivery and control precision.

All Taycan Cross Turismo models have two electric motors on the front and rear axles, which means they come with all-wheel drive as standard. Both the range and the continuous power of the drive benefit from the high efficiency of the permanently excited synchronous motors. The electric motor, transmission, and pulse-controlled inverter are combined in a compact drive module. The possible recuperation power has been increased once again and, at up to 290 kW, is significantly higher than that of the competition. The streamlined aerodynamics with a Cd value as low as 0.26 make a decisive contribution to low energy consumption and thus to a long range. The measures relating to Porsche Active Aerodynamics (PAA) include the adjustable air intakes at the front. The roof spoiler in the rear is fixed.

The Taycan Cross Turismo operates on a system voltage of 800 volts (voltage range 610 V to 835 V) instead of the 400 V commonly found in electric cars. Inside the standard two-deck Performance Battery Plus sit 33 cell modules, each consisting of twelve individual cells (396 total). The total capacity is 93.4 kWh. At home, Taycan Cross Turismo drivers can charge their vehicle with up to 11 kW of alternating current (AC) as standard. An on-board charger with 22 kW is available as an optional extra. On the road, Taycan Cross Turismo drivers benefit from the sophisticated temperature management strategy for the battery. By heating the cells with pinpoint accuracy when approaching a high-power charging station, the batteries can be charged with higher currents (direct current, DC) and thus particularly quickly: Energy for a range of up to 100 km (according to WLTP) is recharged in around five minutes.

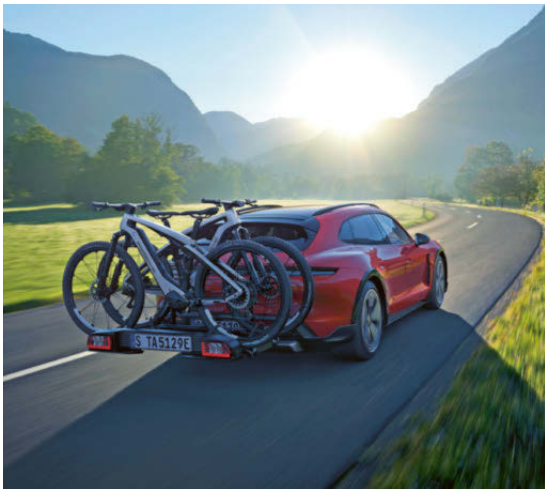
290 kW

maximum recuperation capacity is offered by the Taycan Cross Turismo—significantly more than the competition.

Extensive standard equipment

Porsche has upgraded the standard equipment for the 2021 model year. The Cross Turismo models naturally also benefit from this. Digital radio is standard. Digitally broadcast radio programs in DAB, DAB+, and

Endurance champ: The Taycan Cross Turismo can travel up to 456 km on one battery charge (according to WLTP).



Timeless design: The eBike Sport and eBike Cross are a perfect match for the Taycan Cross Turismo (above). The design in the interior corresponds to the acclaimed styling of the Taycan sports sedan (below).

DMB audio formats offer significantly better sound quality. Porsche has also expanded the standard package in terms of connectivity. For example, Apple® podcasts can now be selected as a separate media source. With LED headlights, Advanced Climate Control (two zones), multifunction sports steering wheel, partial leather interior, and eight-way electrically adjustable comfort seats, the standard equipment in the Taycan 4 Cross Turismo and Taycan 4S Cross Turismo is already extensive. For the Taycan Turbo Cross Turismo, 14-way electrically adjustable comfort seats come as standard. The Taycan Turbo S Cross Turismo features, among other things, 18-way electrically adjustable adaptive sports seats, a leather-free two-tone interior as well as rear-axle steering, Sport Chrono package, and Porsche Electric Sport Sound.

With Functions on Demand (FoD), Taycan drivers can additionally purchase various convenience and assist functions as needed. The great thing: This also works after the purchase and original configuration of the vehicle. A visit to the workshop is not necessary due to online activation. This is currently possible for the Porsche Intelligent Range Manager (PIRM), Power Steering Plus, Active Lane Keeping and Porsche InnoDrive.

Five minutes

to recharge the battery at a DC fast-charging station for up to 100 km.

Digital radio

is standard, guaranteeing significantly better sound quality.

Sporty accessories

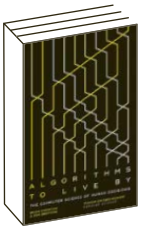
With the eBike Sport and the eBike Cross, Porsche is simultaneously presenting two e-bikes that are an ideal match for the Taycan Cross Turismo. Porsche has also developed a rear rack for up to three bikes for the new electric sports car, which sets standards in terms of pack size and handling. At the same time, it can be used universally for different types of bikes. The tailgate can also be opened when the vehicle is loaded. Roof boxes are also available from Porsche Tequipment for the Taycan and Taycan Cross Turismo model series—including a new performance model that has been tested and approved for higher speeds. The latter includes crossbars for the roof rails of the Taycan Cross Turismo.

Deeper knowledge

High-level analysis

China is on the way to becoming the next superpower. At the same time, the country faces major challenges. In this book, economists from China's leading university and America's best-known think tank analyze key questions about the country's future.

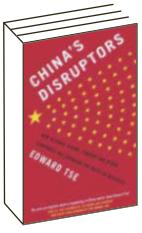
China 2049
David Dollar, Yiping Huang, Yang Yao
Brookings Institution



Living algorithmically

What should we get done in a day or in a lifetime? And what is better left undone? How much clutter can we accept? The authors show how computer algorithms can be used to find answers to such everyday questions.

Algorithms to Live By
Brian Christian, Tom Griffiths
Harper Collins



Exclusive insights

Corporations like Alibaba, Tencent, and Baidu represent China's economic success story. Through exclusive interviews and case studies, the author shows how they came to be and what the country's rise means for the rest of the world.

China's Disruptors
Edward Tse
Penguin

Race of the tech superpowers

China is the largest homogeneous digital market and a huge ecosystem for innovation. Young companies will shape technologies such as the Internet of Things, AI, blockchain, cloud computing, and data analytics—a new competitor for the US and its tech corporations.

The Digital War
Winston Ma
Wiley

The big picture

Golden era of the car

Racers, developers, designers, collectors, or tuners: There are countless colorful guys who have experienced crazy stories and achieved impressive things with their cars. In the *Alte Schule* ("Old School") podcast, they recall their experiences together with host Karsten Arndt. The legendary race drivers Herbert Linge and Walter Röhrl are among the guests.

Alte Schule
https://alte-schule.podigee.io/

Pointed utopias

This podcast from the *Zukunftsinstitut* ("Future Institute") takes a critical but also optimistic look at what lies ahead. Renowned experts from the worlds of business, politics and science discuss current as well as long-term developments with host Tristan Horx every two weeks.

Treffpunkt: Zukunft
https://www.zukunftsinstitut.de/podcast/treffpunkt-zukunft/

Beautiful science

This YouTube channel from Munich wants to make science beautiful. Because its creators firmly believe that science is beautiful! The clips are intended to create awareness of topics from the fields of science, space travel, technology, biology, history, and philosophy. The goal is to inspire people to learn.

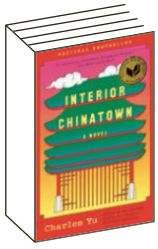
Kurzgesagt—In a Nutshell
www.youtube.com/channel/UCsXVk37bltHxD1rDPwtNM8Q

For the child in all of us

A journey through the digital world

From the C64 to Artificial Intelligence: Bestselling author Alessandro Baricco takes digital natives on an exciting journey through the history of computers, the internet, games, and more. Using vivid examples and with the help of maps of the digital world, the book explains in an easy-to-understand way what digitalization means—as amusing as it is simple.

The Game
Alessandro Baricco
Midas



Suddenly in the limelight

Willis Wu is a bit player in various shows and leads a low-key life. After unexpectedly stumbling into the spotlight, Willis discovers not only the secret history of Chinatown, but also his own family's buried heritage. The National Book Award-winning novel explores themes including pop culture, assimilation, and immigration.

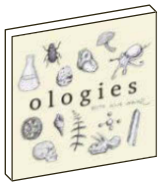
Interior Chinatown
Charles Yu
Vintage

Intelligent entertainment

How everything is connected to everything else

US science journalist Latif Nasser explores the surprising and intricate ways in which we are connected to each other, to the world, and to the universe in this Netflix documentary series. Among other things, we learn what clouds in the sky have to do with the computer cloud.

Connected
Netflix, 2020



Science to go

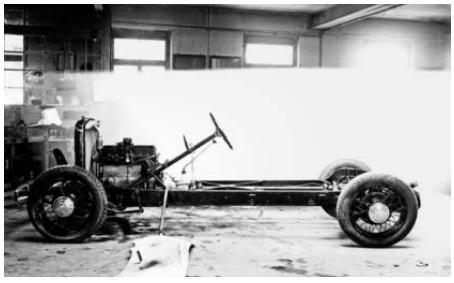
How much space junk orbits the Earth, and how do we get it out of there? How do cicadas survive underground for decades? And how dangerous are scorpions, really? Journalist Alie Ward discusses such questions in her podcast *Ologies* with experts from very different fields of knowledge.

Ologies
www.alieward.com/ologies

Backwards in time

Lead actor John David Washington plays an unnamed CIA agent (referred to as "the Protagonist") who wants to prevent World War III in this science fiction film. In the process, he keeps encountering objects from the future that move backwards in time—bullets that fly back into guns, for example. The agent must track down the source of the phenomenon or the world will end.

Tenet
Christopher Nolan (director), 2020



Early engineering services: Top left: Ferdinand Porsche (left) and engine expert Josef Kales in the Porsche engineering office at Kronenstrasse 24. Bottom left: The Porsche Type7, Porsche's first design. It was built by Wanderer under the designation W21 (1.7 liters) and W22 (2 liters). The car had a six-cylinder in-line engine with 35 and 40 hp respectively and had a curb weight of 1,260 kg. Right: Porsche Type7 (about 1933)

1931

This was the beginning of a long-standing collaboration: On November 29, 1930, the Wanderer-Werke in Chemnitz awarded Ferdinand Porsche his first contract—roughly six months before the engineering office was entered in the Stuttgart commercial register on April 25, 1931. He and his engineers were to design a six-cylinder engine with a displacement of 1.5 liters and an output of 30 hp, as well as a new chassis. Development began in January 1931, and with it the newly minted entrepreneur's business activities were secured for the time being.

The starting point for the project (internally called the Type 7) was development work by Ferdinand Porsche at Steyr, where he had previously developed a new generation of engines and chassis. This enabled him to design the desired new engine series for Wanderer in a short time—after all, the first roadworthy prototypes could be inspected in the courtyard of the Porsche Villa in Stuttgart as early as the beginning of August 1931 and were ready for testing at the Nürburgring in October 1931.

The engines were distinguished by numerous technical innovations, including their in-line six-cylinder design, lightweight construction with an aluminum block, wet liners, low-lying camshafts, overhead valves, and a semi-wet clutch. As a result, they were easy to maintain, had a convincing six-cylinder sound and weighed 40 kg less than the previous generation of Wanderer engines. Based on the prototypes, two variants were initially produced for series use: an engine with 1.7 liters of displacement and 35 hp output, and a 2-liter variant with 40 hp. The only difference between them was the different bore sizes of the liners. The smaller engine was used in the Wanderer model W15, for example, as a 4-window sedan, while its larger counterpart was used in the W17, for example as a 6-window sedan. Both basic types were intended from the outset as interim solutions and were only produced for half a year. The W15 and the W17 were replaced in March 1933 by the W21 and the W22, respectively—brought to the market by the newly founded Auto Union and still powered by straight six-cylinder engines from the Porsche engineering office.

In addition to their innovative engines, the vehicles were also impressive for their innovative swing axle system: The Porsche torsion bar suspension, used for the first time in automobile construction, would prove a trend-setting development in chassis technology. The project was also a milestone for Ferdinand Porsche. The first order for the engineering office was the prelude to close collaboration with Auto Union, which later gave rise to the Porsche Type 22, which became known and successful as the Auto Union race car.

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911 Targa 4 (WLTP): Fuel consumption (in l/100km) combined 10.9–10.5 (25.9–26.9mpg);
CO_2 emissions (in g/km) combined 247–239