Porsche Engineering

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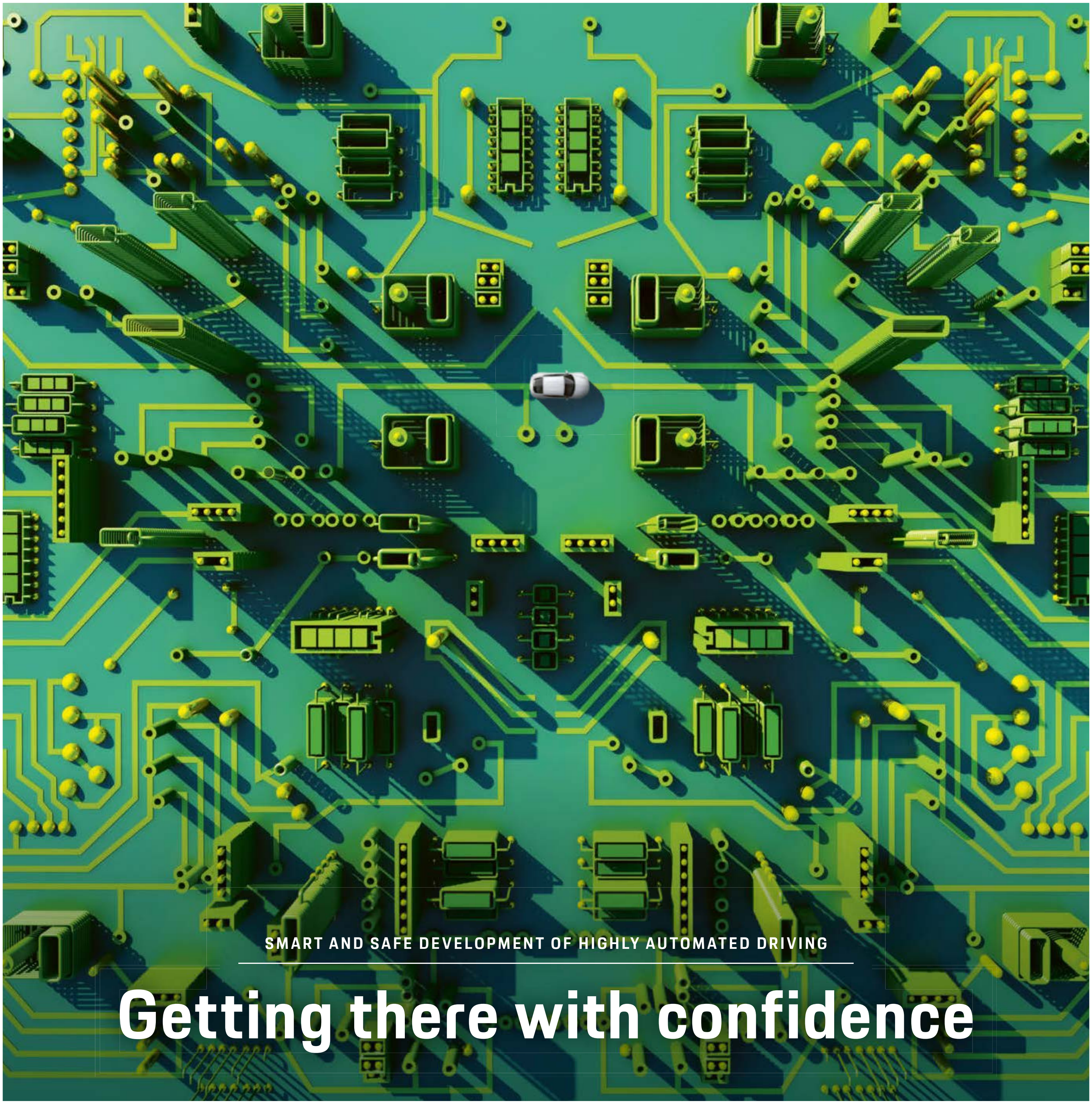


No great story ever started
inside the comfort zone.
The new Macan S. Dare forward.
Fuel consumption in l/100 km: urban 12.3 · extra urban 8.4 · combined 9.9–9.8 (NEDC); combined 11.7–11.1 (WLTP);
CO2 emissions in g/km combined: 225–224 (NEDC); 265–251 (WLTP)
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Dirk Lappe
Managing Director of Porsche Engineering

Dear Reader,

I am a huge science fiction fan. The stories of Jules Verne, Isaac Asimov, or even Andy Weir are not only exciting, but also inspiring. In order to develop something, you first have to picture it in your imagination. And that's exactly what the authors of science fiction stories do—they imagine a wonderful future in which yet-unknown technologies positively shape people's lives. Engineers, too, shape the future by constantly challenging the status quo.

In addition to novels that invite us to imagine a desirable future, there are also dystopian works, such as George Orwell's *1984* or Aldous Huxley's *Brave New World*, with disturbing tales of a world that no one could hope for. Here, a literary description of the future can serve as a warning and appeal to our sense of responsibility. Artificial intelligence, for example, is a powerful tool that we should use wisely. At the same time, artificial intelligence and other technologies create enormous added value for mobility, society, and thus for humanity.

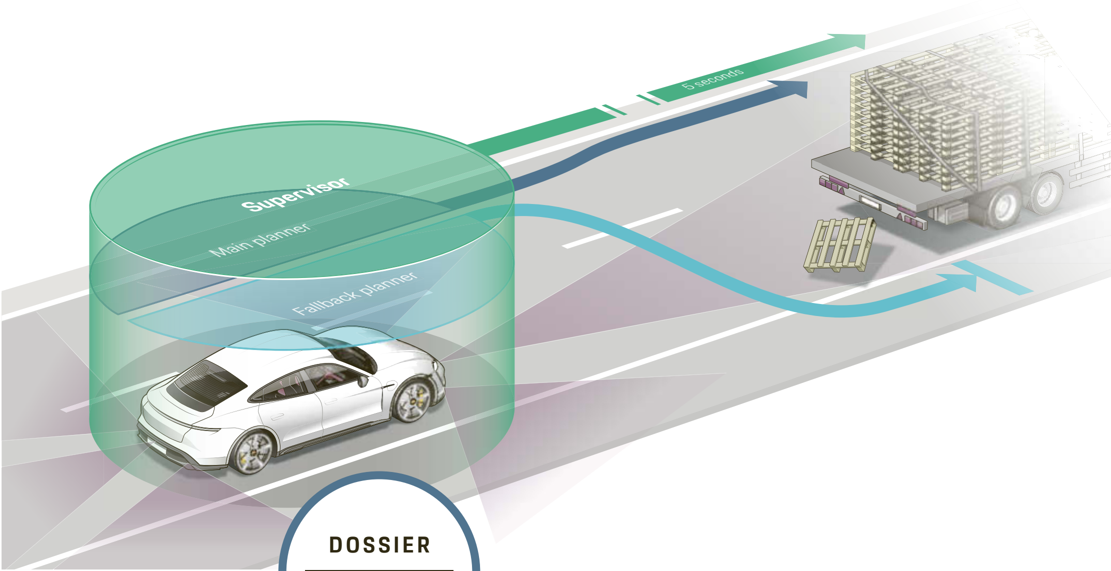
Many of the former figments of someone's imagination have now become reality. This raises the question: Have we perhaps already used up our stores of literary technology ideas, such that nothing groundbreaking can be expected in the future?

Not a chance. We are nowhere near that point of exhaustion—if we think far enough ahead; if we just keep plugging away at development; and if we put those developments to optimal use. On the way to a sustainable future. We see ourselves as a technology partner to our customers, accompanying them on a shared journey. And a partner that fully implements functions like highly automated driving with confidence.

It's a fun way to do science fiction—and an endless source of inspiration for me and the team at Porsche Engineering. I wish you the same as you read our magazine!

Dirk Lappe

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 design office, founded in 1931, into the future and developing the digital vehicle technologies of tomorrow. In doing so, they combine in-depth vehicle expertise with digital and software expertise.



10
Double the planning: Redundant systems make highly automated driving functions even safer.

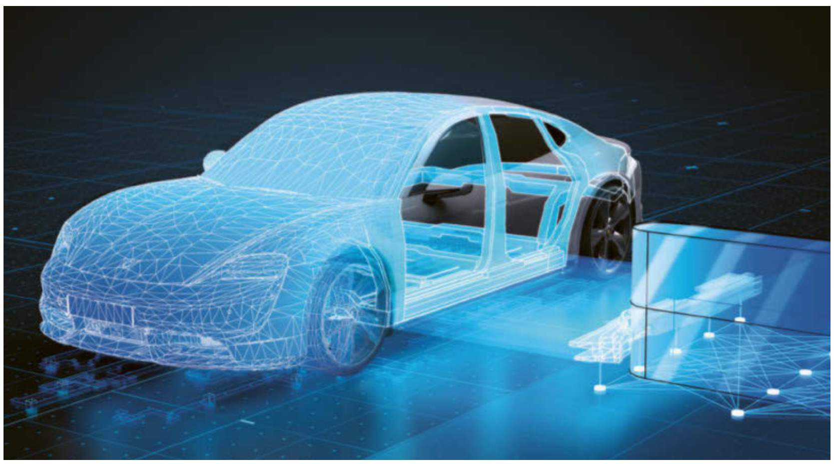
DOSSIER

10 – 29

16 **Teamwork:** Highly automated driving functions are validated across international boundaries using virtual and real methods.

42 **Ergonomic design:** Porsche Engineering has designed a new multifunctional lever for Linde Material Handling's reach trucks.

30 **AI turbo:** New technologies such as quantum computers are expected to speed up calculations in the future.



36 **Optimized by the agent:** Reinforcement learning and neural networks save time and computational effort in the design of a side skirt.

Porsche Engineering Magazine
Issue 1/2022

03 **Editorial**
04 **Contents**
06 **News**

DOSSIER: HIGHLY AUTOMATED DRIVING

10 **Monitored safety**
In highly automated driving functions, parallel systems observe the environment and decide what to do in critical situations

16 **Validating complexity**
Linking virtual and real tests: This is how Porsche Engineering creates the basis for an efficient and reliable validation process

24 **Dynamic development**
The Jupiter platform makes fast development and validation of highly automated driving functions a reality

28 **Science vs. fiction**
Autonomous vehicles have appeared in movies for a long time. But how realistic are the screenwriters' visions?

TRENDS AND TECHNOLOGIES

30 **Taking a quantum leap**
New technologies such as extremely large graphics processors, photonic computers, and quantum computers are expected to speed up AI calculations in the future

PERFORMANCE AND EXPERTISE

36 **Doubly optimized**
A reinforcement learning agent and a neural network improve the crash behavior of a side skirt

42 **All in one hand**
Porsche Engineering and Linde Material Handling have developed a multi-functional lever that makes all functions accessible without reaching around

INSIGHT

48 **A gentleman and a record-breaker**
Gianmaria Aghem has set seven world records with his electrically powered Blizz Primatist on the circuit of the Nardò Technical Center

PORSCHE AND PRODUCT

54 **Mission future**
Porsche presented its vision of an all-electric vehicle for customer motorsport at the IAA MOBILITY 2021: the Mission R

OUTSIDE THE BOX

60 **Outside the box**
Recommendations for thinkers, tinkerers, and geeks

A LOOK BACK

62 **Gorgeous forerunner**
In 1946, Porsche received an order to develop the Type 360 Cisitalia. It would become the cornerstone for sports car construction under its own name

Authors

16 **Yolanda vom Hagen** is a freelance photographer for industry, interiors, portraits, and events. She has lived in Shanghai for twelve years.

30 **Christian Meier** is a journalist and book author. He writes about science, digitalization and artificial intelligence.

36 **Jurij Chrubasik** is a 3D expert and infographic designer from Berlin. His focus is on medicine and technical illustration.

High demand: China is one of the most important markets for Porsche.

"With the new development location in China, we are making great strides toward getting to know and understanding the needs of our local customers even better."

Oliver Blume,
Chairman of the Executive Board of Porsche AG

Further growth in Asia

Porsche expanding development and assembly capacities

Porsche is focusing on further growth in Asia and is expanding its global development and assembly capacities there. The company has a long tradition of using locations abroad and starting next year this will include a research and development site in China.

The new development location will complement the activities of the Porsche Digital location in Shanghai, which was established at the beginning of the year, as well as Porsche Engineering's long-standing development activities for the Chinese market.

Porsche Engineering has already been active in the area for more than 25 years. Through its location in Anting, the company has pursued engineering projects together with its local customers here since 2014. Key fields of research are suspension systems, high-power charging, and software development. In addition to Chinese

OEMs, companies in the VW Group are also important customers. With the additional development capacities in China, Porsche intends to take even better account of customer needs in its largest single market and incorporate them into development at an early stage. "A spirit of inquisitiveness, continuous learning and attention to detail drive us in our quest for the perfect sports car," says Oliver Blume, Chairman of the Executive Board of Porsche AG. "With the new development location in China, we are making great strides toward getting to know and understanding the needs of our local customers even better."

China is the largest market for battery electric vehicles and is on track to become a leader in areas such as highly automated driving. China wants the intelligent and connected vehicle—ICV for short—to be a common sight on its roads by 2025 at the latest. The aim is to have all vehicles communicate in real time and to share data, for example on congested traffic. On top of that, China wants fifteen percent of all vehicles in the country to be highly automated and ten percent to be driving entirely by themselves by no later than 2030.

"In China, high reaction speed is particularly important, because everything happens much faster here," says Kurt Schwaiger, Managing Director of Porsche Engineering China. "Porsche Engineering Shanghai develops solutions for Chinese OEMs and the VW Group, including Porsche. There are currently around 120 engineers working at Anting in all areas of automotive mobility. In the future, we will develop even more China-specific digital functions." One example, he says, is integrating the functions of mobile devices into the vehicle, for example WeChat or Alipay. He notes that they are also working intensively on highly automated driving. "We can only develop and test this in the transport infrastructure that is actually here," says Schwaiger.

Porsche Digital and Porsche Engineering are working closely together in China. "We specialize in the development of vehicle-related functions, while Porsche Digital has a lot of expertise in back-end systems and the integration of content suppliers such as music, news, weather, and map services," explains Joachim Bischoff, Director Intelligent Connected Vehicle department at Porsche Engineering. "We will work together in mixed teams to take an agile approach to new projects in China."

Alongside China, Southeast Asia is also one of the world's most dynamic markets with significant growth and innovation potential. Porsche is also expanding its presence there: Together with its long-standing partner Sime Darby Berhad, the sports car manufacturer is setting up a local vehicle assembly plant in Malaysia. The production facility expands Porsche's European production network and will manufacture Cayenne models designed specifically and exclusively for the Malaysian market from 2022.

In 2020, Porsche increased deliveries in the sports car-loving market by nine percent year-on-year under difficult conditions. As a founding member of ASEAN (Association of Southeast Asian Nations), Malaysia offers good business and development opportunities. In addition, the island state has a well-developed and established automotive landscape.

"In China, high reaction speed is particularly important, because everything happens much faster here."

Kurt Schwaiger, Managing Director of Porsche Engineering China

"We will work together in mixed teams to take an agile approach to new projects in China."

Joachim Bischoff, Director Intelligent Connected Vehicle at Porsche Engineering

For over
25
years, Porsche Engineering has been active in China.

Roughly
120
engineers are currently working at Porsche Engineering in China.

15
percent of all vehicles in China are to be highly automated by 2030 at the latest, with ten percent fully automated.

Exhibition at the Porsche Museum

Exclusive insights

With its special exhibition 50 Years of Porsche Development Weissach running from August to early December 2021, the Porsche Museum offered extensive insights into half a century of research and development at the Weissach location. As part of Porsche development, Porsche Engineering looked back on formative engineering services and presented fascinating stories, vehicles, and innovations.

Expanding the innovation network

New research and development office opened in Timișoara

Porsche Engineering has opened a second location in Romania. With a new research and development office in Timișoara, the company is further expanding its innovation network for the development of the intelligent and connected vehicle of the future. Around 30 employees were recruited there in 2021, and the number is set to rise to 200 over the medium term. Software developers in Timișoara will focus primarily on trends such as highly automated driving functions, machine learning, and virtual energy management. The new location expands and complements Porsche Engineering's digital capabilities at its other Romanian site in Cluj-Napoca, which was founded in 2016 and employs over 250 people. "Our technology activities in Romania represent an impressive success story. The steady growth and the large number of highly qualified function and software specialists in Cluj-Napoca motivated us to consider a second location," says Dirk Lappe, Managing Director of Porsche Engineering. With several technical universities, Timișoara offers an optimal environment. "We plan to establish contacts with the Polytechnic University and West University in Timișoara in order to initiate joint projects," says Marius Mihailovici, Managing Director of Porsche Engineering Romania.

Workshop at the NTC

Scenario-based testing

In collaboration with Leane International and AB Dynamics, the Nardò Technical Center (NTC) hosted the Scenario-based Testing Workshop in September 2021. It was aimed at customers inside and outside the VW Group, as well as the main international OEMs. Participants learned about the latest robotic driving systems, equipment, and the set-up skills for scenario-based testing. From simulation to real-life testing, various case studies were first worked on in virtual environments using a simulator. They were then validated on the track with parallel driving on multi-lane roads, lane changes, intersections, and merging maneuvers. The event also provided an opportunity to showcase the NTC's recent investments in infrastructure and expanded testing capabilities and capabilities in Advanced Driver Assistance Systems/Highly Automated Driving (ADAS/HAD). For example, the NTC has transformed one of its test tracks into a "smart dynamic area" that enables testing of connected and automated vehicles. In addition, the ADAS/HAD engineering team has been expanded.

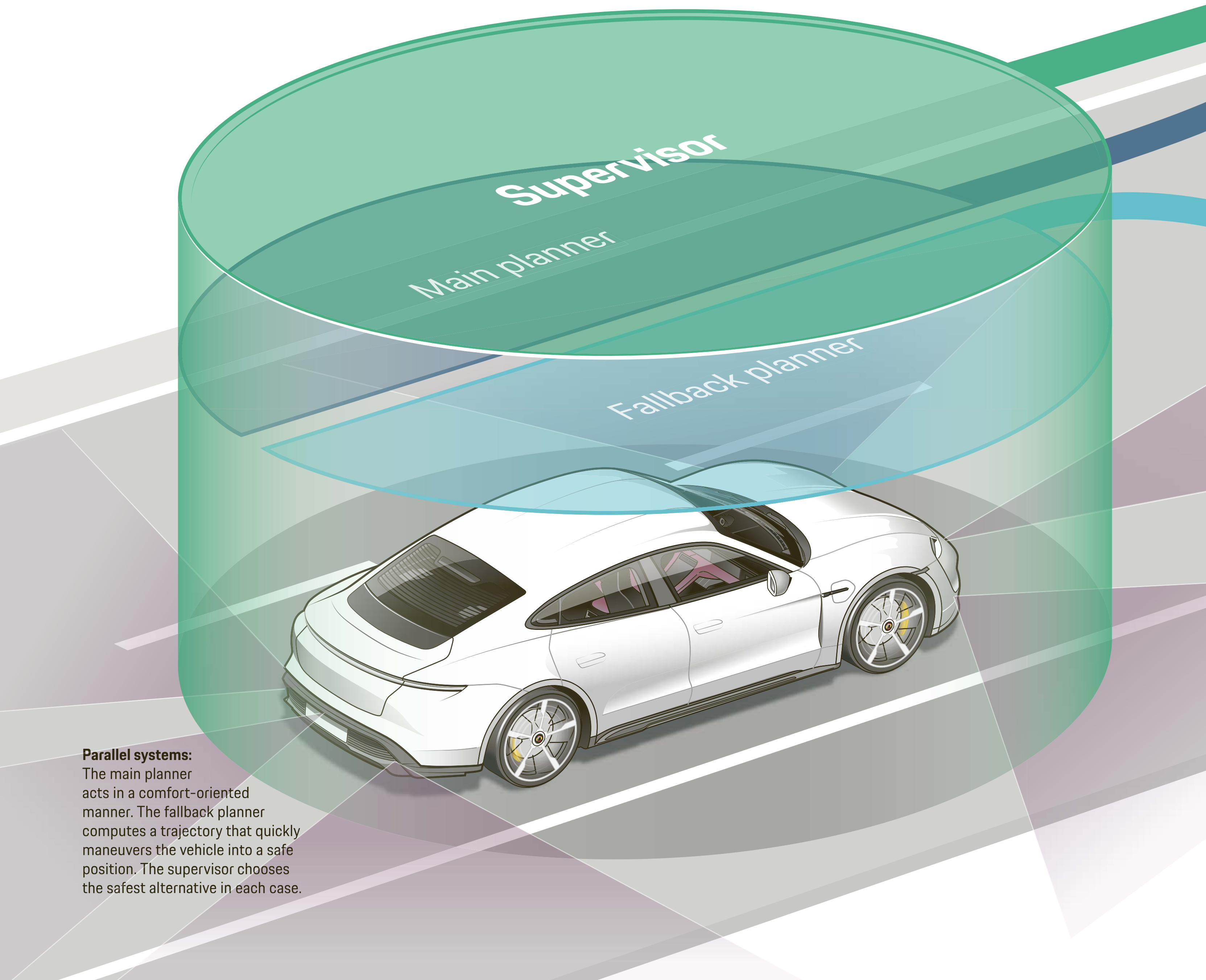
Social commitment in Romania

Support for children and students

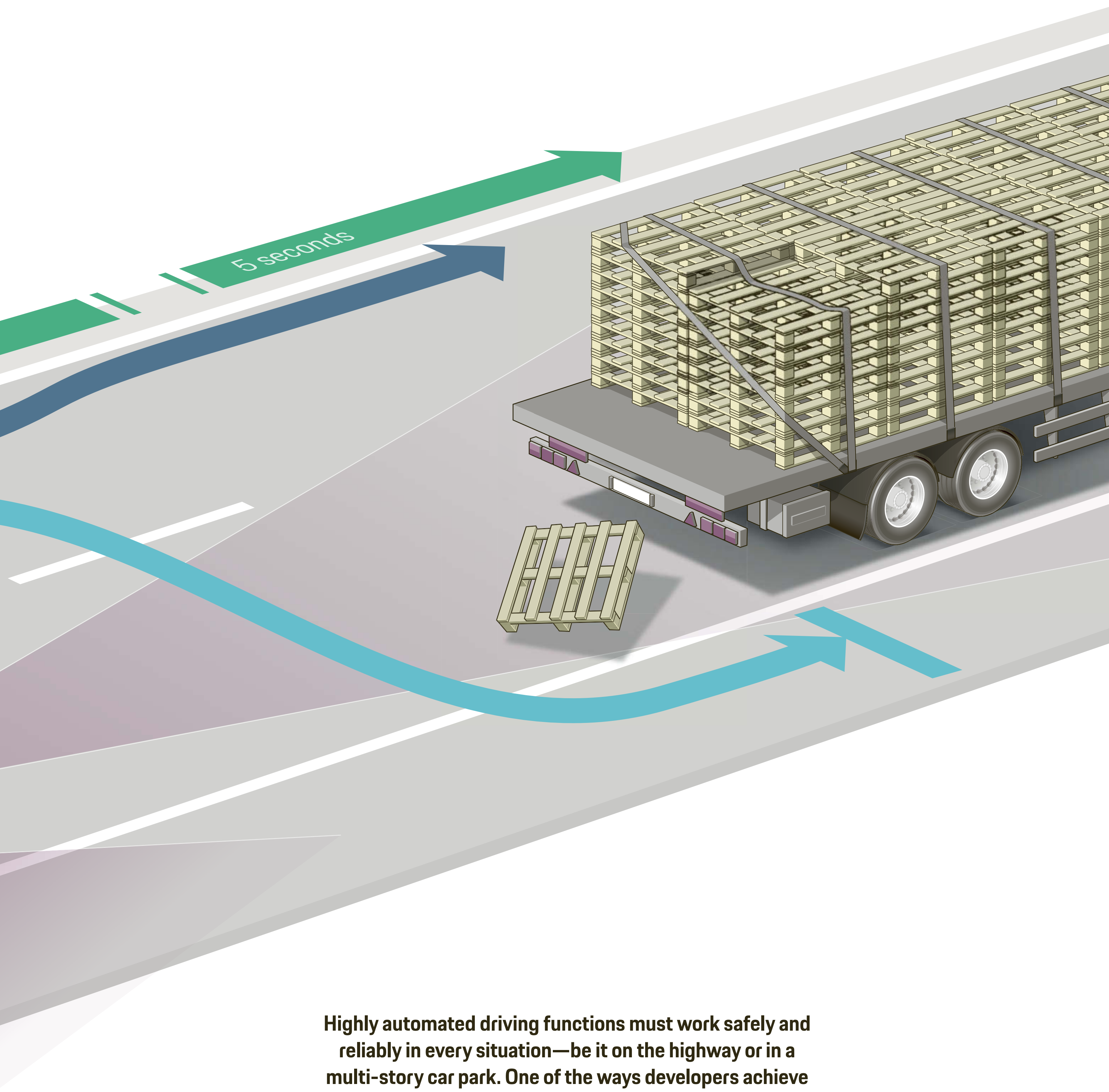
Porsche Engineering Romania supports numerous projects to help local communities and improve the well-being of its employees. For example, the company is the primary sponsor of the Trascău Trail Run in Rimetea, in which quite a few employees took part in 2021. Porsche Engineering Romania also donated 8,000 euros to the Little People association, which supports the renovation efforts for the children's play and therapy room at the Oncology Hospital in Cluj-Napoca. Together with the CERT Transilvania association, Porsche Engineering Romania encourages children to think creatively. In addition, 3,000 euros were collected to buy technical equipment for the children. Ten students took part in the first model-based academy, where they learned modeling techniques.

Monitored safety

Text: Constantin Gillies Illustrations: Andrew Timmins



Parallel systems: The main planner acts in a comfort-oriented manner. The fallback planner computes a trajectory that quickly maneuvers the vehicle into a safe position. The supervisor chooses the safest alternative in each case.



Highly automated driving functions must work safely and reliably in every situation—be it on the highway or in a multi-story car park. One of the ways developers achieve this is through redundancy; parallel systems observe the environment and decide what to do in critical situations.

A truck in front loses its load. An unloaded pallet suddenly falls onto the road and blocks the lane. What causes a moment of shock for a human driver today will be mastered with ease by the highly automated vehicles of the future. The reason is that it works with three parallel systems: The main planner handles normal driving operations and acts in a comfort-oriented manner. It brakes and accelerates gently. System two, the fallback planner, simultaneously calculates a trajectory that quickly maneuvers the vehicle into a safe position if necessary. The third system, the supervisor, constantly checks whether a risk is posed by the main or the fallback path and selects the safest alternative in each case. That's why a pallet falling out of the truck unexpectedly would not be a problem for the highly automated vehicle. Because even in the unlikely event that the main planner overlooked the obstacle, the vehicle would safely take evasive action thanks to the fallback planner—or stop on the shoulder if it were not possible to drive around it.

Such a scenario could soon become reality. Porsche Engineering is working flat out to make highly automated driving (HAD) functions safe and reliable in this way. The crucial strategy along the way is called "decomposition." Instead of having the vehicle controlled by a single system, several planners as well as supervisors are applied as parallel instances. "Together, the systems achieve a much higher level of fail-safety than a single one," explains Jan Gutbrod, team leader for the development of driving assistance systems at Porsche Engineering.

"The biggest challenge is to master every last conceivable situation," says Albrecht Böttiger, head of the ADAS/HAD Project House at Porsche AG. In other words: The overall system must be able to cope with different vehicle types and driving styles, recognize road markings in different colors—even when they are weathered—and safely avoid known and unknown obstacles. This requires a coordinated interaction of the three subsystems, which must prove itself in tests and road trials.

Strict technical segregation of the systems

Parallel systems have been in use in aviation for a long time. Their safety, however, critically depends on the technical design. "To achieve true redundancy, it is important not to simply copy systems," stresses Andreas Nagler, Head of Systems Engineering and Architecture at CARIAD, the Volkswagen Group's software and technology company. What that means is that the instances must be technically isolated from each other, i.e. each must have its own hardware, software and data sources. This is the only way to minimize what are known as "common cause" errors, i.e. failures due to a shared cause.

To achieve this technical separation, the supervisor only uses object lists to make an image of the environment. These lists are generated by the vehicle sensors themselves. A radar sensor, for example, provides a list of all vehicles or objects that can be detected in the vicinity, including their direction of movement. The main and fallback planners, on the other hand, do not

"Together, the systems achieve much higher resilience than a single one."

Jan Gutbrod,
Team Leader in Driving Assistance Systems
Development at Porsche Engineering

"The biggest challenge is to master every last conceivable situation."

Albrecht Böttiger,
Head of the ADAS/HAD Project
House at Porsche AG

work with object lists, but with the raw data from the sensors, for example point clouds from laser scanners (LiDAR). In addition, some components access map data—which the supervisor does not.

Data processing also differs between systems. Main and fallback planners, for example, apply what is known as sensor data fusion: If only a single sensor reports an object in the space, while all other sensors explicitly do not, the algorithm of a sensor data fusion may decide to assess this signal as a false detection and to discard it. The supervisor, on the other hand, considers all sensors strictly separately. The different functional principles of the individual systems ensure that each can form its own picture of the situation. The combined strengths of the systems ensure a safe response.

Taking driving dynamics thresholds into account

The task of the supervisor is to check the paths calculated by the main and fallback planners for possible risks. To this purpose, it constantly generates forecasts with different time horizons. A so-called "ballistic approach" can be used for the immediately upcoming meters of travel: The supervisor assumes that the objects will basically maintain their direction of motion and velocity due to inertia and mass. A second forecast extends several seconds into the future. To predict traffic events so far ahead, highly complex software with thousands of parameters is required. Among other things, speed, road surface, weather conditions, historical motion profiles of surrounding road users and stationary cars are taken into account. This forecast forms the basis for the decision that now follows: "The supervisor puts the trajectories of the path planners into its future scenario," Gutbrod explains. If, for example, the so-called "sovereignty zone" around the vehicle, into which no object is allowed to enter, were to be violated on the planned course, the supervisor would veto this and initiate a path change. It "throws off a planner," as the developers put it.

In doing so, the planning software must be very sensitive. If the supervisor classifies the criticality of potential hazard scenarios too high too quickly, the vehicle can act too cautiously and thus also unsafely. Developers call this effect "too soon too safe." If this occurs, the brakes are applied much too early, for example. The supervisor must also recognize emergency situations in which a change of path would only cost unnecessary time and possibly have negative effects.

With all measures, it is also important to keep an eye on the specified dynamic driving limits. If—as in the highway example—an obstacle suddenly appears, the systems must react so quickly that there is still time to brake comfortably. In the future, paths could, for example, have the option of raising an "emergency flag," Gutbrod says: "In this case, planners could ask the supervisor to enable measures beyond the currently set limits."

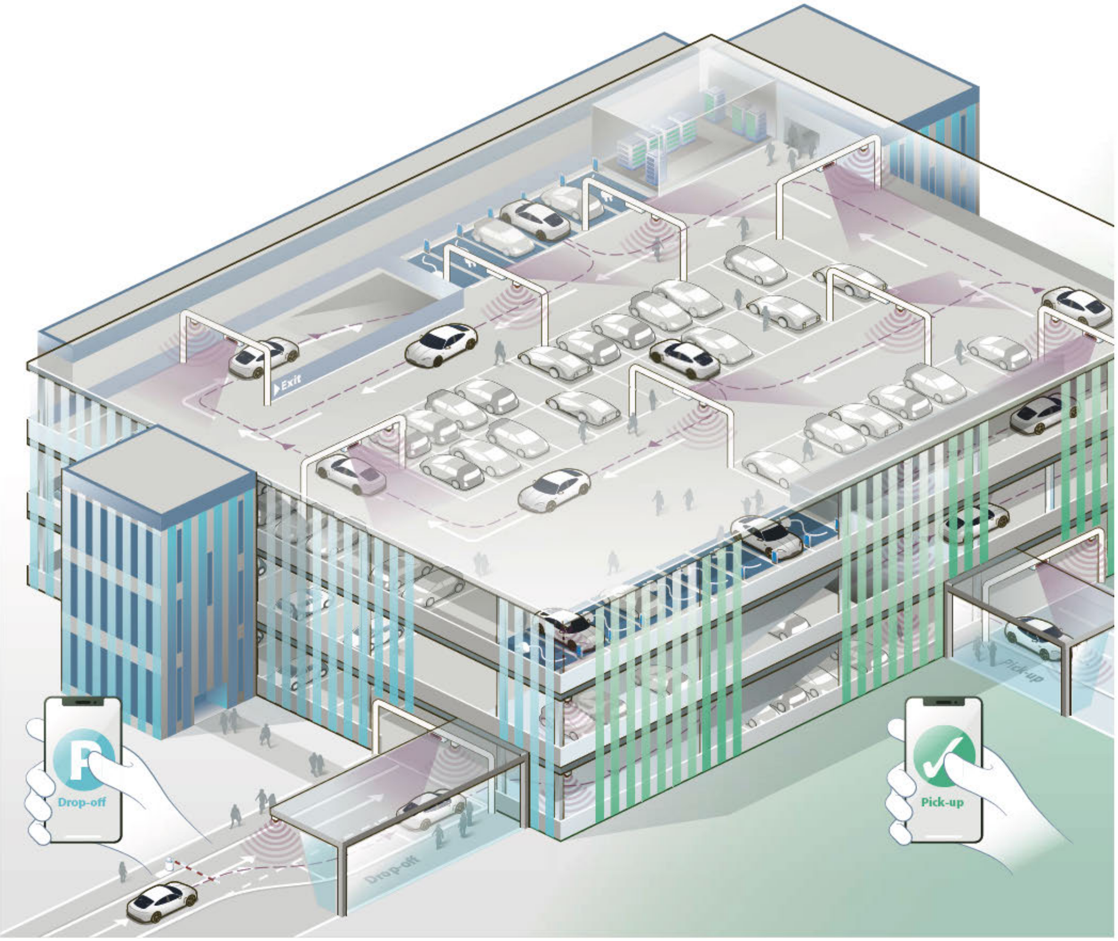
"To achieve true redundancy, it is important not to simply copy systems."

Andreas Nagler,
Head of Systems Engineering and
Architecture at CARIAD

The parking garage of the future: automated charging and parking

In the future, drivers will be able to park their vehicles at the parking garage and transfer control to the technology installed there via an app. The car will then drive remotely through the infrastructure to a charging station. Once the battery is charged, it drives on to a normal parking space. Via the app, the driver can check the current status and call the car back to pick it back up at the exit of the parking garage.

WiFi or 5G transmitters are installed throughout the parking garage for remote control of the vehicles. Infrastructure sensors such as cameras or laser scanners continuously observe the cars as they drive through the parking garage. In critical situations or when the radio connection is interrupted, the vehicle is stopped immediately.



Automated parking has to cope with unexpected situations of a completely different kind. CARIAD demonstrated what this new function will be able to do in the future at IAA MOBILITY last September: The driver of a Porsche Cayenne E-Hybrid dropped off their SUV in a special transition zone in the parking garage and issued the command to park via smartphone. The Cayenne then started moving automatically towards the parking space.

If the driver wishes, the car will first drive to a charging station, where a robotic arm with a charging plug will automatically dock. Then it will automatically move on to the actual parking space. If the driver needs the car again, they can call it back to the transfer zone via the app. The advantages for the driver: The time-consuming search for a space and maneuvering are eliminated, and they can also use the time for recharging.

In principle, automated parking can be implemented in two ways: Either the vehicle steers itself to the parking space or the surrounding infrastructure takes over control. In the latter case, the parking system would give the vehicle the path via radio signals and accelerate or decelerate it as appropriate. The CARIAD demonstration at IAA MOBILITY took this approach. Which of the two approaches will prevail in automated parking in the long run remains to be seen. "Control via

Cayenne E-Hybrid

Consumption (NEDC):
Fuel consumption (combined): 2.5–2.4 l/100 km
CO_2 emissions (combined) (model range): 58–56 g/km
Emissions standard: Euro 6d-ISC-FCM
Energy efficiency class: A+++
Power consumption (combined): 22.0–21.6 kWh/100 km

Consumption (WLTP):
Fuel consumption (weighted) (PHEV model line): 3.7 - 3.1 l/100 km
Power consumption (combined) (weighted) (model range): 26.5 – 25.1 kWh/100 km
CO_2 emissions (combined): 83 - 71 g/km

As of 11/2021

the infrastructure is easier to implement and secure," explains Böttiger. "On the other hand, vehicle-based automated parking allows more parking garages to be used." It is therefore conceivable that there will be a long-term trend towards complete autonomy, including in parking garages.

If, on the other hand, parking is controlled by the infrastructure, redundant systems must be used here—just as in the vehicle itself. The parking control system should therefore work with several parallel instances. In this way, emergency situations could be safely managed, for example pedestrians appearing suddenly in front of the car. This is to be expected, as autonomous and conventional vehicles will continue to share parking garages for some time to come.

Emergency stop concept for maximum safety

Ensuring safety is a task for everyone involved. "We will be closely examining the algorithms of the infrastructure operators," says Sebastian Reikowski, project manager for parking systems at Porsche Engineering. In order to implement externally controlled parking safely, however, extensive adjustments are also necessary in the vehicle. "All communication with the infrastructure via 5G or WiFi must be encrypted to prevent unauthorized access," explains Reikowski. If the radio connection breaks down, the vehicle stops automatically. An emergency stop concept is also needed: If the primary braking system fails, a secondary system would have to kick in and ensure a safe stop. One idea would be to use the recuperation power of the electric motor in conjunction with the parking brake and parking lock.

Further coordination work is needed for a common communication standard—only then could it be possible for vehicles from all manufacturers to use the parking service. A standard defining an interface between vehicles and infrastructure is already in the works (ISO 23374). "In addition, lawmakers still have to define at what point responsibility is transferred from the vehicle to the infrastructure – at what point the parking garage would have to be liable for damage, for example," adds Reikowski.

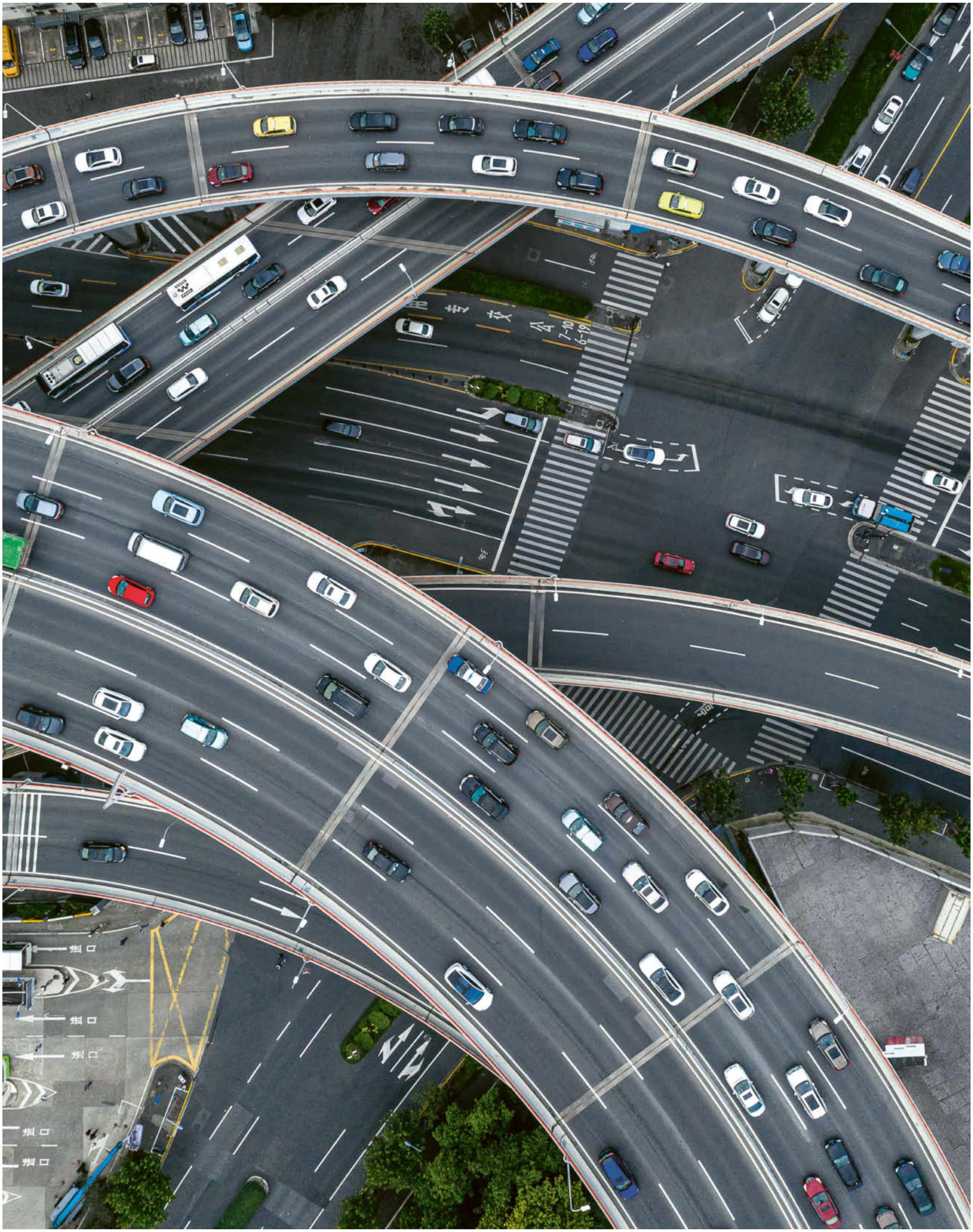
As with highly automated driving in general, continuous improvement will be essential. "A new mindset is needed: The software of vehicles will be continuously developed in the future—much like smartphones today," emphasizes system architect Nagler from CARIAD. The vision of this "data-driven development": Fleets of test vehicles will continuously collect data and transfer it to the cloud. There, the data will be used to improve HAD algorithms. This creates what is known as a "big data loop" (see Porsche Engineering Magazine 2/2021). A special algorithm in the test vehicle, called the Scene Selector, detects unusual situations or situations that have not yet occurred and transmits them to a central server. There, the scenes are used to further train the neural network of the cut-in detection system. "This continuous learning is the path to robust systems," Nagler emphasizes.

"All communication with the infrastructure via 5G or WiFi must be encrypted to prevent unauthorized access."

Sebastian Reikowski,
Project Manager for Parking Systems
at Porsche Engineering

IN BRIEF

Redundant, strictly separated systems make highly automated driving functions safe by enabling switching between different trajectories. In automated parking, the parking garage can take over control. But even in this case, emergency systems in the vehicle ensure safety in all situations.



Complex challenge: Highly automated driving functions must also be able to cope with difficult driving situations such as here in Shanghai—and thus must be validated with due rigor.

Teamwork: Experts such as Tille Karoline Rupp, Clara Marina Martinez, Pierpaolo Positano, and Zhengjun Xu (from left to right) collaborate at the Bietigheim-Bissingen, Nardò, and Shanghai sites to validate highly automated driving functions.

Validating complexity

Text: Richard Backhaus Photos: Yolanda vom Hagen, Annette Cardinale, Danilo Calogiuri

The closer highly automated driving functions come to series introduction, the more important system validation becomes. By closely linking digital and real tests, Porsche Engineering creates the basis for an efficient and reliable validation process—across national borders in its international network of development locations in places such as Bietigheim-Bissingen, Cluj-Napoca, Nardò, Ostrava, and Shanghai.

Switching on autopilot in stressful traffic situations, sitting back and relaxing in the driver's seat, or letting the assistance system take care of the tiresome task of finding a parking space and parking—highly automated driving functions will play a major role in further increasing comfort and safety in road traffic in the future. However, nothing must be left to chance in their development; after all, their job is to ensure a safe trip at all times and in all circumstances. "Validation methods that rely exclusively on real tests inevitably reach the limits of their potential in the area of assistance functions," says Frank Sayer, Senior Manager of the Virtual Vehicle Development discipline at Porsche Engineering. In purely mathematical terms, the test vehicles would have to travel hundreds of millions of kilometers on the road to prove the reliability of the automated functions. Today's standard test vehicle fleets would need several decades to do this—an impossible undertaking.

The same methodology in use worldwide

Together with colleagues from other departments, Sayer and his team have therefore developed a new validation methodology that can be applied with great flexibility. The concept is based on the intermeshing of virtual tests on the simulator and real checks on the road. Developers from the Porsche Engineering Virtual ADAS Testing Center (PEVATeC) platform and colleagues from other areas work together in teams—from validation to function release. "We apply the same methodology worldwide and can ensure a high validation standard," says Sayer. To make this possible, a central server structure was established through which the international project teams can exchange their results and determine the next processing steps.

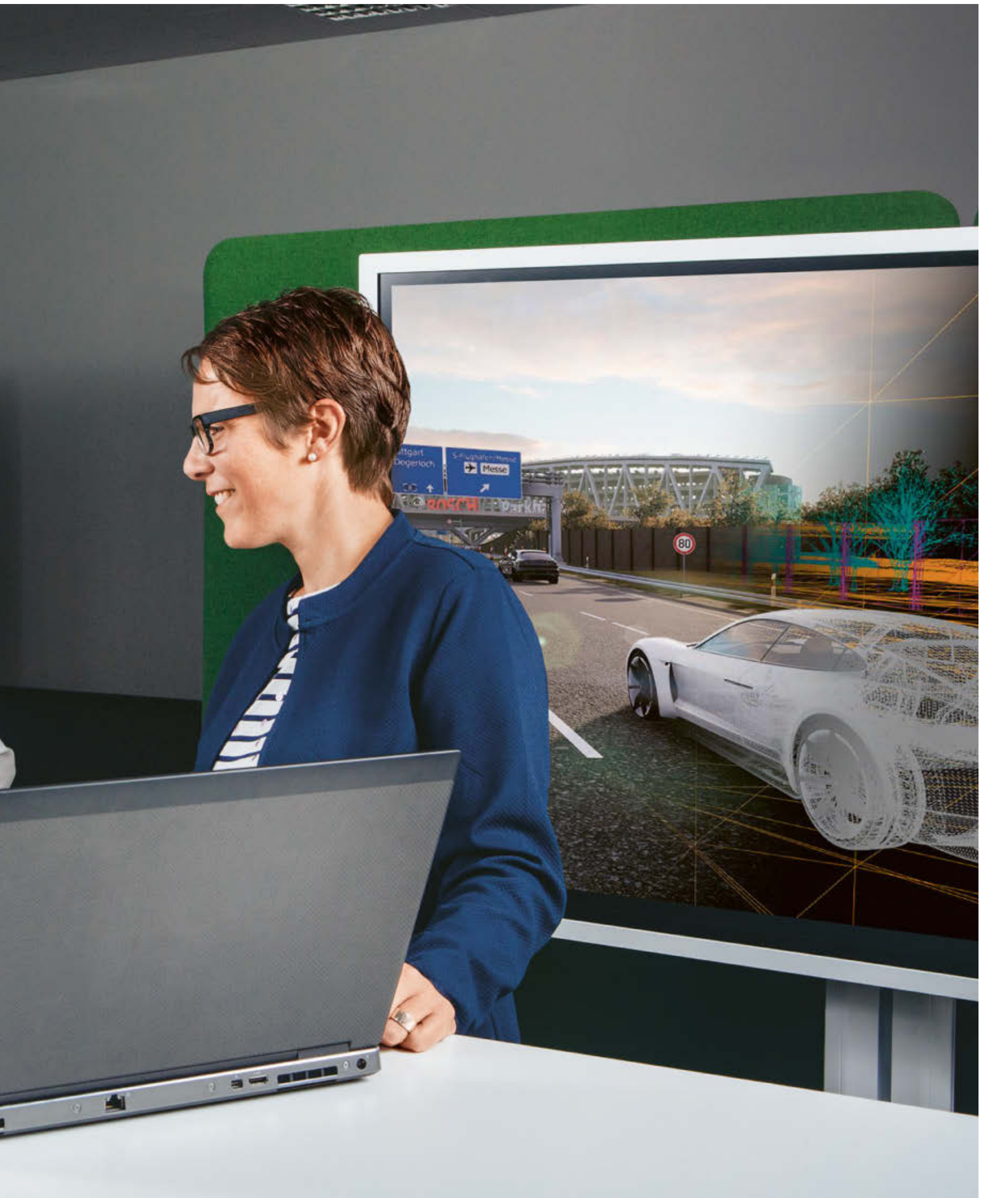
Validating a new driving function usually begins with an intensive exchange of information. "In these discussions, we work out which traffic situations and scenarios are particularly relevant for testing a new driving function," says Tille Karoline Rupp, development engineer at Porsche Engineering. "With a parking assistant, it's a question of maneuvering, whereas with

Bietigheim-Bissingen

The developers of the Porsche Engineering Virtual ADAS Testing Center (PEVATeC) platform and colleagues from other areas work together in teams. Their cooperation begins with the validation and ends with the release of the function. The results of the simulations are evaluated together with the specialist departments.

Experts for tests in the simulator: Clara Marina Martínez (left) and Tille Karoline Rupp create digital track and vehicle models for validation.

> **"We work with the same software platform for simulations as we do for test vehicles."**
>
> Clara Marina Martínez, Development Engineer at Porsche Engineering



automated driving on the highway, the focus is more on safe longitudinal and lateral steering in different speed ranges.”

Based on this information, she creates the digital route model in the computer on which the test simulation will be executed—a task that often takes several days. “The level of detail and thus the effort required for this ‘digital twin’ are highly dependent on the driving function that is to be tested, as well as on the respective phase in the development process,” explains Rupp. “Highly realistic models of streetscapes with dense street networks in inner cities are very time-consuming. In early phases of function development, sometimes simple scenes with a few objects are enough, scenes we can create as a generic model

“The level of detail of the digital twin is highly dependent on the driving function being tested.”

Tille Karoline Rupp,
Development Engineer at Porsche Engineering

from the toolbox.” To limit the effort required for future testing, all route models are cataloged and stored on the server so that the experts can reuse them later. The degree of automation in the creation process is also constantly on the rise, for example creating scenes using configurable algorithms or the use and combination of different map data.

Development engineer Clara Marina Martínez uses these datasets to test the new driving function using virtual vehicles via the PEVATeC platform. In the process, she runs various test scenarios—also defined in advance with the development experts—on the route models. For example, the simulations can be used to test traffic situations that cannot easily be replicated in real road traffic for safety reasons. Weather and lighting phenomena can also be generated and reproduced more easily via simulation. Recurring patterns include, for example, vehicles at intersections crossing in different sequences and with variable speeds, cars overtaking or cutting in, or pedestrians running into the street. The results are then evaluated together with the specialist department.

The next step is usually driving tests. In this stage, the updated software datasets from the simulation computer are transferred to the control units of the test vehicles in order to verify the calculation results

The development engineers, in close coordination with one another, manage simulation and methodology projects for virtual ADAS development at Porsche Engineering and within the VW Group. They also share responsibility for advancing the Porsche Engineering Virtual ADAS Testing Center (PEVATeC).

Clara Marina Martínez has a doctorate in Intelligent Hybrid Electric Vehicles and an M.Sc. in Automotive Mechatronics from Cranfield University.

Tille Karoline Rupp studied mathematics and physics at the University of Stuttgart and has a B.Sc. in electrical engineering from Baden-Württemberg Cooperative State University.

under real driving conditions. The driving tests for the validation of automated driving functions usually take place on a closed test track such as the Nardò Technical Center (NTC); for the validation of automated driving functions, test drives on public roads are the exception for safety reasons.

Here, too, validation methods continue to evolve. For example, engineers at the NTC are working on using driving robots in more and more situations during driving tests. "This enables great precision with regard to driving maneuvers, which can also be fully reproduced," explains Pierpaolo Positano, Senior Manager Engineering at the NTC. Even today, up to six automated vehicles can be used in test scenarios, with mechanical actuators taking over the operation of the accelerator, brake, and steering wheel. The robotic cars are controlled by local computers that create a synchronized multi-vehicle scenario. A digital copy of the entire test track in Nardò was created for this purpose: a detailed computer-based replica of the circuit that reflects all the properties of the real system is created as a digital twin.

Robots control real vehicles

"With the digital twin, the line between simulation and reality is becoming increasingly blurred," says Positano. "Very realistic simulations can be performed on the computer because, in addition to the course of the road, we take 100 percent of the properties such as characteristics of the individual road sections into account. With this basis, we can have real cars on the track controlled by robots. They follow the simulation results and repeat the tests to obtain additional measurements that are compared to the simulation data for final validation. With this continuous chain of simulation and testing, we have developed a procedure in which both parts validate each other. This significantly increases the robustness of the results," says Positano.

New questions often arise from the driving tests at the NTC or on other test tracks, such as the effects of rain and snow on the driving function. The simulations are then adjusted and rerun. Their results are then transferred back to the test vehicle. "We work with the same software platform for simulations as for the test vehicles, so our results can be transferred 1:1 to reality and the vehicle systems can be brought up to our software level quickly and easily," says Martínez. In an iterative collaboration between the simulation and testing departments, the team works through all the validation points until the new highly automated driving function has been validated optimally.

Nardò

The Nardò Technical Center (NTC) is where the real driving tests take place. Robots are increasingly used to control the vehicle to make the results reproducible. In addition, there is a digital twin of the test track that faithfully reflects all the properties of the real system. The simulation and testing thus mutually validate each other.

"We apply the same methodology worldwide and can ensure a high validation standard."

Frank Sayer, Senior Manager Virtual Vehicle Development at Porsche Engineering

Pierpaolo Positano is the Senior Manager for Engineering at the NTC. His focus includes expanding the service portfolio, including for ADAS and highly automated driving functions. Positano holds a master's degree in Mechanical Engineering from Bari Polytechnic.

Digital twins: Two views of the handling track at the NTC, each with a photo above and the virtual image below.

"With the digital twin, the line between simulation and reality is becoming increasingly blurred."

Pierpaolo Positano,
Senior Manager Engineering at the NTC

The new validation methodology is also to be introduced at Porsche Engineering in China in the near future. Since the subsidiary was founded in 2014, the Shanghai location has been the interface to local companies and has been Porsche AG's strategic partner for the Chinese market. Porsche Engineering is currently massively expanding its capacities in the area of highly automated driving in China, also in order to be able to take local conditions into account in optimal fashion during development—for example, the multi-level sections on which traffic is routed above

Building bridges between two worlds: Pierpaolo Positano combines real and virtual validation.

Cayenne E-Hybrid

Consumption (NEDC):
Fuel consumption (combined): 2.5–2.4 l/100 km
CO_2 emissions (combined) (model range): 58–56 g/km
Emissions standard: Euro 6d-ISC-FCM
Energy efficiency class: A+++
Power consumption (combined): 22.0–21.6 kWh/100 km

Consumption (WLTP):
Fuel consumption (weighted) (PHEV model range):
3.7 - 3.1 l/100 km
Power consumption (combined) (weighted)
(model range): 26.5 – 25.1 kWh/100 km
CO_2 emissions (combined): 83 - 71 g/km

As of 11/2021

Cayenne E-Hybrid Coupé

Consumption (NEDC):
Fuel consumption (combined): 2.6–2.5 l/100 km
CO_2 emissions (combined) (model range): 60–58 g/km
Emissions standard: Euro 6d-ISC-FCM
Energy efficiency class: A+++
Power consumption (combined): 22.4–22.0 kWh/100 km

Consumption (WLTP):
Consumption (weighted) (PHEV model range):
3.7 - 3.2 l/100 km
Power consumption (combined) (weighted)
(model range): 26.5 - 25.4 kWh/100 km
CO_2 emissions (combined): 85 - 73 g/km

As of 11/2021

Cayenne Turbo S E-Hybrid

Consumption (NEDC):
Fuel consumption (combined): 3.3–3.2 l/100 km
CO_2 emissions (combined) (model range): 75–72 g/km
Emissions standard: Euro 6d-ISC-FCM
Energy efficiency class: A+++
Power consumption (combined): 23.2–22.8 kWh/100 km

Consumption (WLTP):
Consumption (weighted) (PHEV model range):
4.0 - 3.8 l/100 km
Power consumption (combined) (weighted)
(model range): 25.9 - 25.3 kWh/100 km
CO_2 emissions (combined): 92 - 86 g/km

As of 11/2021

Cayenne Turbo S E-Hybrid Coupé

Consumption (NEDC):
Fuel consumption (combined): 3.3–3.2 l/100 km
CO_2 emissions (combined) (model range): 76–73 g/km
Emissions standard: Euro 6d-ISC-FCM
Energy efficiency class: A+++
Power consumption (combined): 23.5–23.0 kWh/100 km

Consumption (WLTP):
Consumption (weighted) (PHEV model range):
4.1 - 3.8 l/100 km
Power consumption (combined) (weighted)
(model range): 25.9 - 25.4 kWh/100 km
CO_2 emissions (combined): 92 - 87 g/km

As of 11/2021

Zhengjun Xu is Senior Manager, Software Development (HAD and ADAS) at Porsche Engineering China in Shanghai. He holds a master's degree in computer science from Jilin University in Changchun. The picture was taken at the Intelligent Connected Vehicle Test Road in Shanghai.

"China-specific requirements call for extensive local research and development expertise."

Zhengjun Xu, Senior Manager, Software Development (HAD and ADAS) at Porsche Engineering China

Connectivity: Radio modules and LiDAR sensors are used at the Intelligent Connected Vehicle Test Road in Shanghai.

rather than alongside each other for reasons of space. "If the driving function is not designed with this in mind, ADAS malfunctions may occur because there is no elevation model and no sufficient simulation test," says Zhengjun Xu, Senior Manager, Software Development (HAD and ADAS) at Porsche Engineering China. The driving style on China's roads also differs in some respects from Europe. For example, frequent lane changes and lane changes with minimal gaps make the transition between a normal situation and a safety-critical situation much more sudden. A different tuning of the vehicle sensor system is therefore required. "The importance of highly automated driving has been growing in China in recent years," says Zhengjun Xu. "That's because many drivers value convenience features like automated highway driving and automated valet parking. In addition, automated and autonomous driving are key technologies for the future automotive industry, so the Chinese government has issued numerous policies and regulations to guide and accelerate the development of this technology."

Test area for connected vehicles

An area of around 30 square kilometers has been designated on the outskirts of Shanghai for tests under real conditions in public road traffic. A modern 5G mobile network will enable new approaches to data exchange between vehicles and infrastructure to be developed and tested there. "All of these China-specific requirements call for extensive local research and development expertise. The simulation must also be carried out in China," says Zhengjun Xu. "It's a big challenge to simulate so many complex scenarios that are specific to China. We believe that the PEVATeC platform will bring great benefits to the efficiency and quality of China's ADAS and highly automated driving development in the future."

Porsche Engineering is also currently setting up a modern private 5G mobile network in Nardò, which will enable real-time data transmission between the vehicles and stationary computers, for example. "This will create the basis for future test concepts in which we want to perform tests, including the adjustment of test parameters, in a fully automated manner," Positano explains. "The robot-controlled vehicle sends all measurement data to a stationary computer, where it is evaluated and processed. If the results show that parameter changes make sense, they can be transferred to the car in real time so that the effects can then be analyzed while the test is still ongoing."

Shanghai

Porsche Engineering is currently massively expanding its capacities in the field of highly automated driving in China in order to take local conditions optimally into account during development. In addition to real tests, virtual methods will also play an important role there in the future.

IN BRIEF

Porsche Engineering validates highly automated driving functions with a combination of virtual and real driving tests. Teams at the locations in Germany, Italy, and China work closely together. This is the only way to ensure that the new driving functions are as reliable as they are efficient and that country-specific features can be taken into account.

Dynamic development

Text: Constantin Gillies

In the dynamic environment of automated driving functions, fast and efficient development and testing of new functions is more important than ever. To this end, the developers at Porsche Engineering now use the development and collaboration platform Jupiter. This platform makes it possible to develop new functions across locations and to implement practical testing with three test vehicles, making the functions tangible for customers.

Strong dynamics: The atmosphere of the planet Jupiter is characterized by powerful storms. The platform that bears the planet's name accelerates work in the dynamic environment of automated driving functions.

At Porsche Engineering, engineers and software developers around the world work on the latest technologies for the future. One of the most important fields is automated driving. In order to pool knowledge and exploit synergies, the company has created a digital development and collaboration platform: Jupiter (Joint User Personalized Integrated Testing and Engineering Resource). It accelerates development work in two ways. First, Jupiter offers ready-made software modules that can be used to implement ideas for automated driving quickly. Second, the platform makes it easier to distribute development work among several teams—even across international boundaries. "Particularly with this highly complex topic, this is a key to success," says Dr. Arathi Pai, Project Manager Jupiter at Porsche Engineering.

Together with her colleague Marcel Pelzer, she launched the Jupiter project in November 2019. Their aim is to bring together all innovations for automated driving. "The experts at Porsche Engineering do their pioneering work in this field at many locations," explains Co-Project Manager Pelzer. "We pushed the platform idea in order to make it even easier to use the tools and the developed functionalities in different projects."

In addition to the software side, Jupiter also has a practical side: Three Porsche Cayenne test vehicles equipped with additional sensor technology are available at the Bietigheim-Bissingen, Cluj-Napoca, and Prague sites to immediately test new functions and algorithms on the test track. This combination should greatly accelerate the developers' work in the future. With the help of Jupiter, they want to transform new ideas more quickly into a so-called Minimum Viable Product (MVP), i.e. into a first functional version of the new solution. It could then be immediately tested and refined on the test track. It would even be conceivable for a customer to use Jupiter to test their own idea.

"Cross-national cooperation is key to success when it comes to the highly complex topic of HAD."

Dr. Arathi Pai,
Project Manager Jupiter at
Porsche Engineering

The goal is to establish proof of concept in a short period of time—proof that an idea can work and perhaps be further developed to production readiness in the next step. "The developers at the various locations should play with the functionalities," says Pai. The aim, she said, is not only to make automated driving reliable and safe, but also to develop further functions. "Things we haven't thought of before," Pai says.

Open programming framework

To make it easier to transfer the new solutions from one project to another in the future, Jupiter is based on an open programming framework: the Robot Operating System (ROS). This open source solution is widely used and supported by a large community, so solutions can be found quickly when problems arise. In addition, ROS provides many ready-made interfaces, for example for cameras. Sensors that support ROS can often be put into operation on a test vehicle in less than an hour.

The core of Jupiter is a kind of digital toolbox. The platform contains ready-made software modules called ROS nodes that cover all the functions of an automated vehicle. One node, for example, handles the analysis of data coming from cameras and other sensors. Another node determines the vehicle's position in space. Another makes decisions such as changing lanes.

Artificial intelligence (AI) is used in many of these software modules, for example in the node for what is known as instance segmentation. It has the task of recognizing objects in the environment and classifying them correctly. To do this, an AI processes the images from the on-board cameras and surrounds the objects found with a border called a "bounding box." In a second step, the road users are assigned to a group, such as "pedestrian," "car" or "truck."

Perfected nodes for functions

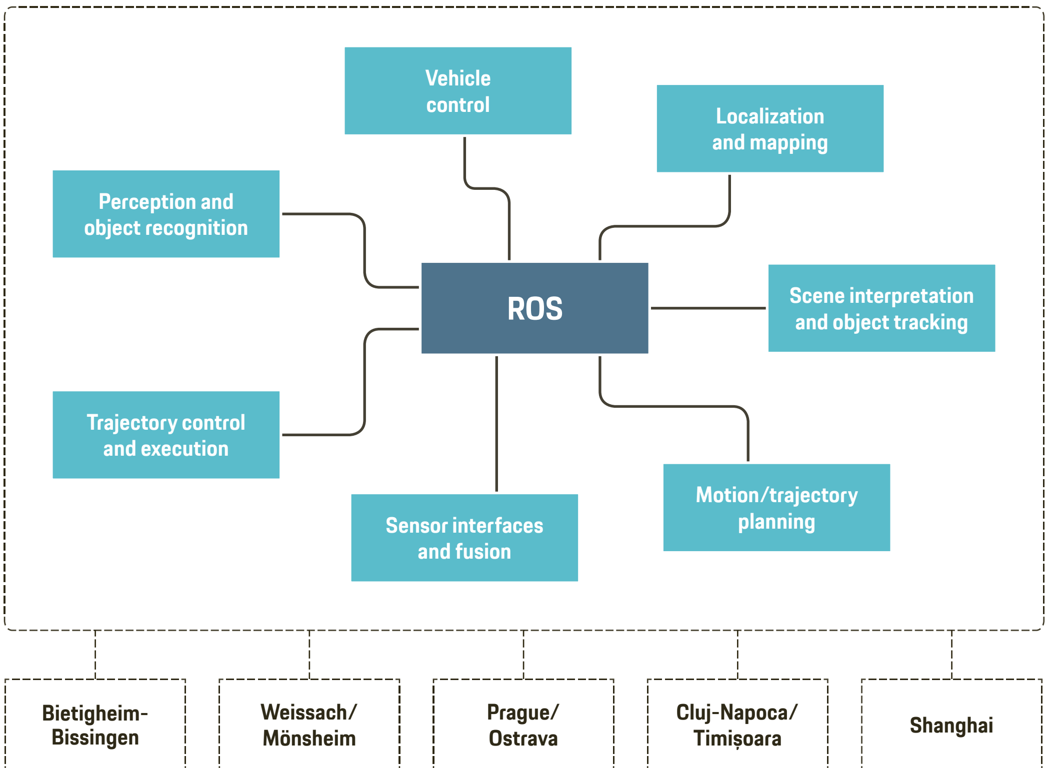
This classification is one of the major challenges in automated driving, because even the smallest details can lead to misjudgments. A bicycle on a trunk rack, for example, could be misinterpreted by an immature algorithm as a moving bike—which would cause the automated vehicle to brake. In the future, Jupiter will provide developers with perfected ROS nodes for instance segmentation and other functions.

Especially in automated driving, software is only one side of the coin. The quality of a new idea only becomes apparent in real-world operation with the three test vehicles. In addition to the standard sensor technology, they are equipped with a laser scanner (LiDAR, light detection and ranging) at the front and rear, for example. These sensors record 240,000 measuring points every second and can locate objects at a distance of up to 250 meters to an accuracy of one centimeter. A stereo camera is added to the LiDAR in the test vehicles, as optical systems are currently still superior to laser scanners in the detection of objects.

One advantage of the additional sensor technology: The developers can access their raw data. "This work at the hardware level is important because it allows us to proceed more independently of the series solution that has already been implemented," explains Pelzer. In addition to the advanced sensor technology, the test vehicles also have high-performance computers

Open platform

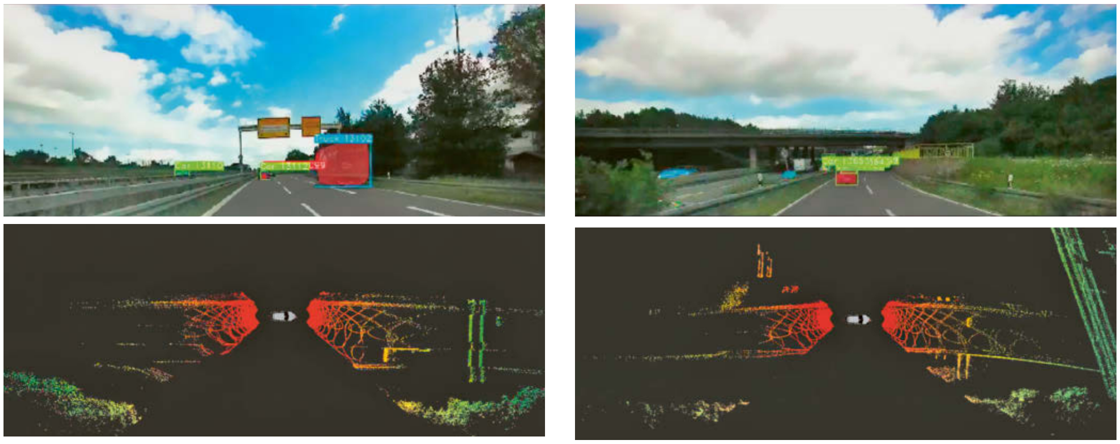
Jupiter is based on the **Robot Operating System** (ROS). It is widely used and supported by a large community. Ready-made software modules called ROS nodes cover all functions of an automated vehicle, for example the evaluation of camera data. Different locations can access the common Jupiter platform. New functions and algorithms can be examined immediately with the help of the three test vehicles.



Ready for the practical test: In addition to the standard sensor technology, the three Jupiter test vehicles are equipped with a laser scanner at the front and rear. They are also equipped with a stereo camera and high-performance computers.

Sensor technology of the future

In addition to cameras, radar, and ultrasonic sensors, laser range finders will also play an important role in new automated driving functions. By reflecting off objects in the environment, they provide point clouds that can be used to locate objects to an accuracy of one centimeter.



“We pushed the platform idea in order to make it even easier to use the tools and the developed functionalities in different projects.”

Marcel Pelzer,
Co-Project Manager Jupiter
at Porsche Engineering

with many CPUs (conventional microprocessors) and GPUs (graphics processors) on board. The CPUs are responsible for communicating with the ROS nodes, while the GPUs can quickly train and evaluate the neural networks for automated driving. Accessing external computing power in the cloud is not possible for the time-critical applications.

With Jupiter, Porsche Engineering is already exploring new ideas such as personalized automated driving. The vision behind it is that in the future, the vehicle will adapt to the style of its driver. To make this possible, Adaptive Cruise Control (ACC), for example, would first observe what is happening on the road and then adopt the user’s habits. If the driver drives in a sporty manner, the algorithm would adapt to this behavior. If, on the other hand, the driver prefers a more relaxed driving style, the automatic distance control system would take this into account. To implement such a personal distance control system, the developers first have to collect data on different driving styles. To this end, test subjects were invited to drive a standardized test circuit through the city and on the highway. Sensors recorded six terabytes of data, which will later serve as learning material for the personalized proximity control system and future assistance systems.

It is only with a tool like Jupiter that he and his colleagues could carry out such a project efficiently, Pelzer emphasizes. This is because the study requires high-precision differential GPS data as well as bus signals and raw camera data. “If there were three separate data pipelines, the time synchronization would be very costly,” he explains. “Jupiter, on the other hand, can simultaneously log and store all data.” In this way, the platform is helping to make the self-driving car of tomorrow a little more human.

The digital hub is quickly taking shape: Around two years after the launch, basic nodes for recording all sensor data are available, and further functions have already been implemented in prototype form and are nearing completion. In August 2021, the three test vehicles were put into service, and further building blocks of the “OODA” architecture will be added in the course of the coming year. The acronym encompasses the functions Observe (processing of camera and LiDAR data), Orient (simultaneous position determination and mapping), Decide (trajectory planning), and Act (motion control).

The Jupiter project will never be completely finished, because the module library will continue to grow. But even the current status is sufficient for Jupiter to be used intensively—for example, for the further development of adaptive cruise control and cut-in detection. In this way, Porsche Engineering can make optimal use of its pool of expertise and qualify and develop new automated driving functions even faster than it does today.

Science vs. fiction

Text: Christian Buck   Contributor: Dr. Christian Koelen

Autonomous vehicles have been the secret stars of feature films for decades. We present five well-known examples and do a reality check: What has come true? And where did Hollywood get it completely wrong?

← *The Fifth Element*

By Luc Besson (1997)
Starring Bruce Willis, Milla Jovovich, Gary Oldman

In their quest to save the world from the persistent villain, the two heroes Leeloo (Milla Jovovich) and Korben Dallas (Bruce Willis) travel in such conveyances as a flying taxi that can also navigate through the futuristic metropolis on autopilot if necessary.

Fact check
Numerous companies around the world are already working on autonomous and electrically powered air taxis. The most commonly cited use scenario is flying between the center of a metropolis and its outlying airport or flying over traffic jams. The first providers aim to enter the market within the coming few years. Technically, autonomous flying taxis are certainly feasible.

→ *Knight Rider*

TV series (1982–1986)
Starring David Hasselhoff

Former police officer Michael Knight (David Hasselhoff) tracks down criminals in a high-tech car called K.I.T.T. (Knight Industries Two Thousand). It can drive autonomously, park automatically, and be summoned via a wristwatch.

Fact check

One of the latest developments in the field of highly automated driving is automated parking: The vehicle drives itself to a parking space and can later be ordered back to the driver (for instance via smartphone). Series introduction of such a function is imminent. This film vision is therefore absolutely realistic.

↑ *Blade Runner 2049*

By Denis Villeneuve (2017)
Starring Ryan Gosling, Harrison Ford

The sequel to Ridley Scott's science fiction classic revisits the theme of the difficult relationship between humans and "replicants," human-like androids who fight for their rights. In his pursuit of the daughter of a replicant and a human, the main protagonist, Officer K (Ryan Gosling), travels in a flying car that can take him to his destination on its own if necessary. There's always a drone on board that can use its sensors to explore the surroundings from the air.

Fact check
The combination of autonomous vehicles and drones could definitely be useful. For example, a map of the route ahead could be generated from a bird's-eye perspective, so the autopilot would always know exactly what to expect in the immediate future. Drones could also fly over parking lots and find free spaces for automated parking. There are plenty of ideas for the use of such advanced sensors, and technical implementation would be possible quickly.

↓ *Total Recall*

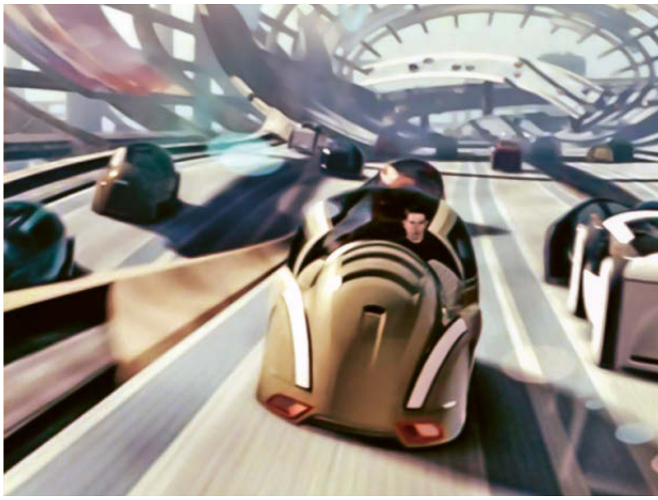
By Paul Verhoeven (1990)
Starring Arnold Schwarzenegger

Construction worker Douglas Quaid, played by Arnold Schwarzenegger, is on the run—in an automated cab ("Johnny Cab") driven by a robot named Johnny. The android responds to voice commands and can also carry on small talk.

Fact check
Autonomous driving fundamentally changes the relationship between passenger and vehicle, with the latter becoming more of an environment for working or relaxing. Small talk with one's car could therefore become part of everyday life in the future. However, there will probably not be a humanoid robot in the passenger compartment. The vehicle of the future is more likely to be something like a rolling assistance system.

↓ *Minority Report*

By Steven Spielberg (2002)
Starring Tom Cruise, Colin Farrell, Samantha Morton



Police officer John Anderton (Tom Cruise) is accused of committing a murder in the future, so he tries to escape in one of the automatic Maglev (magnetic levitation) vehicles. The authorities can interfere with the car's controls, however, so it becomes a trap for Anderton. He is not able to control the vehicle manually any longer.

Fact check
Safety plays a central role in autonomous driving. If the technology were to fail, external intervention would also be conceivable. In 2018, for example, California decided that cars without pedals and steering wheels must be able to be controlled remotely via a mobile network. An operator would take the wheel with the help of live camera images—but only in an emergency and always in compliance with data protection regulations.

Dr. Christian Koelen is Senior Manager of Driver Assistance Systems at Porsche Engineering. He rated the film utopias on autonomous driving.

Taking a quantum leap

Text: Christian Meier

More and more vehicle functions are based on artificial intelligence. However, conventional processors and even graphics chips are increasingly reaching their limits when it comes to calculations required for neural networks. Now an extremely large computer chip, optical computers, and quantum computers are set to remedy the situation.

Artificial intelligence (AI) is a key technology for the automotive industry—and fast hardware is correspondingly important for the complex back-end calculations involved. After all, it will only be possible to bring new functions into series production in the future with high-performance computers. "Autonomous driving is one of the most demanding AI applications of all," explains Dr. Joachim Schaper, Senior Manager AI and Big Data at Porsche Engineering. "The algorithms learn from a multitude of examples collected by test vehicles using cameras, radar, or other sensors in real traffic."

Conventional data centers are increasingly unable to cope with the growing demands. "It now takes days to train a single variant of a neural network," explains Schaper. So in his view, one thing is clear: Car manufacturers need new technologies for AI calculations that can help the algorithms learn much faster. To achieve this, as many vector-matrix multiplications as possible (see box on p. 35) must be executed in parallel in the complex deep neural networks (DNNs)—a task in which graphics processing units (GPUs) specialize. Without them, the amazing advances in AI in recent years would not have been possible.

50 times the size of a GPU

Graphics cards were not originally designed for AI use, however, but to process image data as efficiently as possible. They are increasingly stretched to the limit when it comes to training algorithms for autonomous driving. Hardware specialized in AI is therefore required for even faster calculations. The Californian

Giant chip: Cerebras' Wafer Scale Engine combines enormous computing power on a single integrated circuit with a side length of more than 20 centimeters.

Chip size

46,225 mm²

Number of computing cores

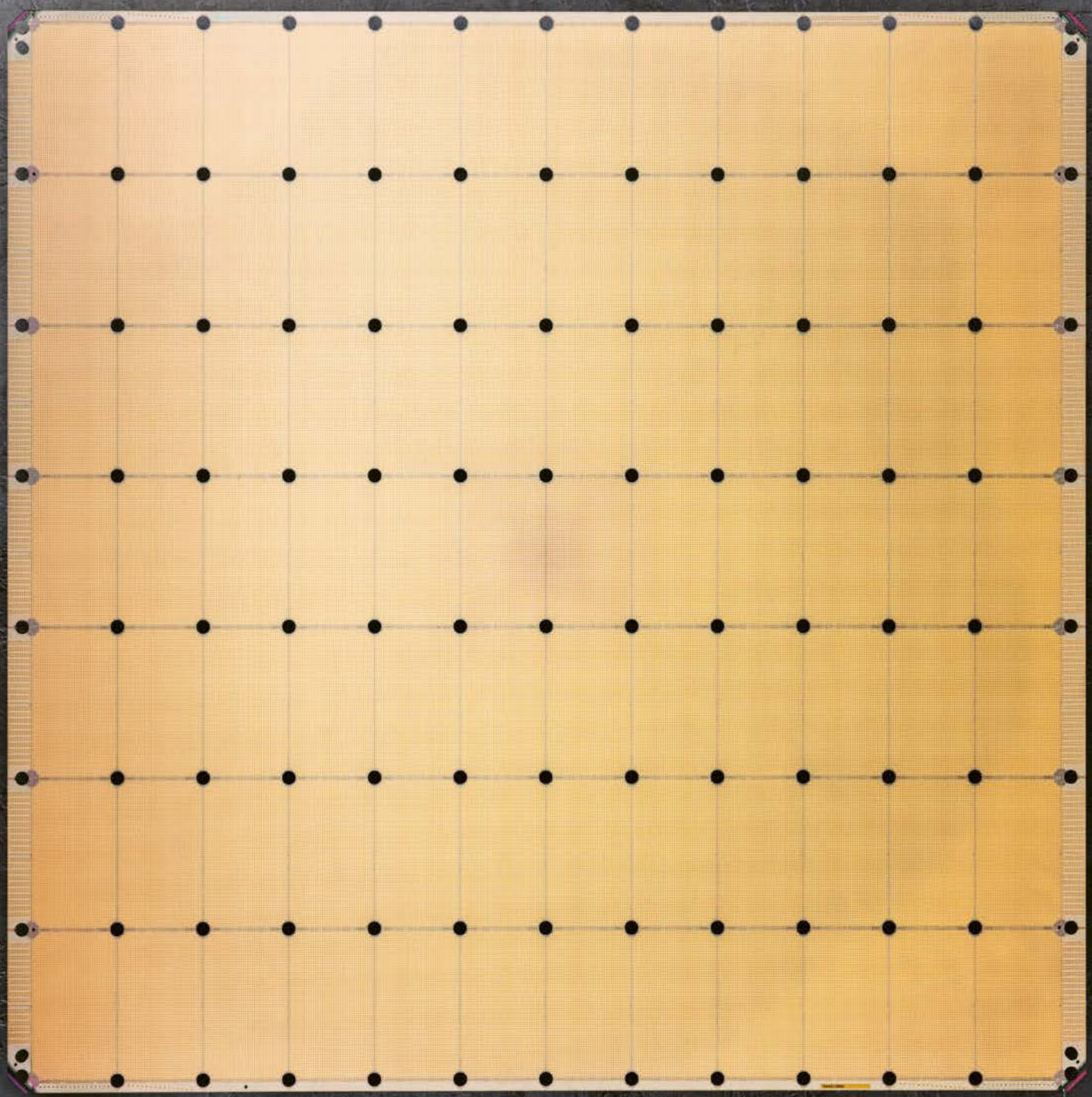
850,000

Number of transistors

2.6 trillion

Memory on the chip

40 gigabytes



Chip in classic format: The A100 GPU from NVIDIA is designed for use in data centers. It consists of 54.2 billion transistors and is 826 square millimeters in size. The chip has 6,192 CUDA and 432 Tensor cores and 40 megabytes of memory.

company Cerebras has presented a possible solution. Their Wafer Scale Engine (WSE) is optimally tailored to the requirements of neural networks by combining as much computing power as possible on one giant computer chip. It is more than 50 times the size of a normal graphics processor and offers space for 850,000 computing cores—over 100 times as many as on a current top GPU. In addition, Cerebras engineers have networked the computational cores together with high-bandwidth data lines. According to the manufacturer, the network on the Wafer Scale Engine transports 220 petabits per second. Cerebras has also widened the bottleneck within the GPUs: Data travels between memory and computing unit nearly 10,000 times faster than in high-performance GPUs—at 20 petabytes per second.

To save even more time, Cerebras mimics a trick of the brain. There, neurons work only when they get signals from other neurons. The many connections that are currently inactive do not need any resources. In DNNs, on the other hand, vector-matrix multiplication often involves multiplying by the number zero. This costs time unnecessarily. The Wafer Scale Engine therefore refrains from doing so. “All zeros are filtered out,” Cerebras writes in its white paper on the WSE. So the chip only performs operations that produce a non-zero result.

One drawback of the chip is its high electrical power requirement of 23 kW and requires water cooling. Cerebras has therefore developed its own server housing for use in data centers. The Wafer Scale Engine is already being tested in the data centers of some research institutes. AI expert Joachim Schaper believes the giant chip from California could also accelerate automotive development. “By using this chip, a week’s training could theoretically be reduced to just a few hours,” he estimates. “However, the technology has yet to prove that in practical tests.”

Light instead of electrons

As unusual as the new chip is, like its conventional predecessors it also works with conventional transistors. Companies like Boston-based Lightelligence and Lightmatter want to use the much faster medium of light for AI calculations instead of comparatively slow electronics, and are building optical chips to do so. DNNs could thus work “at least several hundred times faster than electronic ones,” write developers at Lightelligence.

To do this, Lightelligence and Lightmatter use the phenomenon of interference. When light waves amplify or cancel each other, they form a light-dark pattern. If you direct the interference in a certain way, the new pattern corresponds to the vector-matrix multiplication of the old pattern. So the light waves can “do math.” To make this practical, the Boston developers etched tiny light guides into a silicon chip. Like in a textile fabric, they cross each other several times. Interference takes place at the crossings. In between, tiny heating elements regulate the refractive index of the light guide, allowing the light waves to be shifted against each other. This makes it possible to control their interference and perform vector-matrix multiplications.

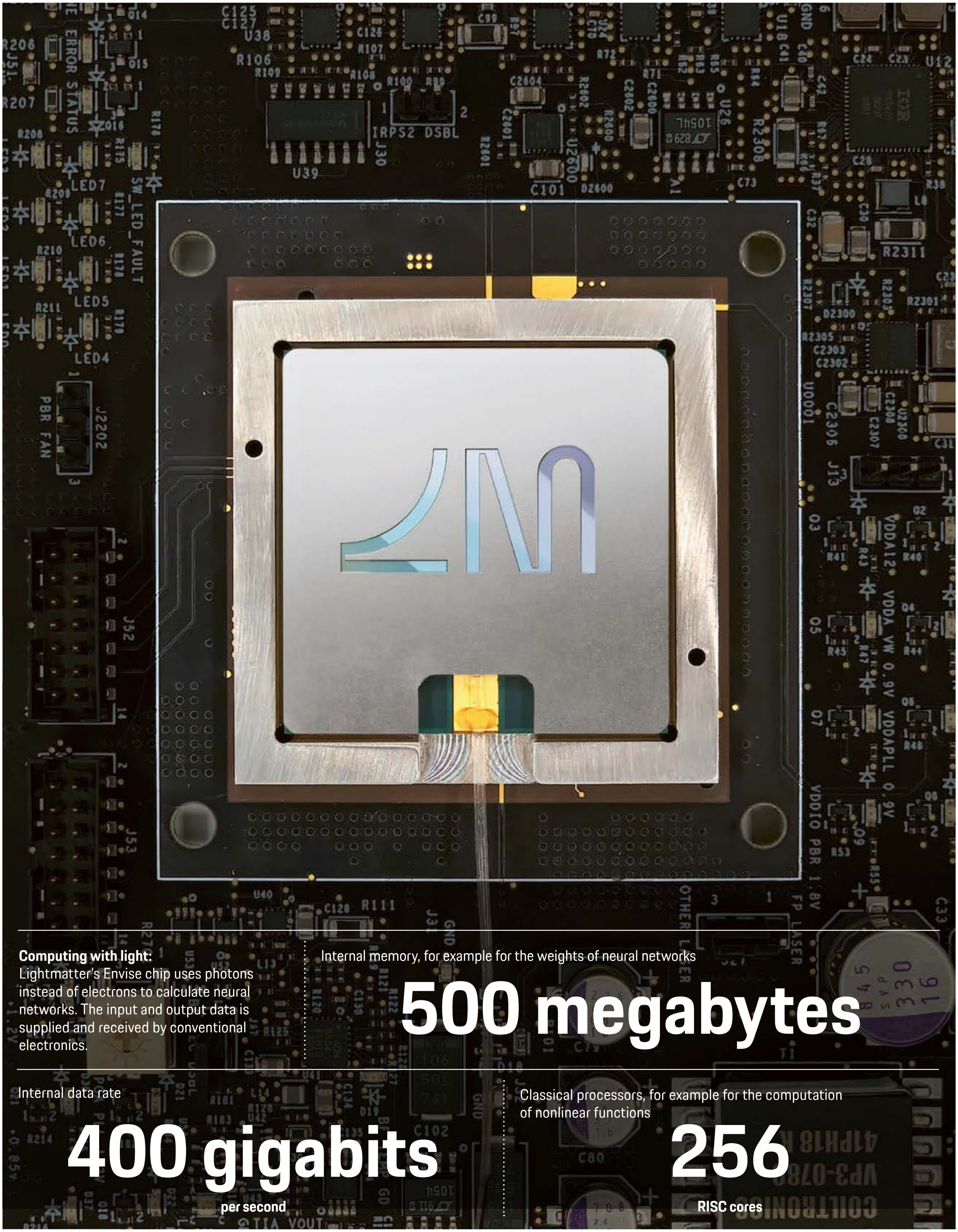
However, the Boston companies do not dispense with electronics altogether. They combine their light computers with conventional electronic components that store data and perform all calculations except vector-matrix multiplications. These include, for example, the nonlinear activation functions that modify the output values of each neuron before they move on to the next layer.

With the combination of optical and digital computing, DNNs can be computed extremely quickly. “Their main advantage is low latency,” explains Lindsey Hunt, a spokesperson for Lightelligence. For example, this allows the DNN to detect objects in images faster, such as pedestrians and e-scooter riders. In autonomous driving, this could lead to faster reactions in critical situations. “In addition, the optical system makes more decisions per watt of electrical energy,” Hunt said. That’s especially important as increasing computing power in vehicles increasingly comes at the expense of fuel economy and range.

The solutions from Lightmatter and Lightelligence can be inserted as modules into conventional computers to speed up AI computations—much like graphics cards. In principle, they could also be integrated into

“With the Wafer Scale Engine, a week of training could theoretically be reduced to just a few hours.”

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



Computing with light:
Lightmatter's Envise chip uses photons instead of electrons to calculate neural networks. The input and output data is supplied and received by conventional electronics.

Internal memory, for example for the weights of neural networks

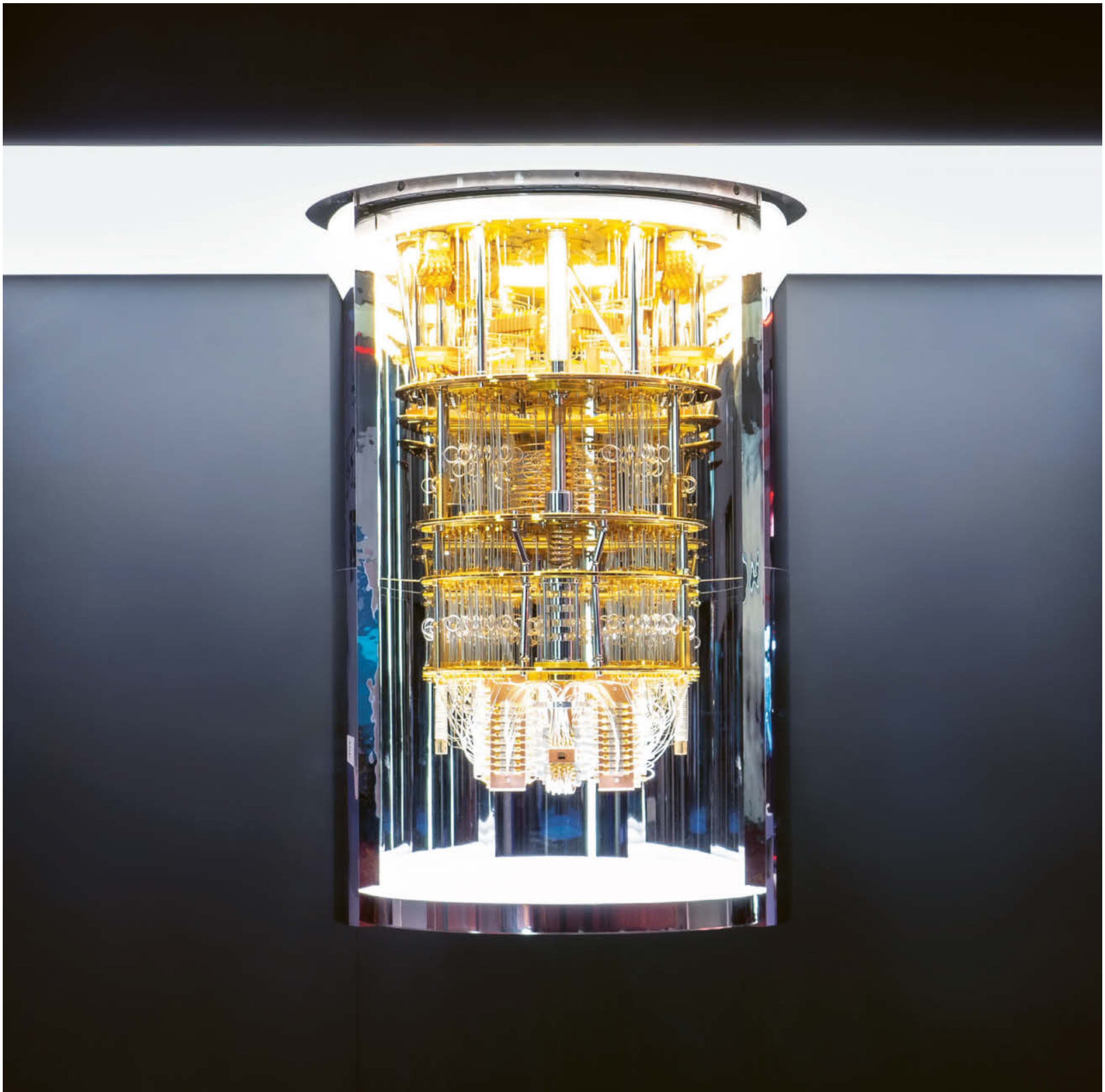
500 megabytes

Internal data rate

400 gigabits
per second

Classical processors, for example for the computation of nonlinear functions

256
RISC cores



World premiere:
The Q System One quantum computer from IBM was unveiled in 2019 and, according to the company, was the first of its kind intended for commercial use.

Fraunhofer-Gesellschaft's quantum computer

27 qubits

Most powerful IBM quantum computer

127 qubits

Users worldwide

370,000

Operating temperature

-273 degrees Celsius

“The more complicated the patterns, the more difficulty conventional computers have distinguishing classes.”

Heike Riel, Lead IBM Research Quantum Europe/Africa

vehicles, for example to implement autonomous driving functions. “Our technology is very well suited to serve as an inference engine for an autonomous car,” explains Lindsey Hunt. AI expert Schaper has a similar view: “If Lightelligence succeeds in building components suitable for automobiles, this could greatly accelerate the introduction of complex AI functions in vehicles.” The technology is now ready for the market: The company is planning its first pilot tests with customers in the year 2022.

The quantum computer as an AI turbo

Quantum computers are somewhat further away from practical application. They, too, will accelerate AI calculations because they can process vast amounts of data in parallel. To do this, they work with so-called “qubits.” Unlike the classical unit of information, the bit, a qubit can represent the two binary values 0 and 1 simultaneously. The two numbers coexist in a superposition state that is only possible in quantum mechanics.

Quantum computers could turbocharge artificial intelligence when if comes to classifying things, for example in traffic. There are many different categories of objects there, including bicycles, cars, pedestrians, signs, wet and dry roads. They differ in terms of many properties, which is why experts talk about “pattern recognition in higher-dimensional spaces.”

“The more complicated the patterns, the harder it is for conventional computers to distinguish classes,” explains Heike Riel, who heads IBM’s quantum research in Europe and Africa. That’s because with each dimension, it becomes more costly to calculate the similarity of two objects: How similar are an e-scooter rider and a rollator user trying to cross the street? Quantum computers can work efficiently in high-dimensional spaces compared to conventional computers. For certain problems, this property could be useful and result in some problems being solved faster with the help of quantum computers than with conventional high-performance computers.

IBM researchers have analyzed statistical models that can be trained for data classification. Initial results suggest that cleverly chosen quantum models work better than conventional methods for certain datasets. The quantum models are easier to train and appear to have greater capacity—allowing them to learn more complicated relationships.

Riel admits that while today’s quantum computers can be used to test these algorithms, they do not yet have an advantage over conventional computers. However, the development of quantum computers is progressing rapidly. Both the number of qubits and their quality are steadily increasing. Another important factor is speed, measured in Circuit Layer Operations per Second (CLOPS). This number denotes how many quantum circuits can run on the quantum computer per time. It is one of the three important performance criteria of a quantum computer: scalability, quality, and speed.

In the foreseeable future, it should be possible to demonstrate the superiority of quantum computers for certain applications—that is, that they solve problems faster, more efficiently, and more precisely than a conventional computer. But building a powerful, error-corrected, general-purpose quantum computer will still take some time. Experts estimate that it will take at least another ten years.

But the wait could be worth it. Like optical chips or new architectures for electronic computers, quantum computers could be the key to the mobility of the future.

Typical AI computation

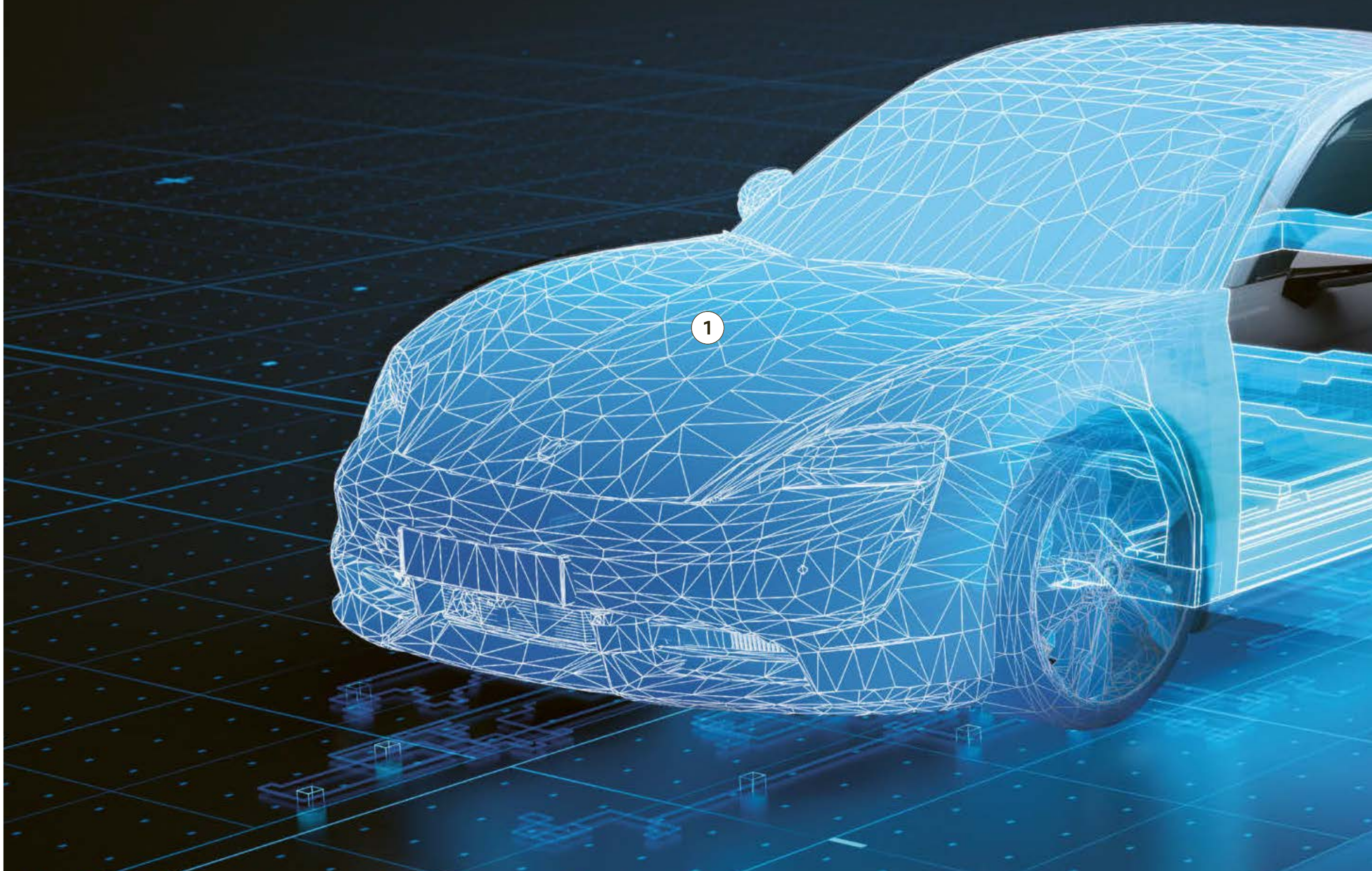
In deep neural networks, vector-matrix multiplications predominantly take place. Here, the input value of an artificial neuron of a layer is the sum of the output values of the neurons of the upstream layer, each multiplied by a factor. This corresponds exactly to multiplying a vector by a matrix to produce a new vector. These calculations are highly suitable for parallelization.

IN BRIEF

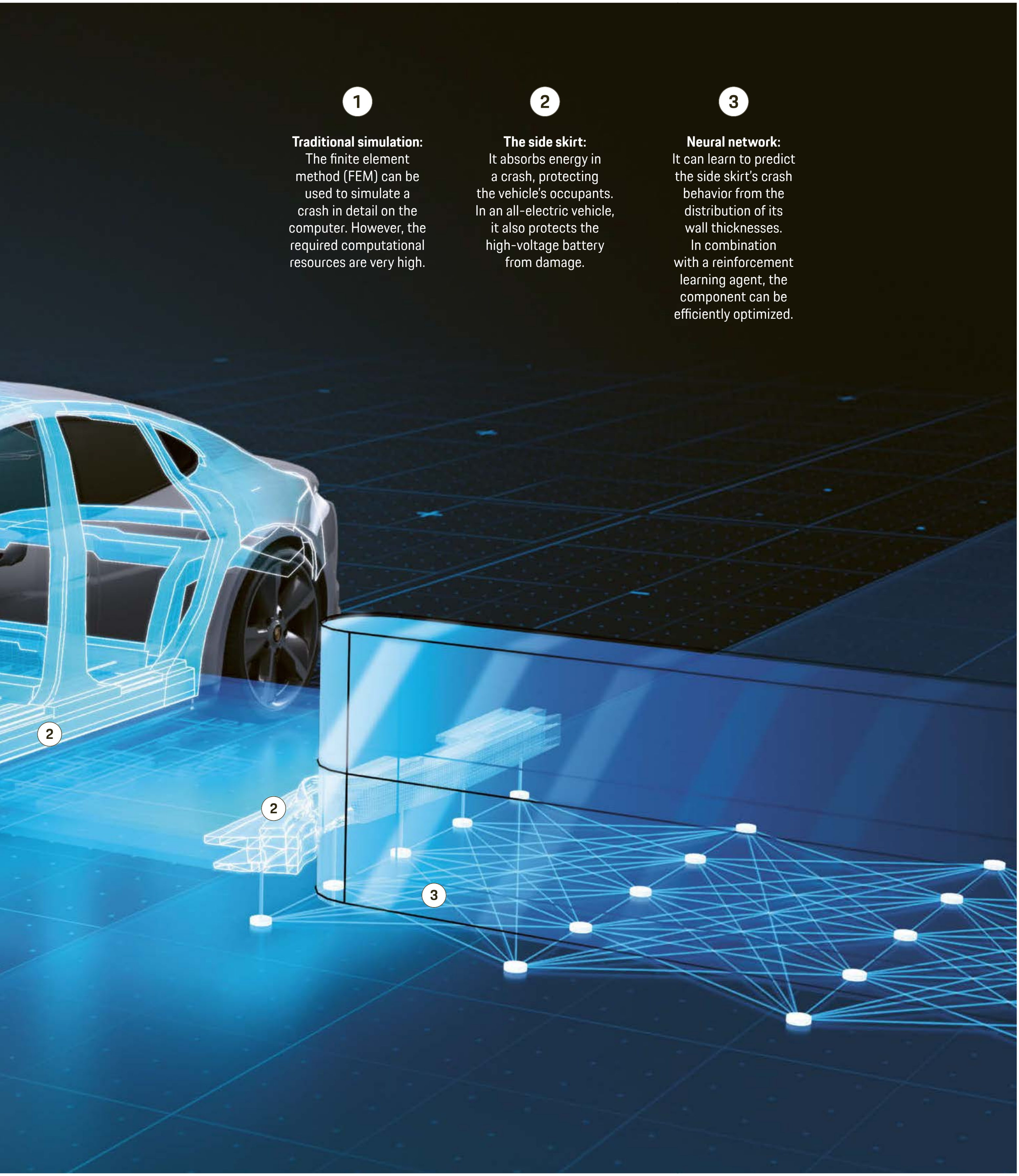
When it comes to AI calculations, not only conventional microprocessors, but also graphics chips, are now reaching their limits. Companies and researchers worldwide are therefore working on new solutions. Chips in wafer format and light computers are close to becoming reality. In a few years, these could be supplemented by quantum computers for particularly demanding calculations.

Doubly optimized

Text: Christian Buck   Illustrations: Jurij Chrubasik



Porsche Engineering has combined two artificial intelligence methods to efficiently optimize a side skirt: A reinforcement learning agent finds the best variant of the component—supported by a neural network that greatly accelerates the individual optimization loops. This process could also point the way forward in other areas of vehicle development.



Intelligent design: Instead of complex simulations (left), Porsche Engineering uses efficient AI methods (right) to find the optimal side skirt.

They are inconspicuous lifesavers: The two side skirts protect the occupants in case a vehicle leaves the road and has a side impact with a tree, for example. In all-electric vehicles, they have another important task—protecting the high-voltage battery, which is housed between the left and right side skirts and must not be excessively deformed in the event of an accident. Developers invest a corresponding amount of work in optimizing the crash behavior of the component.

They have a clear idea of the optimal crash behavior of a side skirt: The deformation (intrusion) should have as steady a progression as possible without too many local fluctuations. This relationship between external force during the crash and side-skirt intrusion can be represented by an ideal curve (see the figure on page 40). The actual behavior of the component should come as close as possible to this ideal curve.

During development, simulations are usually used for such optimizations, because prototypes for crash tests are expensive. In the widely used finite element method (FEM), the real vehicle or component is usually broken down into small squares ("elements") for crash simulations, the corners of which are called "nodes." The behavior in the event of a collision can be calculated from the reaction of the individual elements to external forces—and the more elements and nodes the FEM model contains, the more precisely it can be calculated. "However, higher accuracy is also reflected in greater computational effort," explains Johannes Pfahler, computational engineer at Porsche Engineering. "FEM simulations require high-performance computers, and for a complete vehicle model, a single crash calculation can take a day or more."

This was also true for the crash simulation of the side skirt in an all-electric vehicle. The component originated from a pre-development project at Porsche AG. To optimize the component, Porsche Engineering engineers were able to vary 14 wall thicknesses and compare the crash behavior of each variant with the ideal curve. If the computational engineers had used an FEM overall vehicle model with 9.6 million elements and 6.6 million nodes for this purpose, a computer with 128 microprocessor cores (CPUs) would have been busy for almost 20 hours—just to calculate the crash behavior of a single skirt variant. A simplified FEM partial model consisting of a side skirt, an underbody, and a battery construction (1.6 million elements and 1.9 million nodes) would still have occupied a computer with 64 CPUs for just over four hours per simulation. So a more efficient method was required to examine hundreds or thousands of skirt variants with different wall thicknesses with regard to their individual crash behavior.

A case for the RL agent

This is where Dr. Joachim Schaper, Senior Manager of AI and Big Data at Porsche Engineering, and the company's other AI experts came into play. Their idea: Combining the two AI methods of reinforcement learning (RL) and neural networks (NN), it should be possible to find the optimal skirt variant with a reasonable computational effort. In reinforcement learning, an algorithm (called an "agent") interacts with its environment and constantly learns through feedback—by being rewarded with bonus points for actions that lead to a good result and penalized with

9.6 million

elements are involved in the CAE complete vehicle model. One crash calculation takes 19.5 hours on a computer with 128 CPUs.

1.6 million

elements are involved in a simplified CAE model with the essential components. A crash calculation still takes 4.25 hours on a computer with 64 CPUs.

132,000

elements are involved in a reduced CAE model of the side skirt. A crash calculation now takes only about one hour—on a normal workstation with four CPUs. This model was used to generate the training and validation data for the neural network.

"We used simulation data to train the neural network to predict the crash behavior of the side skirt as an output using the wall thicknesses as input."

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

The objective: finding the optimal side skirt!

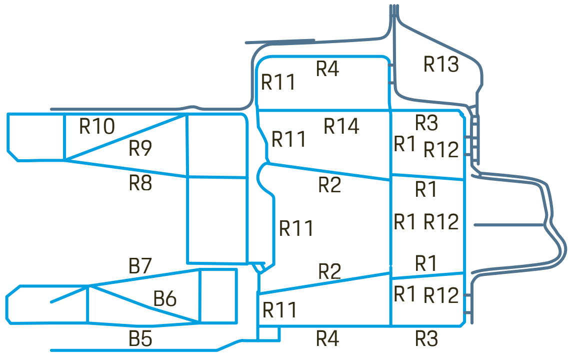
Safety-critical component

The side skirt to be optimized consists of two individual extruded aluminum profiles that are screwed together ("B" is screwed into "R"). The component weighs about 20 kg. Its construction is predetermined; only the wall thicknesses can still be varied within certain limits. This is precisely the task of the **reinforcement learning agent,** supported by a neural network.

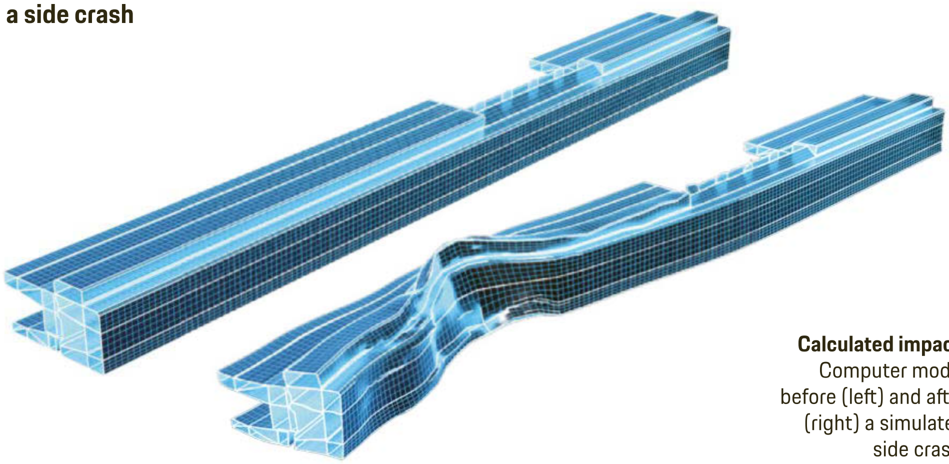
14

Wall thicknesses (right) determine how well the side skirt can protect the occupants and the high-voltage battery in a crash.

Cross-section of the side skirt



Behavior in a side crash



Calculated impact: Computer model before (left) and after (right) a simulated side crash.

Generation of training data

The **crash behavior** of the side skirt can be calculated with a computer model (left). A standard workstation with four CPUs needs about one hour for each design variant with 14 specific wall thicknesses. As input for a neural network, 548 simulations were carried out using the model, which corresponds to a simulation effort of 23 days. 300 of these simulations were to serve as training data for the neural network, and 248 were to be used for subsequent validation.

deductions for failures. Its goal in this case was to find the variant with the highest possible score over time. To do this, the RL agent had to get closer and closer to the ideal crash behavior of the side skirt by varying the 14 wall thicknesses.

How well it succeeded in doing this in each individual case could in principle be determined by an FEM-based simulation of the crash behavior of each proposed variant—if the computational effort and time required for this were not far too high. This is significantly reduced by the second AI method used: The feedback for the RL agent is not provided by a simulation, but by a neural network. "We previously used simulation data to train it to predict the crash behavior of the side skirt as an output using the wall thicknesses as input," explains Schaper. "This takes only seconds for each side skirt variant, as opposed to hours for a conventional simulation. Yet we don't have to make any sacrifices with regard to feedback accuracy with the RL agent."

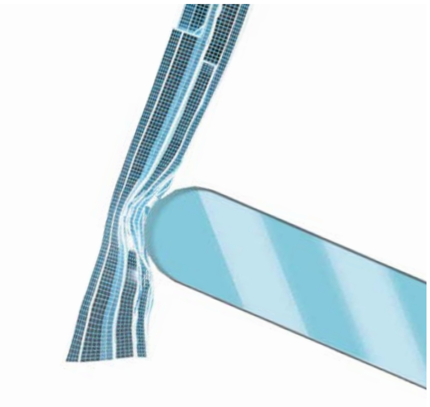
With this combination of the two AI methods, the skirt optimization could get underway. The 14 wall thicknesses for the first loop were not chosen at random, but came from Dr. Philipp Kellner, specialist in body predevelopment at Porsche AG. "As an expert, he knew from many years of experience what a good combi-

It takes

23

days to find the optimum side skirt using a normal workstation. By using several computers in parallel, the time was reduced to just eight days.

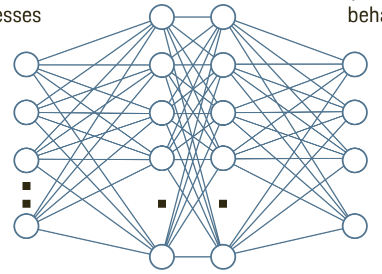
First optimization: Neural network replaces simulation



Training of the neural network

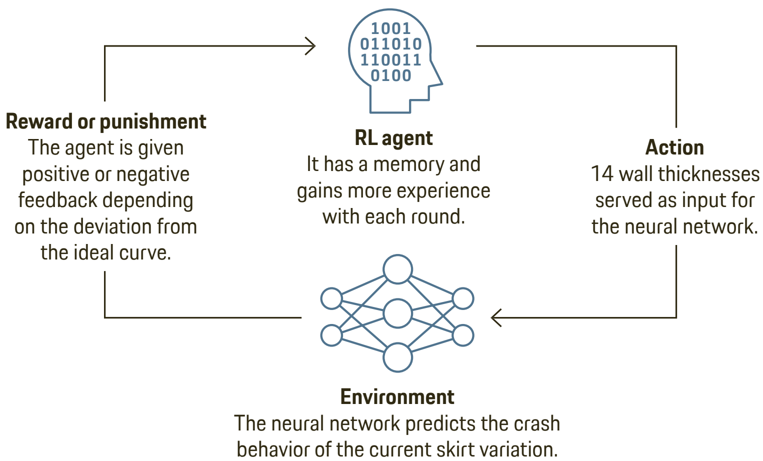
A **neural network** (right) learns using the **training data** (left) to predict the crash behavior of the skirt—as a substitute for a simulation. It has 14 inputs (wall thicknesses) and four outputs: the total mass and the energy at 40, 60, and 80 millimeters of intrusion. In between, there are two hidden layers. A total of 384 weights were trained. The crash behavior of each skirt variant can be calculated in **seconds** using the neural network.

Structure of the neural network

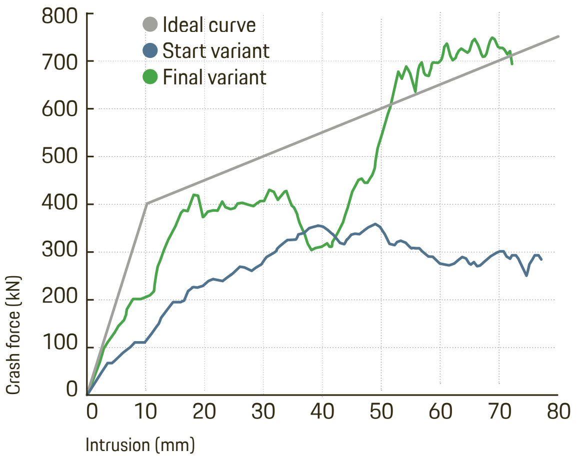


Second optimization: RL agent varies wall thicknesses

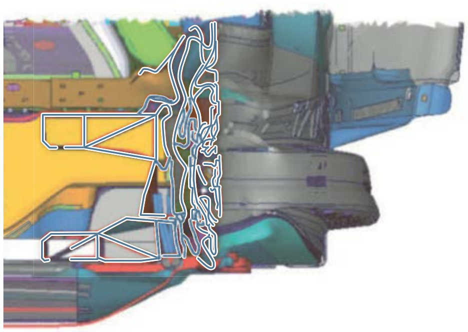
Optimization of the wall thicknesses



Close to the ideal curve



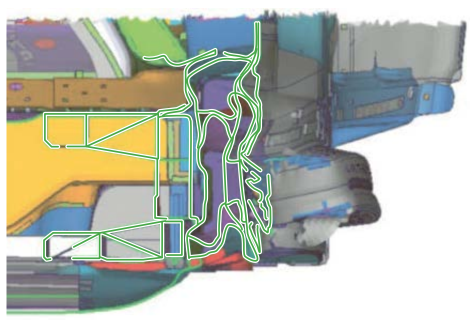
Starting point for the optimization



Task solved!

Starting from the **start variant** (left figure, blue curve above), after thousands of optimization runs, the RL agent has found a side skirt that, with its 14 wall thicknesses, comes close to the gray ideal curve (right figure, green curve above). This **final variant** shows a uniform deformation of the side skirt from the outer to the inner side as well as over the height of the component during a side crash.

Final variant after optimization



nation might be," says Pfahler. "So the reinforcement learning agent was well set up right from the start." The neural network then compared the crash behavior of this particular side skirt variant with the ideal progression and fed the deviation as feedback to the agent, which in turn delivered the next combination of 14 wall thicknesses to the neural network. This process was repeated several thousand times, and with each iteration the AI team of the RL agent and neural network came a little closer to its goal of finding the optimal side skirt.

This is also where the power of reinforcement learning became apparent. "We thought for a long time about which AI method might work best for this task," Schaper reports. "The advantage of reinforcement learning: The agent remembers the history of its attempts. So it knows what has worked well so far and what hasn't—an important prerequisite for developing a good strategy for the efficient optimization of the side skirt." His confidence in the RL approach proved justified: After several thousand iterations, the two AI methods produced a side-skirt variant that sufficiently matched the ideal curve (see the figure on page 40). The goal was achieved—in a fraction of the time that a conventional approach would have required.

Learning from experience

In total, the developers needed about 23 days of computing time to reach their goal. By far the greatest effort went into the 548 crash simulations used to train and validate the neural network. They were based on a further simplified FEM model of the side skirt, consisting of only about 132,000 elements and 129,000 nodes. Each crash could thus be calculated for each variant in one hour—on a normal workstation with four CPUs. "If we had searched for the optimal side skirt using traditional simulations among 548 variants, a high-performance computer would have been busy for 96 days," says Pfahler. "In addition, we might have missed the optimal wall thicknesses if we had looked for them in the wrong part of the parameter range—which would have entailed further costly simulations."

The optimization project started at the end of 2020 with an analysis of the current state of the art. By the first quarter of 2021, the training and validation dataset was already available for the neural network, which was trained in the second quarter. At the same time, the AI experts at Porsche Engineering developed the RL agent and then had it execute the side skirt optimization. They are currently working on using the successful pairing of the two AI processes for further optimizations. "For example, we want to find out whether the pre-trained RL agent needs to develop a completely new strategy for a different crash or component, or whether it can reuse the old one," says Pfahler.

"If we had searched using conventional simulations, a high-performance computer would have been busy for around 96 days."

Johannes Pfahler,
Computational Engineer at Porsche Engineering

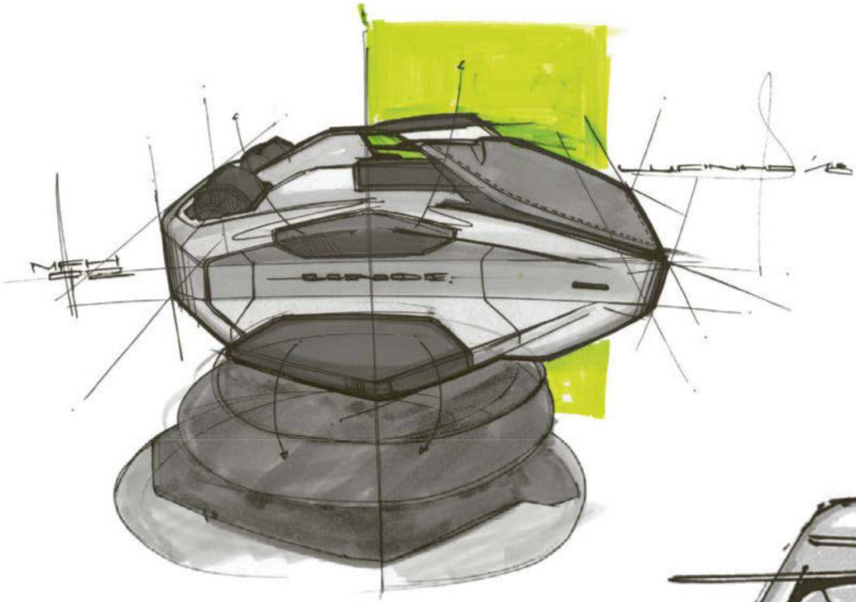
Aiming for more efficient implementation

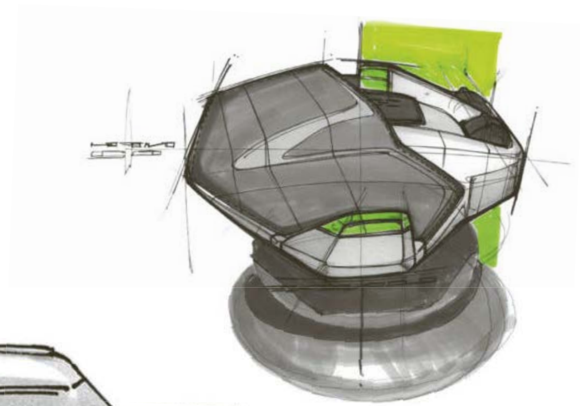
In the future, the RL agent will be used to find optimization potential for front and rear crashes. Schaper, Pfahler and their colleagues also want to investigate how the method can be implemented even more efficiently. "We trained the neural network for side-skirt optimization with 300 datasets, which allowed it to yield very precise results," Schaper reports. "That's an unusually large amount of data, though—usually only ten to 20 simulation results are available for training." The focus is now on asking questions like: Can the neural network still provide accurate information about crash behavior even with significantly less training data? Where is the ideal point of compromise between training effort and precision? What error rate of the neural network can be tolerated? "What is already certain is that we can use AI to optimize components," Pfahler says. "Now it's a matter of improving the process and integrating it into series development."

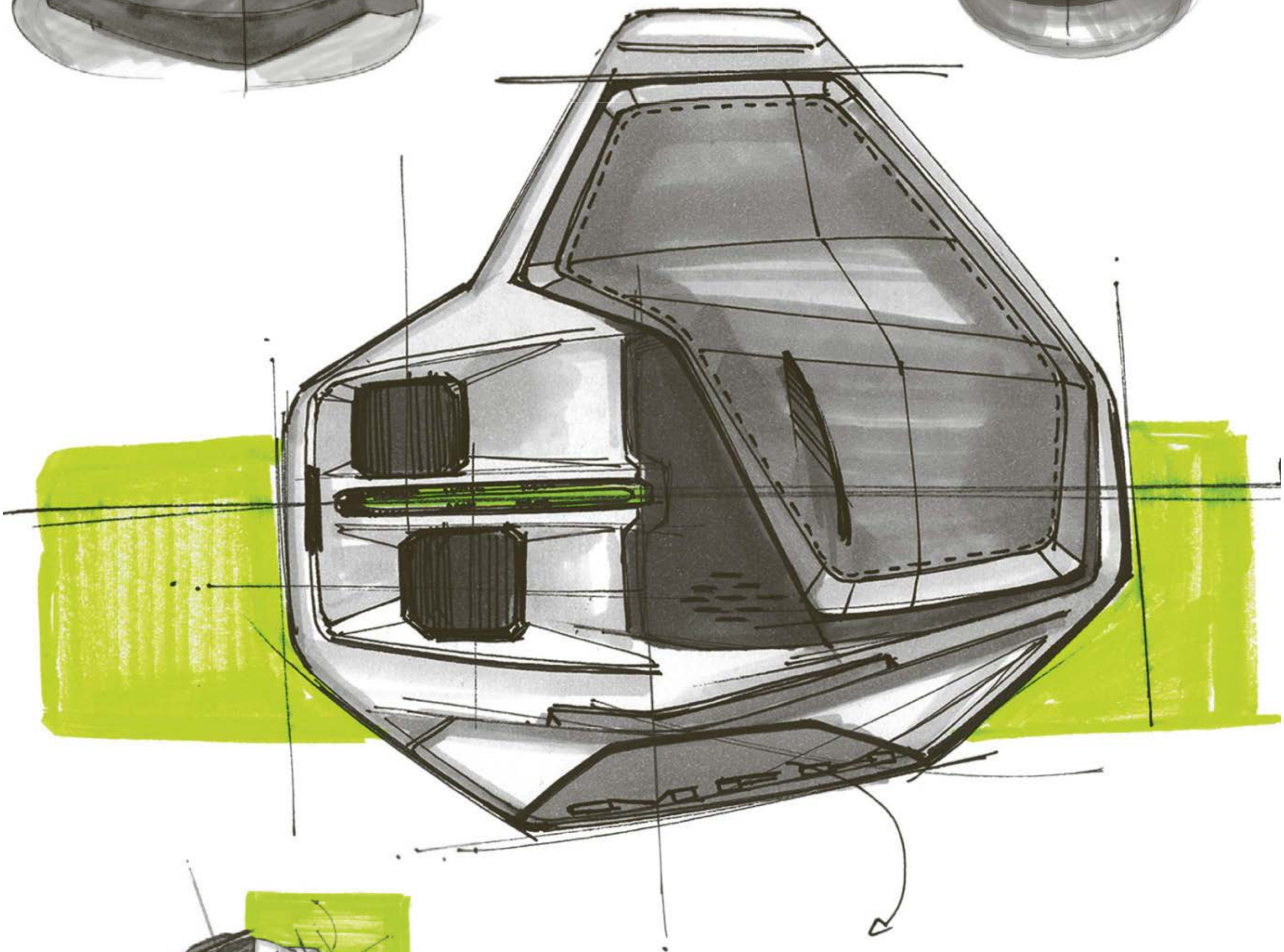
The AI experts at Porsche Engineering have already learned from the PERL project (Porsche Engineering Reinforcement Learning, see issue 1/2021) that the combination of reinforcement learning and neural networks can yield valuable insights: With RL, they succeeded in automatically finding an optimal application strategy for engines that can be used universally for models with different designs and displacements as well as with different turbocharging systems. "There are many parallels between PERL and the current project: In both cases, for example, it is a matter of finding the optimum constellation in a large search area," explains Schaper. "And it has been proven again: Reinforcement learning is the crème de la crème in terms of AI for optimization tasks."

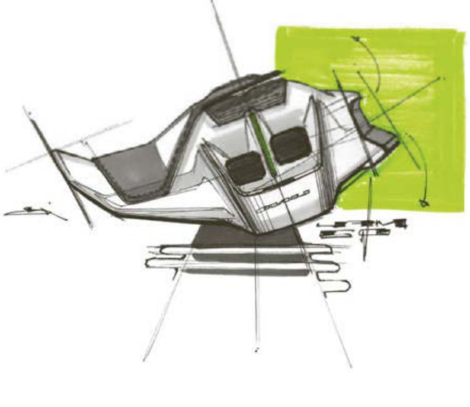
IN BRIEF

By combining the two AI methods of reinforcement learning and neural network, Porsche Engineering was able to optimize a side skirt very efficiently without the use of high-performance computers. Now the investigation will explore how the method itself can be further improved and in what other areas it could be used.









Ergonomic: The handrest of the multifunctional lever has a roughly 30-degree incline, which corresponds to a natural hand position.

All in one hand

Text: Jost Burger

Porsche Engineering has designed a new multifunctional lever for reach trucks for Linde Material Handling. The result is an innovative solution that perfectly combines functionality and ergonomic design.

You can see them in DIY stores, between high shelves in wholesale markets, and in the warehouses of large logistics companies or in the food industry: reach trucks. Their main task in the warehouse is replenishment. They are designed to maneuver in confined spaces while storing and retrieving large loads well over ten meters high in the racks. This is made possible by their compact design. Unlike with front-loaders, the operator of a reach truck sits at right angles to the direction of travel. Thanks to the compact design with a reach mast, the vehicle can even maneuver in aisles that are no more than three meters wide.

One task of the reach truck, for example, is to transfer pallets from an upper shelf level to a lower one. Once at the rack location, the driver extends the mast upwards and moves the forks along the load arms to the required pallet. In order to be able to load and unload the pallet quickly and safely, the forks can also be tilted backwards and forwards and moved sideways. In order to work quickly and safely, the driver ideally has the load in view without having to devote more attention than necessary to operating the reach truck.

Well over
10 meters
is how high a reach truck can lift heavy loads in a confined space.

Operating without repositioning

Improving the ergonomics of the trucks is therefore an ongoing development aim at Linde Material Handling (MH). The goal was to do just that for the reach trucks of the Linde R10 to R25 series, with a new control unit for controlling the mast functions. The goods handling

Evolution of ergonomics

During the project, designers approached the finished product in several steps.

❶ **Starting point:** This 3D printer model shows the approximate layout of the controls.

❷ **New elements:** The CAD graphic shows the winglet (top left) and rib (center).

❸ **Close to series production:** In this 3D model, the controls are in their final positions.

specialist brought Porsche Engineering on board as a partner for the design of the new multifunctional lever (MFL). “We wanted to develop an operating concept that combines all hydraulic functions in one lever,” says Fabian Scherer, who works for Linde MH as the product manager for reach trucks. Previously, there were two or four individual levers, depending on which operating concept the operator preferred. “Even if the operator is familiar with the levers, they still have to change hand positions again and again when loading,” explains Scherer. This takes time and may require the operator to briefly shift his gaze from the load to the levers. This is precisely what the new MFL was designed to change. The idea behind it is that all travel, push and lift functions can be controlled intuitively with little physical effort required from the wrist and fingers and it is no longer necessary to raise and lower one’s hand. This enables intuitive operation and increases productivity.

Alternatives to single lever control already existed on the market. They functioned like a joystick that the operator grips with their fist: Lifting and lowering as well as extending and retracting the fork is controlled by forward or sideways movements of the joystick, respectively. Other functions, such as tilting the fork, can be accessed via buttons or sliders on the joystick. Linde MH also wanted to use the basic principle of the joystick, but improve on it. “We wanted a solution where the hand rests instead of gripping around the joystick. This is less tiring,” says Scherer’s colleague Michael Pieritz, development engineer for Reach Trucks at the company. “Our goal was the greatest possible ergonomics.”

“Cold storage and gloves are one extreme, the other is the hand of a petite woman.”

Stefan Stark,
Designer for Porsche Engineering

The hand finds its natural position

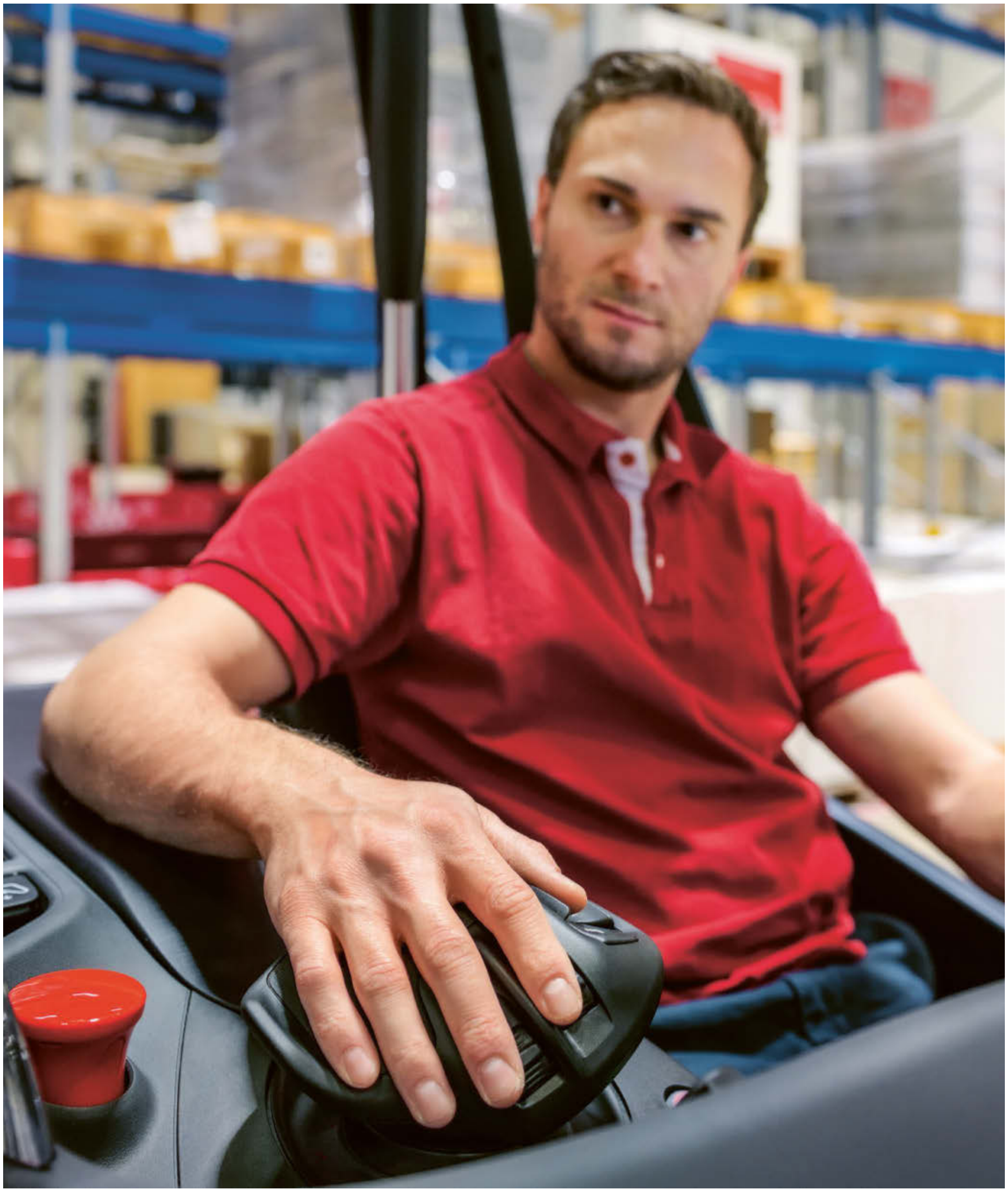
At the same time, the new solution had to make it as easy as possible to switch from other operating concepts. “A de facto standard had developed in the industry as far as the arrangement of the operating elements was concerned,” explains Pieritz. That’s why the developers at Linde MH first conducted an analysis of existing operating concepts. They also used a 3D printer to produce an initial prototype that showed the basic arrangement of the controls—a joystick attachment that looks more like a computer mouse, on which the cupped hand can comfortably find its natural position, and which can be moved smoothly in all four directions. The entire lever is moved back and forth to raise or lower the lift mast. The mast forward reach is directed with movements to the left and right.

Tilt and sideways movement of the forks should be controlled with the index and middle finger by way of two throttle controls. Besides the horn, the thumb controls the forward and reverse motion of the vehicle in the single-pedal version.

Linde MH took this prototype to the Fraunhofer Institute for Industrial Engineering (IAO). In a study, the institute's experts recommended tilting the handrest of the multifunction lever at an angle of around 40 degrees. This corresponds to the natural hand position—and would be unique on the market.

"Drivers are enthusiastic and particularly praise the sensitivity of the controls."

Fabian Scherer, Product Manager for Reach Trucks at Linde Material Handling.



A reach truck is designed for **20,000** operating hours.

An average of **30** pallet operations are carried out per hour.

This corresponds to roughly **600,000** pallets over the entire service life of the reach truck.

The multifunctional lever will be used for approximately **2.4 million** operating cycles.

NEW MULTIFUNCTIONAL LEVER

All functions accessible with one hand

❶ **Lift or lower a load, extend or retract a mast:** To lift a load, the entire multi-functional lever is pulled toward the driver. To lower the load, it is pushed away from the driver. To extend the mast, the driver pushes the multifunctional lever to the right. If the driver pushes it to the left, the mast will retract, making the reach truck shorter.

❷ **Tilting the load:** The operator can tilt the load forward on the forks for unloading using the wheel. To do this, the index finger turns the control forward. If it is rotated backwards, the load is tilted back-wards after being picked up. Pressing the wheel resets the tilt of the fork back to zero degrees.

❸ **Side slider:** This wheel is operated with the middle finger. If the driver turns it forwards, the fork shifts to the left by a maximum of eight centimeters. If the driver turns it backwards, the fork moves a maximum of eight centimeters to the right. Pressing the dial moves the fork back to the center position.

❹ **Horn:** With a press of the thumb, the driver operates the horn.

❺ **Driving direction:** Also using their thumb, the drive can choose to drive forward (rocking to the left) or backward (rocking to the right).

Innovative: The 39X generation of forklifts was distinguished by its load-bearing overhead guard with overhead tilt cylin-ders, among other features.

40 years of cooperation

Linde Material Handling and **Porsche Engineering** have been working together for 40 years, including on the product design of Linde industrial trucks. The very first collaborative project was the Linde H30 diesel counterbalance truck (BR 351): a design project with the aim of making the functional, design features of the truck visible through its external appearance. The maxim “form follows function” has since been implemented in many other vehicle developments and received numerous awards—more than 25 design awards have been collected since the beginning of the collaboration. “When Porsche Engineering started designing Linde forklifts 40 years ago, they still looked significantly different. In the intervening years, there have been major realignments as well as progressive evolution,” reports Wolfgang Rüber, Sales Director at Porsche Engineering. “The 39X series of 2001 was style-defining—a real design revolution that is still having an effect today. But we also deliberately take Linde Material Handling’s heritage into account to sharpen the established brand image—just as we do with Porsche vehicles.”

This prototype was the starting point for the work of Manuel Aydt and Stefan Stark. The two designers have been working for Porsche Engineering for many years and were commissioned to design the multifunctional lever. Their task was to harmonize the new operating concept with the design of the Linde reach trucks while at the same time implementing the ergonomic requirements. This included the tilt that was designed with a 30-degrees angle due to the installation space available. In addition the multifunctional lever also had to be suitable for all hand sizes and function reliably even under difficult conditions. "The switches integrated into the handrest had to be absolutely safe to operate. The hand should not to slip off even when the operators were traveling in a refrigerated warehouse and wearing gloves," recalls Aydt. His colleague Stark adds: "Cold storage and gloves are one extreme, the other is the hand of a petite woman."

Rib and winglet for better ergonomics

Two ideas by the engineers were key in solving the task. A rib between the index and middle fingers helps orientation on the multifunction lever. It also ensures that the hand is always correctly positioned, even when wearing thick gloves and regardless of their size. Secondly, the designers added a wing to the right side of the multifunctional lever. This "winglet" prevents the hand from slipping off due to the tilted position of the lever. And it gives the multifunctional lever a bit of the look of a manta ray. "We even toyed with the idea of calling it the manta," Pieritz recalls. In any case, it follows in the line of other components of the Linde forklifts, whose design language was also developed by Porsche Engineering—such as the "shark fin," a design element on the side.

The designers approached the finished product in several stages—manual drawings, 3D designs on the computer, and prototypes from the 3D printer. Linde MH repeatedly tested the prototypes directly on the vehicles during the process. "The first step was to find the right size so that the multifunctional lever could move easily in the available installation space," recalls Aydt. The second step was then to test advanced prototypes that already contained the controls for the individual functions.

After six months, the multifunctional lever was finally ready for series production. "We were very pleased when we held the final product in our hands," says Stark. His colleague Aydt adds: "The rib and the winglet clearly set us apart from the competition." Another result also makes the designers proud: "At the end of our creative work, the multifunctional lever was implemented in series production exactly as we had designed it," says Aydt. With their expertise, the designers succeeded in achieving the desired combination of design and functionality.

"At the end of our creative work, the multifunctional lever was implemented in series production exactly as we had designed it."

Manuel Aydt,
Designer for Porsche Engineering

Drivers are enthusiastic

Linde MH is also pleased with the outcome of the collaboration. "We have been working with Porsche Engineering for 40 years," says product manager Scherer. "There is a high level of understanding for the respective working methods."

Various tests followed—including at customers and dealers—as well as subsequent integration into series production. At the end of 2020, the reach trucks with the new multifunctional lever came onto the market. "The drivers are enthusiastic and particularly praise the sensitivity of the controls," says Scherer. "This customer assessment is the greatest validation of all for us."

IN BRIEF

Until now, Linde Material Handling's reach trucks have been operated with two or four individual levers. Together with Porsche Engineering, the company has developed a new multifunctional lever that makes all functions accessible with just one hand. This means that the drivers do not have to change hand positions and always have their eyes on the load.

A gentleman and a record-breaker

Text: Mirko Heinemann

With his electrically powered Blizz Primatist, the Italian entrepreneur Gianmaria Aghem set seven world records on the circuit of the Nardò Technical Center, impressively demonstrating the potential of electric mobility. He dispensed with an eighth record attempt out of respect for his great role model, the Z.E.R. from Bertone.

Blizz-speed: with 147 kW of power at its disposal, the electrically powered vehicle reaches more than 300 km/h.

“I wanted to show that a battery-powered car can travel long distances at a high speed. I achieved that.”

Gianmaria Aghem, entrepreneur and record-breaking driver

Gianmaria Aghem has already driven more than 400 vintage car rallies in his life, and he has won a fair share of them. His car: a 1965 Lancia Fulvia Coupé. “I love the classic design, the vintage technology, and the sound of the engine,” says the 74-year-old entrepreneur from Turin with evident delight. His living room is adorned with over 70 trophies.

And now another standout achievement that one might not have expected from a classic car fan like Aghem has been added to his bevy of awards: In the spring of 2021, he set seven world records on the grounds of the Nardò Technical Center (NTC) in southern Italy. He was driving the ultra-modern electric single-seater Blizz Primatist, a car that he played a key role in developing and which has little in common with his Lancia Fulvia Coupé. You’ll search in vain for the flashing chrome radiator grille, rally headlights, or classic curved shapes of the Lancia. Indeed, the four-meter-long and one-meter-wide vehicle with a tailfin is more reminiscent of a torpedo. When accelerating, you won’t hear the rich throatiness of a four-cylinder, but only the quiet hum of the e-drive.

The “Blizz” in Blizz Primatist references Aghem’s company Blizz Timing, which he founded a few years ago and which manufactures high-quality chronometers for rallying, while “Primatist” underscores the vehicle’s aspiration of always being the first to cross the finish line. The car was modeled on the legendary Z.E.R. (Zero Emission Record) launched by the Italian design firm Bertone in 1994. With its sensational C_d value of 0.11, the electric vehicle was a futuristic reinterpretation of the Abarth 750 Record, a 1950s racing car also built by Bertone.

Instantly impressed by the Z.E.R

Like its forebear, the Z.E.R. was designed exclusively to deliver top performance. And it certainly did: The electrically powered car set two world records. One came in 1994, when it covered a distance of 199.881 km in one hour. The following year, it set a new top-speed record for electrically powered vehicles: 303.977 km/h.

Gianmaria Aghem saw the Z.E.R. for the first time in 1996 at the AutoClassica fair in Milan. He was immediately impressed by the concept. For Aghem, the Z.E.R. was more than just a Bertone classic. To him, the car’s new drive technology represented a foray into uncharted territory. And that is exactly what the Turin

Historic role model: Bertone’s Z.E.R. from the year 1994 had sensationally low drag and set two world records on the NTC circuit.

Record-breaking: The Blizz Primatist was running at speeds between 200 and 250 km/h on the NTC circuit. More records are set to follow next year.

Seven in one go: Gianmaria Aghem after his record-breaking drive in the spring of 2021. Both Z.E.R. records are still on the board at the NTC. One of them is now held by the Blizz Primatist.

car fan wanted to do roughly a quarter of a century later as well: Drive the Z.E.R., improve it, and set new records with it. Unfortunately for him, the car was not available. After Bertone's bankruptcy, the Italian classic car club ASI (Automotoclub Storico Italiano) bought the entire collection of the Bertone Museum. Now the vehicles—including the Z.E.R.—were on exhibit at Volandia, a museum near Milan Malpensa Airport.

So Aghem decided to design his own vehicle. Having acquired in-depth expertise in automotive engineering over the years, he had the requisite knowledge. "When engineers get stuck, they call here and ask him," says his wife, Rossella Conti. Aghem also brought in engineer Eugenio Pagliano, who had developed the Z.E.R. and was now to join him in launching its unofficial successor. But the Blizz Primatist was never intended to be a mere improved copy of the Z.E.R. "We developed all the components from scratch," Aghem emphasizes.

"Testing the limits of the automotive future is part of our DNA—whether it's through safeguarding the vehicles of tomorrow or through unique record-breaking attempts."

Antonio Gratis, Managing Director of the NTC

The capabilities of the electric engine and the efficiency of the battery cells are state of the art. The battery in the Blizz Primatist consists of 2,688 lithium-ion cells that deliver a total of 34 kWh of energy. Electric propulsion is provided by a 20 kg, three-phase asynchronous motor from Switzerland, which can deliver a peak output of more than 147 kW and enable a top speed of more than 300 km/h. Energy management is handled by a complex algorithm that determines the maximum speed at a given distance or time. All information coalesces in the cockpit, with its digital readouts and black-and-gray LCD displays, which is almost as spartan as a Formula 1 cockpit. The electric car is steered with a yoke similar to those used in airplanes.

Design optimization in the wind tunnel

However, Aghem's engineers were determined to adopt one thing from the Z.E.R.: the low Cx value of 0.11. To achieve this, the designers and constructors from Podium Engineering in Valle d'Aosta optimized the drag of the Blizz Primatist on the computer and measured it in the wind tunnel at the Polytechnic University of Turin. The car's long range is due in no small part to the modern lightweight carbon-fiber construction contributed by the Carbonteam company based in Saluzzo in Piedmont. In the end, the engineers stayed below the specified limit of 500 kg with the extremely low vehicle weight of 499 kg. The idea was to make it possible to compete in two different classes: electric vehicles weighing up to 500 kg and—with a few kg of ballast—electric vehicles weighing 500 to 1,000 kg. The 890 kg Z.E.R., outfitted with lead batteries, also competed in that class.

The Z.E.R. set its two world records on the circular track at the NTC in Apulia. So it was only logical for its successor to test its mettle on the same track. Antonio Gratis, managing director of the NTC, still remembers the call from Gianmaria Aghem clearly: "When I was asked if I could imagine opening the track for the record attempts, I didn't have to think twice. Testing the limits of the automotive future is part of our DNA—whether it's through safeguarding the vehicles of tomorrow or through unique record-breaking attempts. Automotive history has been written on our track. What would the Nardò Technical Center be without records?"

New track record over one hour

After the track had been inspected and certified by the FIA (Fédération Internationale de l'Automobile), the big day arrived on April 30, 2021. A tow truck towed the Blizz Primatist to the starting position of the 12.6 km high-speed circular track at the NTC. The countdown ticked down on a display panel, and when it reached zero the black torpedo with the Italian tricolor painted on it started moving almost silently. The Blizz Primatist had embarked on its quest to break the record. At the wheel: Gianmaria Aghem.

On that day and the following, he roared around the track at constant speeds of between 200 and 250 km/h, setting seven records in two vehicle classes. On April 30, he covered the ten-mile, 100-km and 100-mile distances at the highest average speed that electric vehicles weighing up to 500 kg had ever achieved to date. Aghem also bettered the course record for the hour, covering 225.184 km. At the end of the day, the battery still had a charge of four percent. Thanks to intelligent energy management, Aghem had made optimal use of the available energy.

Overnight, the battery was charged again, and on May 1, three further records followed in the ten-mile, 100-km and 100-mile time trials in the 500 to 1,000 kg electric vehicle class. The times were certified by the FIA, whose experts traveled to the event

The seven world records of the Blizz Primatist

Category A Group VIII, Class 1: to 500 kg (Blizz Primatist: 499 kg)

Ten miles at an average speed of
210.741
km/h

100 km at an average speed of
229.715
km/h

100 miles at an average speed of
231.188
km/h

One-hour time trial:
225.184
km

together with representatives of the Italian automobile club ACI (Automobile Club d'Italia). If he had taken more time and recharged the battery, Aghem could have achieved even higher speeds. "That wasn't my objective, though," he says. "I wanted to show that a battery-powered car can travel long distances at a high speed. I have achieved that." Now he hopes that his vehicle will serve as an example to automotive manufacturer and spur them on. "This achievement was unimaginable just a few years ago," Aghem said. And already next year he wants to increase it further: Aghem has announced that in May 2022 he wants to travel to Nardò with the Blizz Primatist and break more records.

Antonio Gratis is equally impressed: "Gianmaria Aghem's records are proof of the great progress made in electric powertrain systems. Compared to the Z.E.R., the Blizz Primatist has a much higher range and thus represents a huge technological leap. I'm quite certain that the public will soon see more fascinating records in the electric vehicle class. And I am sure that NTC will play a major role as a ground of great achievements."

Gianmaria Aghem passed on the chance to set an eighth record: the one-hour time trial for electric vehicles weighing up to 1,000 kg. That record is still held by the Z.E.R., at 199.881 km. "I could have topped that if I had driven slower in the other three categories on the second day," Aghem said. "But I chose not to break that Z.E.R. record. That's what my respect for the legend demanded." His wife chimes in: "Do you hear that? My husband is not a cold-blooded record-hunter. He's a gentleman."

Category A Group VIII, Class 2: from 500 kg to 1000 kg (Blizz Primatist: 507 kg with ballast)

Ten miles at an average speed of

227.492

km/h

100 km at an average speed of

243.133

km/h

100 miles at an average speed of

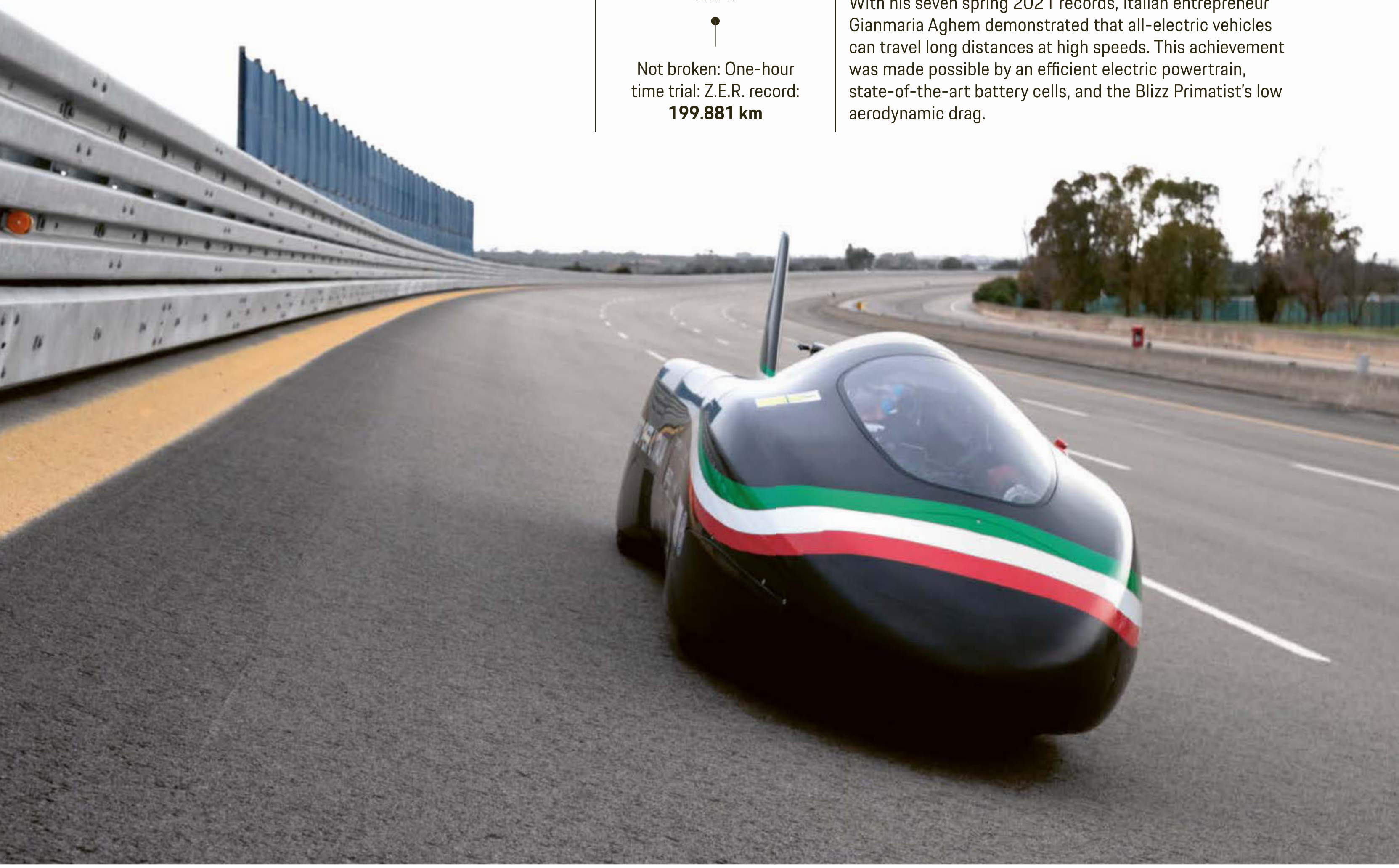
242.859

km/h

Not broken: One-hour time trial: Z.E.R. record: **199.881 km**

IN BRIEF

With his seven spring 2021 records, Italian entrepreneur Gianmaria Aghem demonstrated that all-electric vehicles can travel long distances at high speeds. This achievement was made possible by an efficient electric powertrain, state-of-the-art battery cells, and the Blizz Primatist's low aerodynamic drag.



Electric performance: The Mission R achieves the performance level of the 911 GT3 Cup.

Mission future

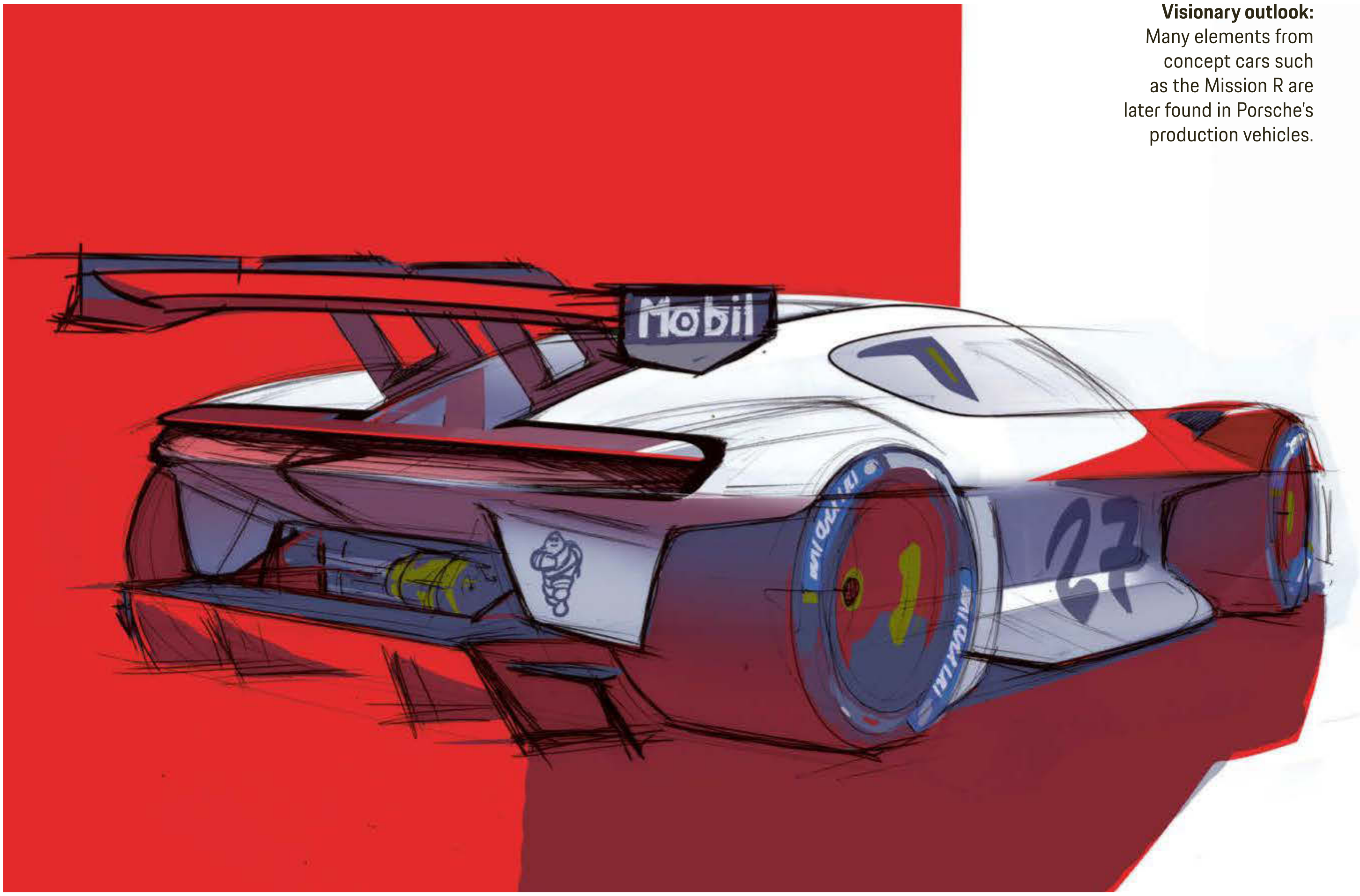
Text and photos: Dr. Ing. h.c. F. Porsche AG

Porsche presented its vision of an all-electric vehicle for customer motorsport at IAA MOBILITY 2021. The Mission R concept car combines state-of-the-art technologies and sustainable materials such as natural fiber-reinforced plastics with a passion for racing. It's the next logical step toward a sustainable motorsport future.

Porsche is the most successful brand in customer motorsport: 30 one-make cups worldwide with around 500 participants and more than 4,400 Cup vehicles produced based on the 911 speak for themselves. This year's motorsport season saw the launch of the latest version of the Porsche 911 GT3 Cup—and now the Porsche Mission R is offering a glimpse of what the future of one-make cups with all-electric vehicles might look like.

The electrically powered Mission R attains the performance level of the Porsche 911 GT3 Cup. The front axle boasts an electric motor with up to 320 kW (435 hp), and the rear axle motor puts out a maximum of 480 kW (653 hp). In qualification mode, the all-wheel drive vehicle achieves a peak system output of over 800 kW (1,088 hp). Its continuous system output in race mode is 500 kW (680 hp). Thanks to its powerful drive, the roughly 1,500 kg electric race car accelerates from 0 to 100 km/h in less than 2.5 seconds. The top speed of the Mission R is over 300 km/h.

"It's indescribable, the immediate surge of power from the two electric motors is something you simply have to experience for yourself," says Timo Bernhard, discussing the drive system of the Mission R. The Porsche Brand Ambassador and former works driver knows



Visionary outlook: Many elements from concept cars such as the Mission R are later found in Porsche's production vehicles.

"The only time I've ever experienced such an amazingly powerful boost was in the Le Mans-winning Porsche 919 Hybrid car."

Timo Bernhard, Porsche Brand Ambassador

A lot of power in a small space: The Mission R stands out for its extreme compactness. Cameras up on the roof edge act as mirror replacements.

the technical basis behind the concept study and has already been on the race track with the technology platform as a test driver. “The only time I’ve ever experienced such an amazingly powerful boost was in the Le Mans-winning Porsche 919 Hybrid car.”

Electric motors with direct oil cooling

The power output of the Mission R remains constant over the entire duration of the race, so there is no thermally induced derating—a major advantage of the electric motors with direct oil cooling developed by Porsche. They offer a preview of the next generation of extremely powerful and highly efficient electric motors that Porsche has been working on since 2018.

The most important innovation of these permanently excited synchronous motors (PSMs) is the direct oil cooling of the stator, which allows a very high peak and continuous power as well as a very high efficiency. While in conventional electric machines cooling fluid flows through a jacket outside the stator, the oil flows directly along the copper windings. It therefore dissipates more heat directly at the source. In addition, this allowed the slots in the stator to be smaller-dimensioned, which allows better efficiency in real driving cycles.

As with the Taycan’s electric motors, the hairpin winding also contributes to a high yield of power and torque in the Mission R while maintaining compact dimensions. It consists of rectangular wires that are bent and then inserted into the stator’s laminated core. Their shape is reminiscent of hairpins—hence the name. The open ends are welded together by laser beam. The shape and position of the magnets in the rotor have also been optimized. The new geometry combines excellent electromagnetic properties with high mechanical strength at very high engine speeds.

The battery in the Mission R sits behind the driver and has a total capacity of 82 kWh. This means it is designed for a sprint-format race distance of 25 to 40 minutes. High-end cells are used to achieve a high power density. Here, too, direct oil cooling offers major thermal advantages: Because it utilizes the entire surface of the cells, a large heat flow can be transported from the battery into the cooling system.

The Porsche Taycan was the first production vehicle to feature an 800-volt system voltage—instead of the 400 volts commonly used in electric vehicles. With the Mission R, Porsche raises the bar a notch higher again. Its 900-volt technology will result in further improvements in continuous power, weight, and charging time. This allows the race car to be charged from five to 80 percent SoC (State of Charge) in around 15 minutes at DC fast-charging stations. The maximum charging capacity is 350 kW.

The high-voltage safety concept of the Mission R fulfills the high standard of Porsche production vehicles. This means that, in the event of a collision, the battery connections to the vehicle and the high-voltage consumers are automatically disconnected to ensure no voltage is present. The Mission R adds a special alert system for the pit crew: special LEDs behind the windshield and on the roof provide quick and clear information about the operating status of the high-voltage system. If they light up green, the Mission R is high-voltage safe. If the LEDs are red, however, only high-voltage trained personnel should access the vehicle. There is also a light in the roof module behind the pitot tube for speed measurement, which is part of this color-coded warning system.

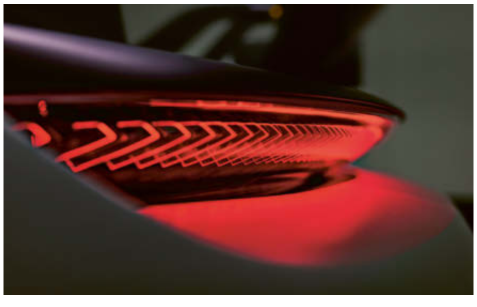
Compact design, low drag

The Porsche Mission R bears the brand’s typical racing design, but also breaks new ground. Looking at the car from the outside, the first thing you notice is its extreme compactness: It measures 4,326 millimeters in length and 1,990 millimeters in width. The wheelbase is 2,560 millimeters. As is typical for a race car, the electric design sits very low on the road, with a height of 1,190 millimeters. The narrowly shaped cabin reduces the frontal area of the Mission R and contributes to outstanding electric performance through lower drag. Cameras are mounted on the edge of the roof as a digital replacement for conventional exterior mirrors.

In typical Porsche style, the front hood slopes down between the two sharply curved fenders. The large side air intakes, each with three slats, the front splitter with

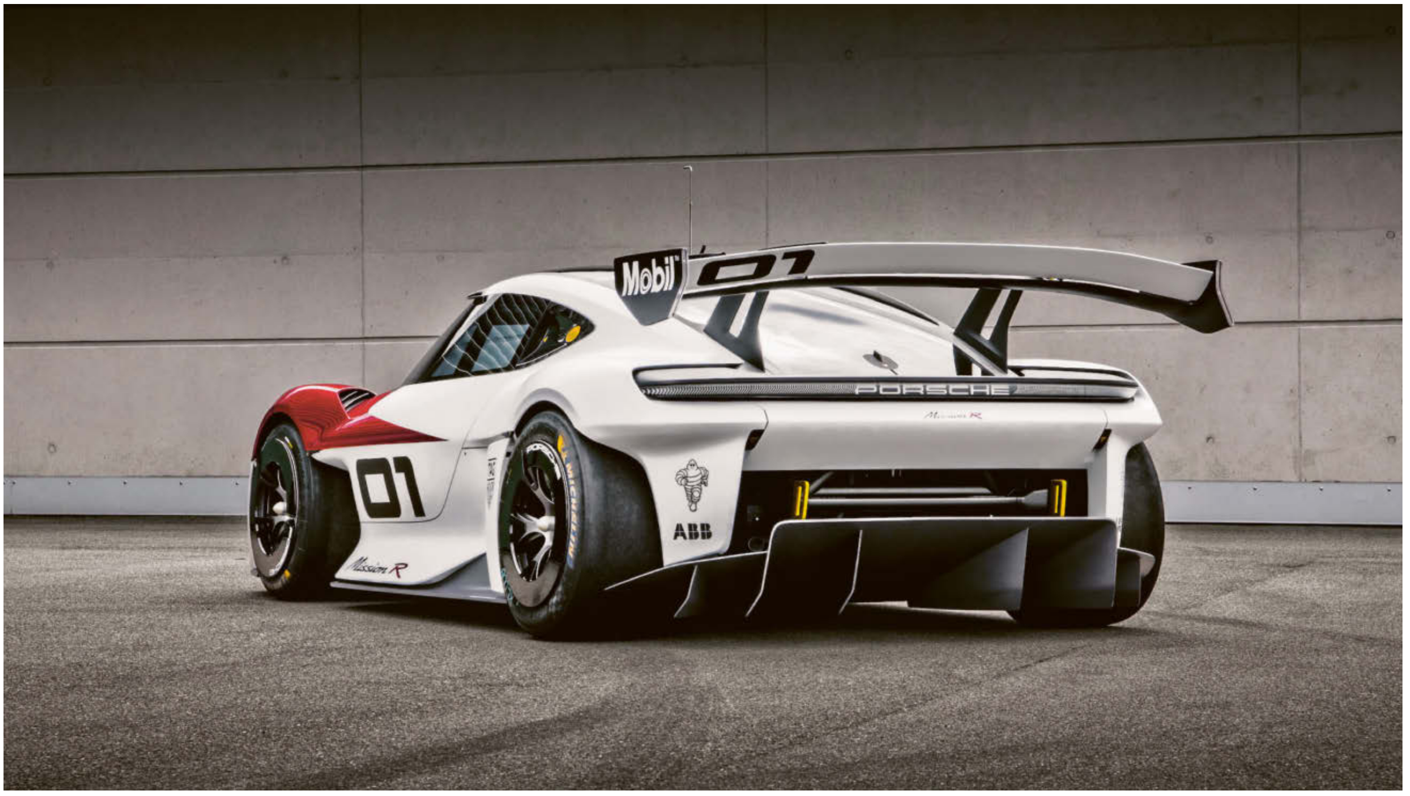
30 minutes
is the typical race duration for which the Mission R’s battery is designed.

50%
of the energy can be recovered during the race via recuperation, or even more depending on the race track.



Striking: Flat LED headlights dominate the front end. The rear features the typical Porsche light strip.

The Mission R at a glance



System output

680 hp
Race mode

1,088 hp
Qualification mode

Speed and acceleration

> 300 km/h
Top speed

< 2.5 seconds
from 0 to 100 km/h

High-voltage system

System voltage
900 volts

Battery capacity
82 kWh

Dimensions

L
4,326 millimeters
Length

B
1,990 millimeters
Width

H
1,190 millimeters
Height

R
2,560 millimeters
Wheelbase

At DC fast-charging stations, the Mission R can be charged from five to **80 percent** SoC (State of Charge) in around **15 minutes**. The maximum charging capacity is **350 kW.** The charging connector for the battery is located in the middle of the rear window behind a flap.

Weight

1,500 kg

visible natural fiber mix and the flat LED headlights dominate the nose. The four-point light emblem ties in with the design of the headlights on the Porsche Taycan electric sports car. The rear view is dominated by the diffuser and spoiler aerodynamic components. The two-section spoiler is made of carbon. The designers have integrated the brake and rain lights into the profile of its wing plates—so they can be easily seen by following drivers even in spray conditions. The rear features the typical Porsche light strip. It consists of a multitude of vertical elements, to the right and left of the lettering, which is also illuminated. The charging connector for the battery is located in the middle of the rear window behind a flap.

In addition to the battery-electric drive concept, the body of the Mission R also contributes to CO_2 reduction and sustainability: it consists largely of natural fiber-reinforced plastic (NFRP). The basis is provided by flax fibers from agriculture. This environmentally sound material is also used for the front splitter, diffuser, and side skirts. NFRP is also used extensively in the interior of the Mission R, for example for the inner door panels, the rear bulkhead, and the seat.

Beautiful and sleek: The Mission R rolls on 18-inch Cup wheels in a five-twin-spoke design with central locking. The carbon aero trims make the wheels particularly streamlined.

Livestreams from the cockpit

The design of the interior puts the driver at the center in all areas. An ergonomically positioned display between the hand positions on the yoke shows relevant data during racing. The monitor above the steering column displays the images from the side mirror camera and the central rear camera. A touch display to the right of the seat can be used to call up the driver's biometric data, among other things. Two cameras mounted on the roof frame and on a rail above the passenger side show what is happening inside the car in real time during the race. The live images can be transmitted directly to the community using a livestream button. In turn, fans can communicate directly with the driver, for example, by sending them likes.

The full bucket seat provides a high level of protection for the driver. At the same time, it has an innovative design and is partially manufactured using 3D printing technology as a 3D bodyform full bucket seat. The seat shell is made of the same natural fiber-reinforced material as the exterior add-on parts. The center section of the seat, i.e. the cushion and backrest, comes in part from a 3D printer.

The monocoque-like driver cell of the Mission R is designed as a module and can be used in identical form outside the vehicle as a simulator. This allows racers to prepare for their next race virtually in a familiar environment, and motorsport enthusiasts of tomorrow can participate in esports events. With the aid of movable, electrically controlled supports, the dynamic forces that impact on the driver can be simulated—when braking, for example, or as a result of rolling motions during fast cornering. Thanks to familiar surroundings with the same display and control elements and the same full bucket seat, such training would be extremely realistic and highly efficient.

"Porsche is the brand for people who fulfill their dreams. This is also true in motorsports. We experience our innovative strength on the race track, demonstrate courage in pursuing new avenues, and delight car owners with sporting performance," says Oliver Blume, Chairman of the Executive Board of Porsche AG. "In addition to our involvement in the Formula E World Championship, we are now taking the next big step forward in electro mobility. The concept study is our vision of all-electric customer motorsports. The Mission R embodies everything that makes Porsche strong: performance, design, and sustainability."

The world of motorsport also benefits every driver of a Porsche, because racetracks are important development laboratories for new technologies such as electro mobility: No automotive company cultivates a more intensive exchange of technology between motorsport and production vehicles than Porsche. Traditionally, the brand uses racing as a test laboratory in which innovative solutions have to prove themselves under the toughest conditions. Every current Porsche therefore contains more race-proven technology than ever before.

IN BRIEF

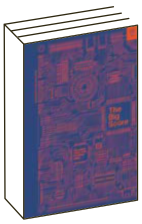
The Porsche Mission R is the vision of an all-electric vehicle for customer motorsport. Its performance is on par with the Porsche 911 GT3 Cup. At the same time, it points the way to a sustainable motorsport future. Customers of all-electric production vehicles will also benefit from the Mission R.

Deeper knowledge

Futuristic

Artificial intelligence, autonomous vehicles, and "augmented humans": This wide-ranging website shows where new technologies could take us in the future.

Futurism
https://futurism.com/

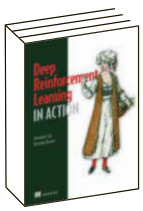


The beginnings of Silicon Valley

Over the past 50 years, the technology industry has become one of the most important sectors in the global economy. Silicon Valley is home to many of its key players. The book describes the beginnings of the legendary valley.

The Big Score
Michael S. Malone
Stripe Press

AI for engineering



The AI method of reinforcement learning is particularly suitable for optimization tasks in engineering. This book elucidates its theoretical foundations and describes how to easily program software agents in Python using PyTorch.

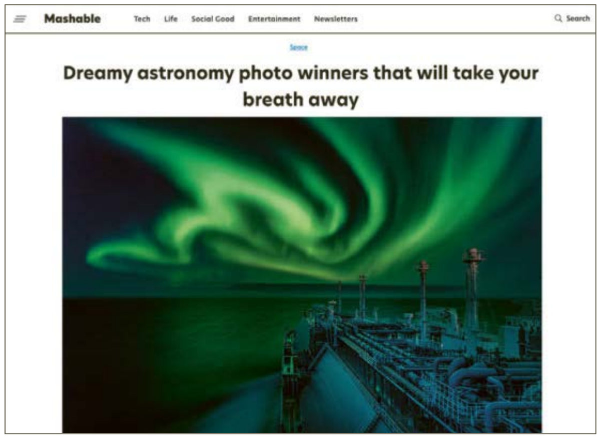
Deep Reinforcement Learning in Action
Alexander Zai, Brandon Brown
Manning

News from the world of science

From the far reaches of space to the tiniest microbes: The *Science Friday* podcast is your trusted source for news about science, technology and other cool stuff.

Science Friday
https://www.sciencefriday.com/science-friday-podcasts/

The big picture



Cornucopia of topics

Technology, lifestyle, social issues, and entertainment: This website offers a colorful mix of topics. In addition to interesting texts, there are also a great many videos to discover.

Mashable
https://mashable.com/

Where are we going?

In these 12 essays, Jeanette Winterson explores artificial intelligence in all its various manifestations. She describes how radically our lives could soon change in many areas as a result of the new technology.

12 Bytes
Jeanette Winterson
Jonathan Cape

Weekly food for thought

Host Chris Duffy talks with his guests each week in this podcast about how to become a better person—be it at work, at home, in your mind, or in your heart.

How to Be a Better Human
https://www.ted.com/podcasts/how-to-be-a-better-human

For the child in all of us

The card game for geeks

Playing-card perfection for programmers: These 55 playing cards contain code in Assembler, Bash, C++, Python, Objective-C, C#, Java, PHP, JavaScript, SQL, and HTML, among others. The un-computer-savvy can also play along: The cards have all the usual values like ace of spades and queen of clubs as well.

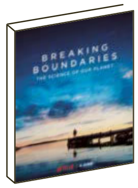
Code:Deck
www.amazon.com

Mini computer on tour

This kit gets the Raspberry Pi moving: A mobile base and three sensor modules (ultrasonic obstacle avoidance, light follower, and line follower) provide a playful introduction to programming and autonomous driving.

Raspberry Pi Car DIY Robot Kit
www.amazon.com

Intelligent entertainment



Preserving biodiversity

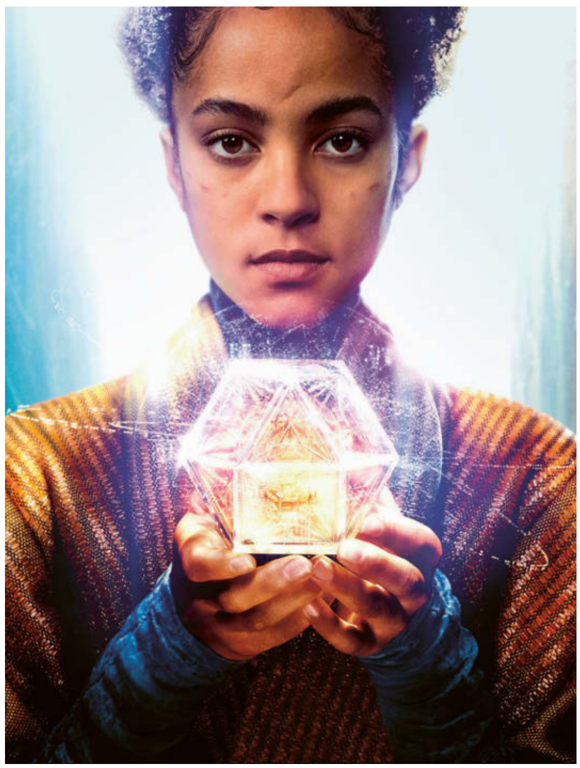
Filmmaker David Attenborough and scientist Johan Rockström, director of the Potsdam Institute for Climate Impact Research, examine the collapse of Earth's biodiversity and show how this crisis can still be averted.

Breaking Boundaries
Netflix, 2021

Galactic epic

Apple TV brings Isaac Asimov's *Foundation* trilogy of novels to screens as a series. A group of outcasts aims to save and rebuild human civilization amid the fall of the Galactic Empire.

Foundation
Rupert Sanders, Alex Graves, Andrew Bernstein (directors)
Apple TV, 2021



Gorgeous forerunner: The Type 360 Cisitalia would become the cornerstone for Porsche to build sports cars under its own name. The last of its kind is now in the Porsche Museum.

1946

In 1946, Turinese Piero Dusio hatched an ambitious plan: To have a Formula 1 race car of his own developed. A number of small race cars for rich customers of the Cisitalia brand had been developed under his leadership in the past, and now the car-loving entrepreneur wanted to move up into the top class of motor racing, which at this time was dominated by Alfa Romeo and Maserati. In search of a partner for his fledgling automotive company, Dusio turned to a source with proven racing expertise: the engineering office of Ferdinand Porsche, then headed by Ferry Porsche and based in Gmünd, Austria. On December 15, 1946, the contract was awarded. Later, on February 2, 1947, the final contract for construction of the race car was signed.

The work on the first major post-war order began in 1947. While Ferry Porsche and Karl Rabe led the development team in Gmünd, Robert Eberan von Eberhorst handled the coordination on-site in Turin. Piero Dusio's specifications essentially amounted to one point: The race car with Porsche design number Type 360 was supposed to have an engine with 1.5 liters of displacement and a supercharging system. Otherwise, the developers were given a free hand from design to construction.

They opted for a 12-cylinder, 180-degree V supercharger and placed the driver roughly in the center between the wheel axles. In the cockpit of the race car, which was just under four meters long and 1.6 meters wide, the driver was able to switch from two- to four-wheel drive via a lever. “We had projected a very high engine output,” Ferry Porsche said later. “With the narrow racing tires available at the time, it was impossible to bring it all to the road via the rear axle alone.” After all, the supercharged engine, with its four overhead camshafts and a displacement of 1,493 cubic centimeters, delivered 385 hp at 10,600 rpm.

Hidden beneath the magnesium body of the race car was a support structure made of chrome molybdenum steel that could withstand the external forces with virtually no bending or torsion. The front axle featured a double-wishbone suspension, which had already proven itself in the Volkswagen and would later also be used in the Porsche 356.

The Porsche Type 360 Cisitalia was complete and ready for handover to Piero Dusio in 1948. It would never be used in a race, however: The client left Italy in 1951 to start a new life in Argentina. There, test driver Clemar Bucci attempted to set a new speed record for South America in 1953 with the Cisitalia race car—unsuccessfully, as it turned out, because the wrong fuel was used and the weather was unfavorable. Otherwise, it stood unused in a garage for many years. In 1960, the Type 360 was finally brought back to its homeland. Today it has a place of honor in the Porsche Museum in Stuttgart-Zuffenhausen. Although the Type 360 did not compete in any races for financial reasons, it became the cornerstone for Porsche to build sports cars under its own name.

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