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Porsche Engineering Magazine

NEW HORIZONS

Creating new opportunities with
high-tech solutions and AI-driven tools

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Data-driven development
Interview with ESA astronaut Matthias Maurer
AI-based soft switching


Time to make some new good old times.
THE NEW 911 SPIRIT 70.
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PORSCHE
911 Spirit 70 (WLTP): Fuel consumption combined: 10.9 – 10.7 l/100 km; CO_2 emissions combined: 246 – 242 g/km; CO_2 class: G; Status: 05/2025

Markus-Christian Eberl
CEO of Porsche Engineering

Dear Reader,

Almost a year has passed since the last issue of Porsche Engineering Magazine—a year in which the general conditions faced by our sector have continued to change rapidly. Having an active, forward-looking, and future-focused management that keeps its ear close to both the market and the customer—coupled with a high degree of flexibility—remains particularly important.

For some time now, we have been observing two key trends that are set to continue: An increasing speed of development and technical progress, as well as a growing level of complexity with ever-longer end-to-end chains.

In order to face these developments actively, technical answers are needed—and these answers form the core content of this magazine. What's more, we are aware that in addition to high technical competence, another "ingredient" is required to continue providing our customers with our valued expertise in comprehensive solutions in this fast and complex world: A management and organizational culture that is fit for purpose. That is why we at Porsche Engineering are investing in these skills and in new technical competencies in equal measure.

We apply the "Push the Boundaries" concept in a comprehensive way—not only when it comes to technologies, but also with regard to the processing structure and methodology used for projects. We are constantly opening up new paths at the interface between innovation, standardization, speed, quality, pragmatism, plannability, agility, and costs. Doing so has recently earned us positive feedback from international customers, something that further encourages us and reinforces our approach.

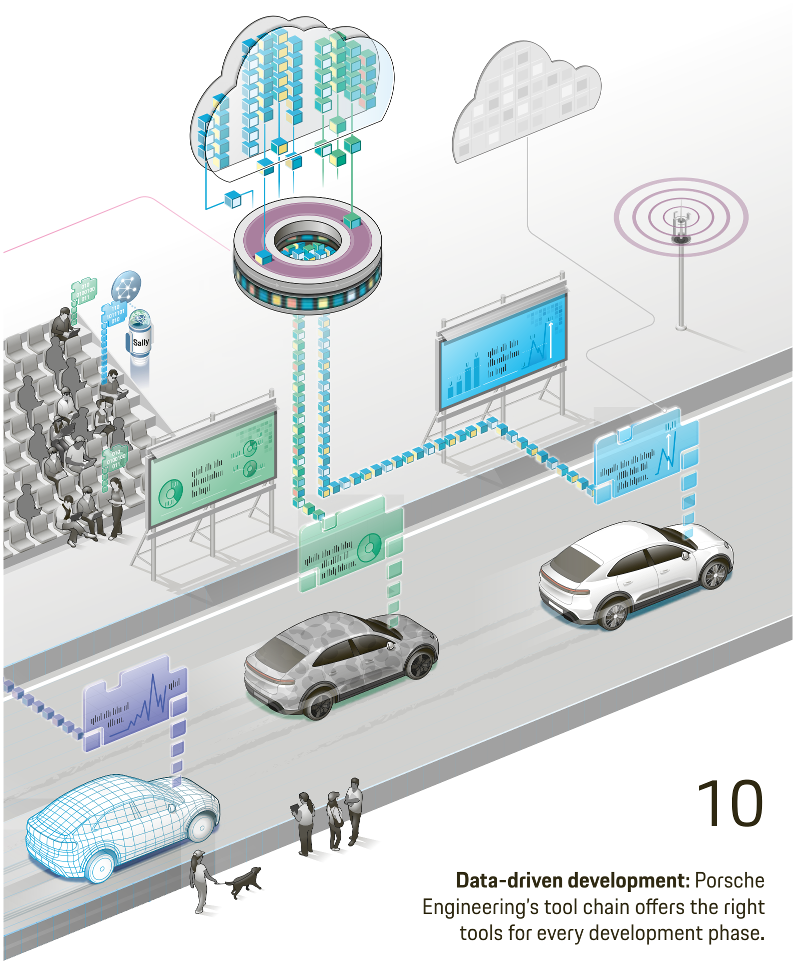
Systematically pushing our boundaries has also widened our own horizons; we have been thinking outside the box and addressing topics that go beyond the automotive sector—from the road to the water and out into space. You can read more about that in the interview that my colleague Dr. Christoph Roggendorf conducted with ESA astronaut Dr. Matthias Maurer. Flexibility, without losing sight of the big picture of a tool chain, is something we are illustrating with a modular system for data-driven development. We are also reporting on that in this issue of Porsche Engineering Magazine.

Despite all the changes in technology and methods, one thing always remains the same: The satisfaction of our customers is our benchmark and our highest goal.

I hope you enjoy reading this issue of the magazine!

Markus-Christian Eberl

ABOUT PORSCHE ENGINEERING: Porsche Engineering Group GmbH is an international technology partner for the automotive industry and beyond. As a subsidiary of Dr. Ing. h.c. F. Porsche AG, the company focuses on the development and integration of system, hardware, function, and software solutions for its B2B customers. Some 2,000 conceptual experts, engineers and software architects and 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. Their aim is to carry the tradition of Ferdinand Porsche's design office, founded in 1931, into the future and develop and integrate innovative solutions for the top tech challenges of their industry customers. In doing so, they combine in-depth vehicle and system expertise with digital and software expertise.



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Data-driven development: Porsche Engineering's tool chain offers the right tools for every development phase.

Pushing boundaries: ESA astronaut Dr. Matthias Maurer (left) and Dr. Christoph Roggendorf met for an interview at the ESA training center in Cologne.

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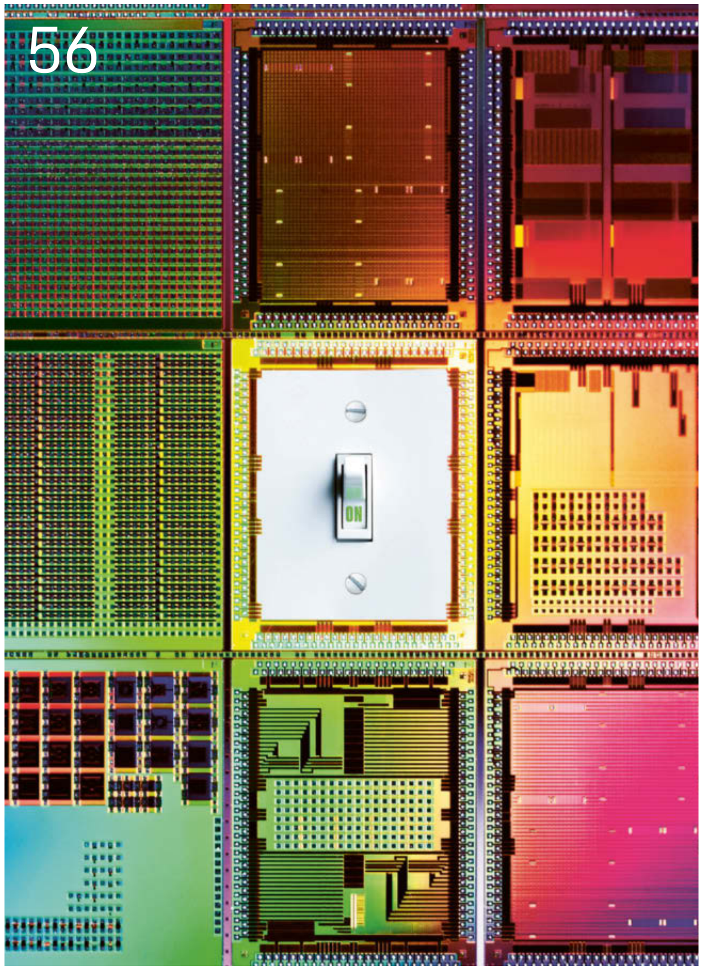
Soft switching: Porsche Engineering uses AI to intelligently control power transistors in electric vehicles.



Technology transfer: The Frauscher 850 Fantom Air electric boat shows how components from electric vehicles can be used in other domains.

CONTRIBUTORS

Max Brunnert
is a portrait and features photographer from Düsseldorf. He took the pictures for the double interview.

Heike Hientzsch
is a freelance journalist from Wiesbaden. She spoke with Dr. Matthias Maurer and Dr. Christoph Roggendorf.

Andrew Timmins
is an infographic artist from Hamburg. He created the illustrations for modular data driven development.

NEWS 01/2025

50 years of Nardò Technical Center

SHAPING THE MOBILITY OF TOMORROW

Porsche Engineering's Nardò Technical Center (NTC) celebrates its 50th anniversary this year, making this a good time to reflect on an impressive history marked by innovation, technological pioneering and historic records. Since its opening in 1975, NTC has been continuously modernized and has evolved from its base in Apulia, Southern Italy, into a leading test center for the international automotive industry, driving forward cutting-edge mobility technologies. Porsche acquired the center in 2012, and it has since become an integral part of Porsche Engineering's international network and its development and testing capabilities.

With highly qualified experts and state-of-the-art facilities, NTC supports its global customers year-round in the integrated development and testing of vehicles. NTC is a central location for high-performance testing and the validation of intelligent, connected and safe vehicles of the future.

Spanning 700 hectares, the site features 20 test tracks and facilities, including a unique 12.5-kilometer ring track, a 6.2-kilometer handling course and advanced simulation capabilities. Since 2023, a software unit in nearby Lecce has been expanding technological expertise in Southern Italy.

Marking its 50th anniversary, NTC celebrates another significant milestone while clearly focusing on the future and its key role in shaping the mobility of tomorrow.

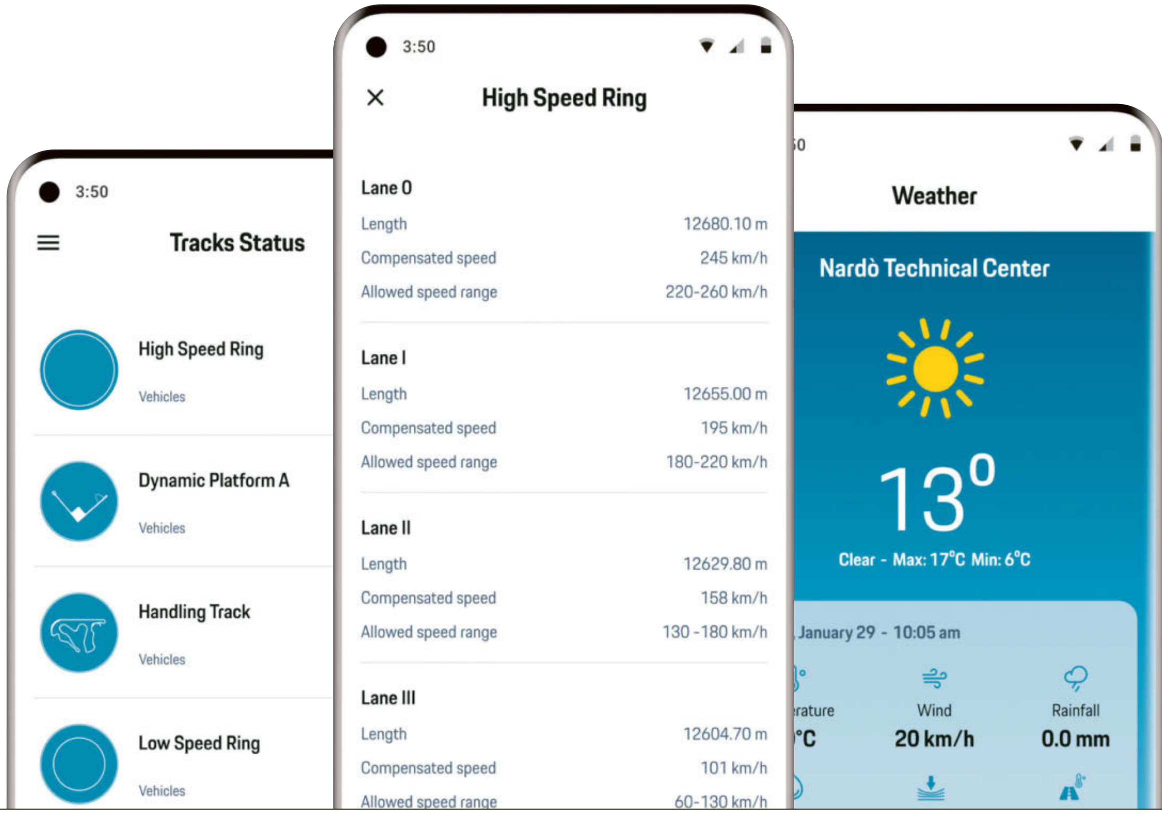
Five years on the Innovation Campus

ADVANCING TECHNOLOGIES IN OSTRAVA

Courage to innovate:
Together with his team, Dr. Miloš Polášek develops robust solutions for Porsche Engineering's customers.

In June 2025, Porsche Engineering Services s.r.o. celebrated the fifth anniversary of its site at the Innovation Campus in Ostrava. Activities at Porsche Engineering's second Czech location, alongside Prague, began seven years ago, followed shortly by the move to the high-tech campus. Ostrava plays a key role in Porsche Engineering's international development network and focuses on forward-looking E/E architectures, high-voltage systems, and connected mobility. In Ostrava, development teams work with artificial intelligence, cloud-based platforms, and advanced simulation environments to ensure fast, scalable, and reliable system integration. "With a highly skilled and motivated team, strong regional partnerships and the courage to innovate, we are shaping tomorrow's technologies today," explains Dr. Miloš Polášek, Managing Director of Porsche Engineering Services s.r.o. "Our work goes beyond individual projects. We translate forward-looking ideas into robust solutions that support our customers' long-term strategic goals—whether on the road or in space." The Moravian-Silesian region, where Ostrava is located, offers many advantages thanks to its strong industrial tradition, leading technical universities, skilled workforce, and proximity to key automotive hubs in Central and Eastern Europe.

Center of High-Tech Development:
The Moravian-Silesian region has a strong industrial tradition and is home to leading technical universities.



NTC test track app

LEVERAGING TEST ACTIVITIES ON SITE

Since January 2025, customers of the Nardò Technical Center (NTC) have had access to a multilingual app (in Italian, English and German) that provides up-to-date information on test operation. Users can use their smartphones at any time to view which test tracks—such as the high-speed and low-speed ring, the dynamic platforms A and B, or the handling track—are occupied or open for test operation. The app also offers an occupancy plan for all test tracks with advance planning for four weeks.

The service is supplemented by comprehensive weather data and forecasts, including asphalt temperatures, wind speeds, and air pressure, as well as forecasts for the next five days. These contribute to the effective planning and evaluation of test activities. An integrated ticket system provides fast and efficient support in the event of issues in NTC workshops by sending prompt replies via push messages. A new feature will be introduced in the second half of the year: real-time information on the availability of NTC charging stations.

The app has been developed and regularly updated by Porsche Engineering Romania since 2024. It is available for iOS and Android devices and can be downloaded by authorized users from public app stores or the Porsche App Store.

Apple
App Store

Google Play
App Store

Porsche Engineering Forum in Shanghai

EXCHANGE OF IDEAS ON FUTURE-ORIENTED TECHNOLOGIES

The Porsche Engineering Forum 2025 took place in Shanghai on March 19, 2025, under the slogan "Innovate to Lead, Integrate to Succeed". More than 100 leading industry experts from over 30 Chinese B2B companies and technology companies came together for an inspiring exchange of ideas at the Porsche Experience Center. The key focus was on the question of how innovative development solutions can be implemented seamlessly across different regions in a technically heterogeneous world in order to fulfill different customer needs, market requirements, and differing regulations. Attendees were welcomed by Uwe Pichler-Necek, CEO of Porsche Engineering China, and Markus-Christian Eberl, CEO of Porsche Engineering, each of whom started with a strategic assessment. Dirk Lappe, CTO of Porsche Engineering, then gave an overview of current trends, requirements, and solutions for international automotive development. Experts from Porsche Engineering subsequently spoke about topics such as highly integrated battery systems, advanced thermal management, automated driving functions, and sophisticated driving dynamics technologies. Leading Chinese car manufacturers were also represented and gave exclusive insights into their work.

Inspiring event: The participants met for discussions at the Porsche Experience Center. The program also included real trips around the test track.

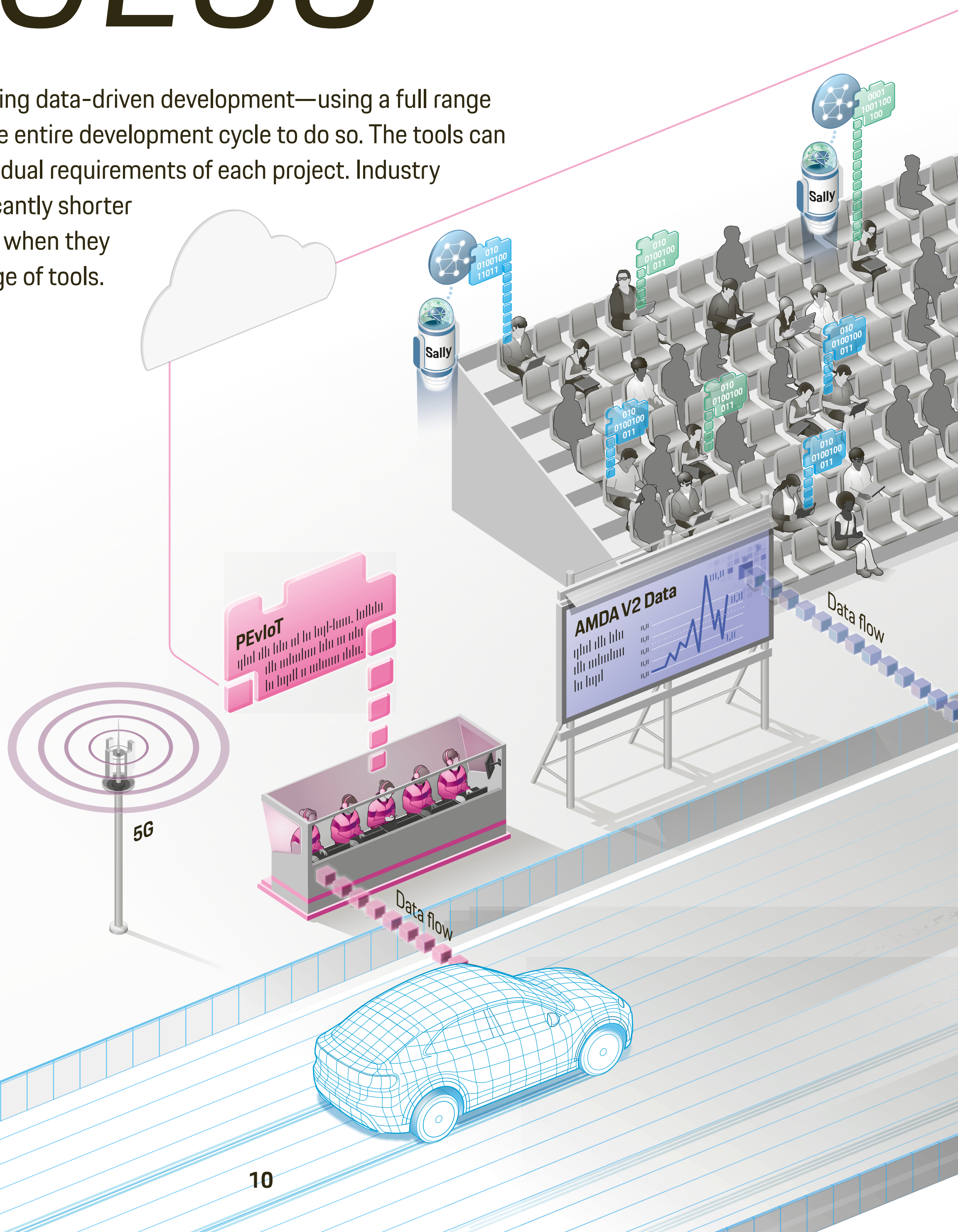
THE BUILDING BLOCKS OF SUCCESS

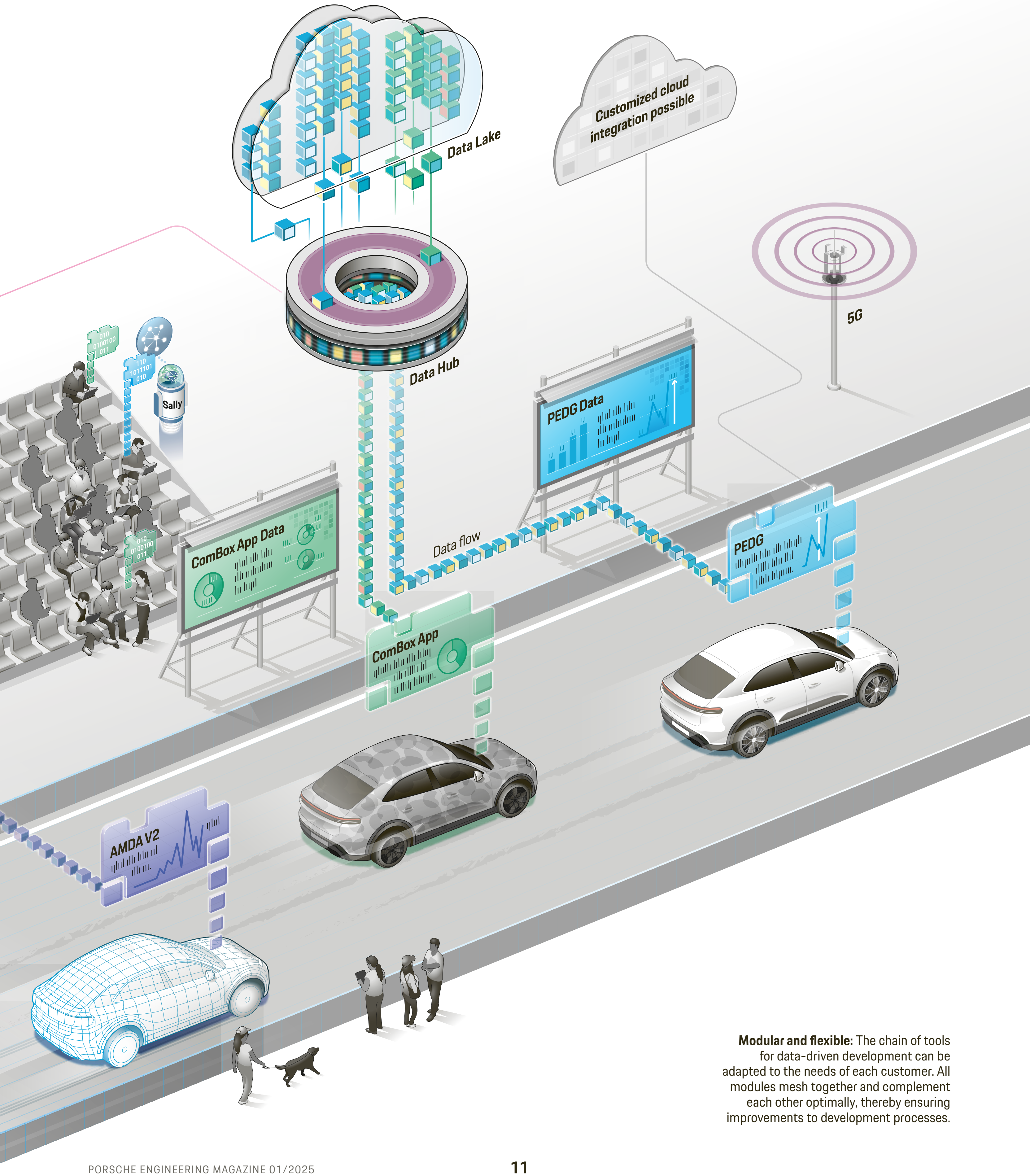
Porsche Engineering is embracing data-driven development—using a full range of modular tools throughout the entire development cycle to do so. The tools can be flexibly adapted to the individual requirements of each project. Industry customers benefit from significantly shorter development cycles, especially when they make maximum use of the range of tools.

Text: Christian Buck
Illustrations: Andrew Timmins

TITLE

MODULAR DATA-DRIVEN DEVELOPMENT ECOSYSTEM





Modular and flexible: The chain of tools for data-driven development can be adapted to the needs of each customer. All modules mesh together and complement each other optimally, thereby ensuring improvements to development processes.

Data is the new gold. This much-quoted statement is particularly true when it comes to vehicle development. Data analyses and data-driven development based on them are becoming increasingly important in this field. And that's no wonder, as they allow engineers to obtain faster insights into the current performance of new vehicle functions—and to draw conclusions from early phases, see what works, and identify where there are still issues. "With the help of data-driven development, we are now in a position to optimize new functions much more quickly and expedite their market maturity," reports Leon David Lange, Project Lead ADAS Data Analysis at Porsche Engineering. "Without this acceleration, particularly complex vehicle features could not be realized at all in a reasonable time."

However, the fast feedback loops from the development or testing phases require a tool chain that is as seamless as possible. "The benefits of data-driven development can be fully utilized if you have the necessary tools along the entire development chain," explains engineer Dr. Hagen Stübing, Senior Manager Software Engineering at Porsche Engineering. "This is why several specialist disciplines at Porsche Engineering have developed an integrated modular set of tools for different development phases. These tools optimize the development process both when used in isolation and as a complete range of tools—from recording and evaluating the data in the vehicle to its transport to the backend, storage, and analysis in the cloud, through to the transfer of new software versions back to the vehicle."

The tool chain has a modular structure and can therefore be flexibly adapted to the individual requirements of every industry customer. "Some customers only need the tools during development, while others want to use them end-to-end—that is, throughout the entire life cycle of a new vehicle," says Dr. Heiko Helble, Project Lead for Data Gatherers at Porsche Engineering. "Modularization means that we can adapt

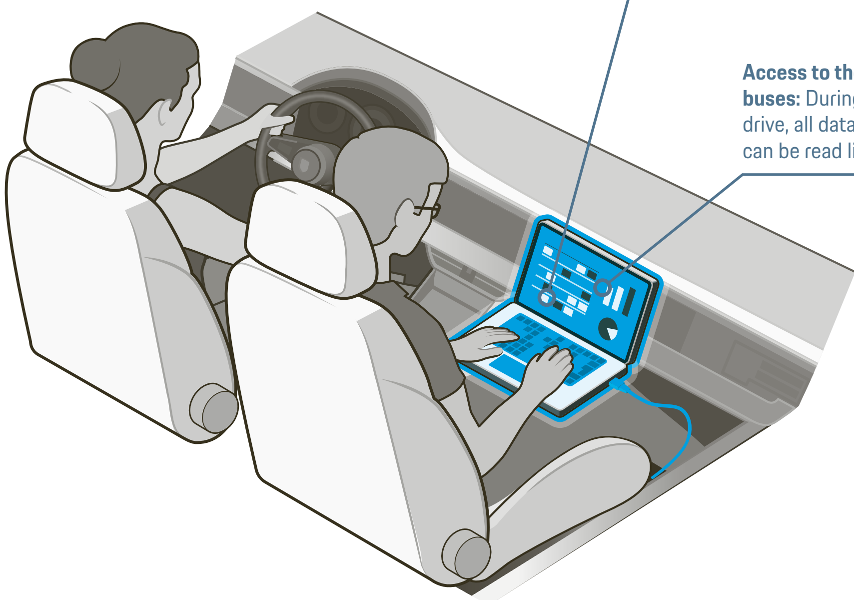
"With the help of data-driven development, we are now in a position to optimize new functions more quickly and expedite their market maturity."

Leon David Lange
Project Lead ADAS Data Analysis at Porsche Engineering

AUTOMATED MEASUREMENT DATA EVALUATION
AMDA V2

AMDA V2 (Automated Measured Data Evaluation Tool, version 2) is software for evaluating measurement data automatically and directly at the point of origin. It has access to the data buses of the test vehicle, which means that it can read the full data traffic live and immediately analyze relevant signals while the vehicle is moving. In this way, AMDA V2 is able to detect certain driving scenarios, such as a vehicle in front merging. At the same time, AMDA V2 records the reaction of the vehicle functions—in this example, the reaction of the adaptive cruise control longitudinal controller to the merging road user. Using key performance indicators (KPIs) based on vehicle data, the tool then objectively assesses whether the system has handled the situation well or not sufficiently.

Analysis directly in the test vehicle using AMDA V2 means that no large amounts of data need to be transferred to the cloud for evaluation. This not only reduces development costs, but also contributes to more efficient test procedures and increases the objective assessability of a function.



Evaluation in the vehicle: The data is analyzed directly in the vehicle with no need to send large amounts of data to the cloud.

Access to the data buses: During a test drive, all data traffic can be read live.

to any request." Porsche Engineering has developed a tool chain in-house that can be used from the initial development steps to endurance testing and series production. This increases the speed with which changes in the market can be responded to—with custom-fit tools at the right time.

PORTFOLIO OF SIX TOOLS

The Porsche Engineering portfolio currently includes six tools for data-driven development: The Automated Measured Data Evaluation Tool (AMDA V2) has been developed to evaluate measurements automatically, and directly in the vehicle. It is used in the early development phases. When the vehicle is closer to series production, the Porsche Engineering Data Gatherer (PEDG) that is integrated in the vehicle will then be used to collect data. The ComBox app, which runs on a standard Android smartphone, provides support for data provision and validation of test drives (see the detailed report starting on page 30). The LLM service platform SALLY specializes in use in vehicle development. SALLY is a digital assistant that supports developers. The PE IoT edge platform (PEvIoT) manages devices such as measurement technology via 5G from the cloud. It is integrated into a vehicle-based PC. The PEvIoT platform transfers all recorded data to a data lake in the cloud—the Porsche Engineering Data Hub (PEDH).

"Our tools incorporate the experience gained from many years of vehicle development at Porsche Engineering," says Daniel Schumacher, Specialist for Cloud Architecture at Porsche Engineering. "We can advance and adapt the tools and, as a development service provider, put them into use, because they were developed completely in-house." Porsche Engineering uses the tool chain in development projects, however also offers it to industry customers as "software as a product" via licensing. All tools can be booked on a modular basis, but the benefits offered by the overall package are particularly high.

"The benefits of data-driven development can be fully utilized if you have the necessary tools along the entire development chain."

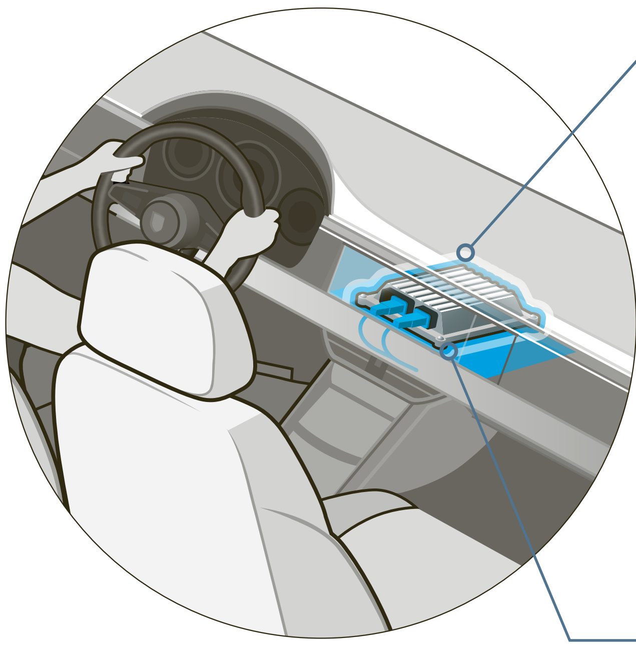
Dr. Hagen Stübing
Senior Manager Software Engineering at Porsche Engineering

DATA GATHERERS IN SERIES PRODUCTION CARS

PEDG

The Porsche Engineering Data Gatherer (PEDG) is a data collector designed for series use. In contrast to AMDA V2, the tool does not run on separate hardware (a PC in the vehicle or notebook), but can be embedded in an existing series control unit. This is why the PEDG is only used in later development phases and after the start of series production.

The PEDG can be set remotely using mobile technology (over-the-air) to automatically detect certain processes—for example, switching on a vehicle system or emergency handling of a situation. In this case, the tool automatically records all relevant signals and automatically returns them to a back end, where further analyses can then be carried out. The great advantage of the PEDG is that it is possible to record data in series-produced fleets without the need for physical access to the vehicles, for example by visiting a workshop.



"Modularization means that we can adapt to any request."

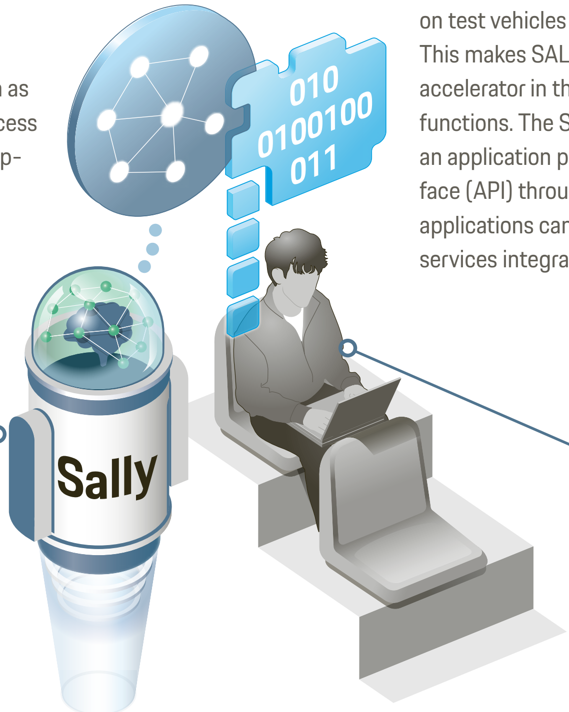
Dr. Heiko Helble
Project Lead for Data Gatherers at Porsche Engineering

LLM SERVICE PLATFORM FOR DEVELOPMENT

SALLY

SALLY is a platform in the cloud that software developers can access via their computers and that aids them in their work by acting as a digital assistant. Users can, for example, access information about the current status of tickets for specific events and receive support when working on new software functions via a prompt in natural language.

In contrast to well-known large language model (LLM) platforms such as ChatGPT or Deep Seek, SALLY has access to domain knowledge from the development of advanced driver assistance systems (ADAS); further domain knowledge is dockable. This allows SALLY to be used in areas such as developing ACC functions—on the one hand, to efficiently retrieve knowledge from the requirements and, on the other hand, to provide direct support during software development. For example, the tool can create code snippets, correct code, and create documentation from existing code. This allows new software functions to be created, analyzed and tested more quickly. In particular, the time required for troubleshooting and subsequent installation on test vehicles is significantly reduced. This makes SALLY a development accelerator in the area of new ADAS functions. The SALLY platform has an application programming interface (API) through which further AI applications can be set up and existing services integrated.



Digital assistant: The large language model provides natural language prompting and has domain knowledge from ADAS development.

Faster access to new software features: Among other functions, SALLY can assist in creating and correcting code.

DIGITAL ASSISTANT FOR TEST DRIVES

COMBOX APP

The ComBox app is a software that runs on a smartphone and serves as a digital assistant for the test driver. During test drives, it accesses the vehicle data from the data logger automatically or after a manual trigger; the data is then transferred to the cloud via the mobile network—and in some cases is pre-processed using AI. Currently, the ComBox app offers six different modes: Basic service, traffic sign recognition, scene recognition, acoustic complaints, infotainment recording as well as automated shift and test reports.

→ The ComBox app is presented in more detail from page 30 onwards.

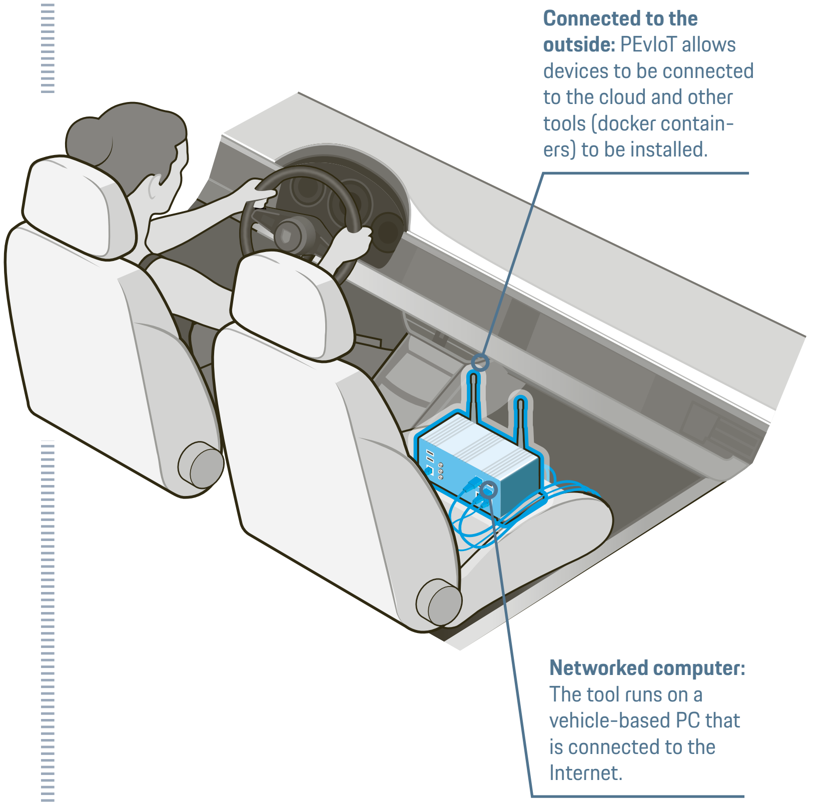
A meticulous record-keeper: The ComBox app records vehicle data after a trigger and sends it to the cloud.

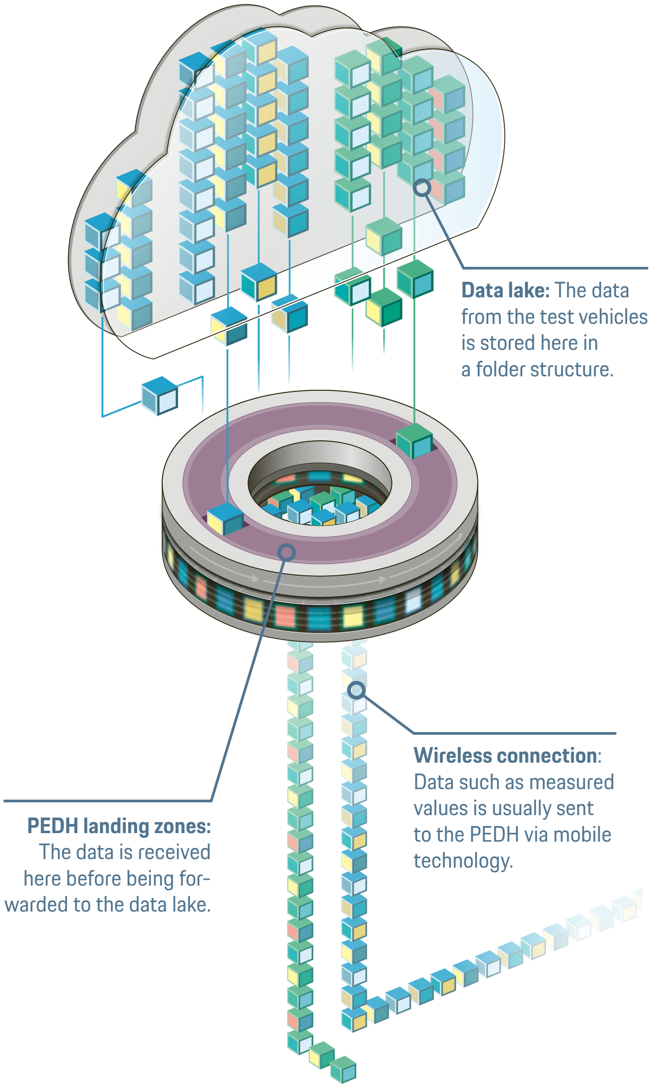
DATA LAKE IN THE CLOUD
PEDH

The Porsche Engineering Data Hub (PEDH) is another cloud platform from Porsche Engineering that can log all recorded data from the test vehicles in a data lake and store it in a folder structure—comparable to the file explorer on a PC, only scalable to an entire fleet of development vehicles. Developers in the Porsche network can access it, while indexing the metadata for the uploaded files allows for efficient filtering and searching. This makes it possible to immediately see information such as which vehicle uploaded the data, which tools have been used for recording it, and which software version was installed on the control units.

"Our tools incorporate the experience gained from many years of vehicle development at Porsche Engineering."

Daniel Schumacher
Specialist for Cloud Architecture at Porsche Engineering

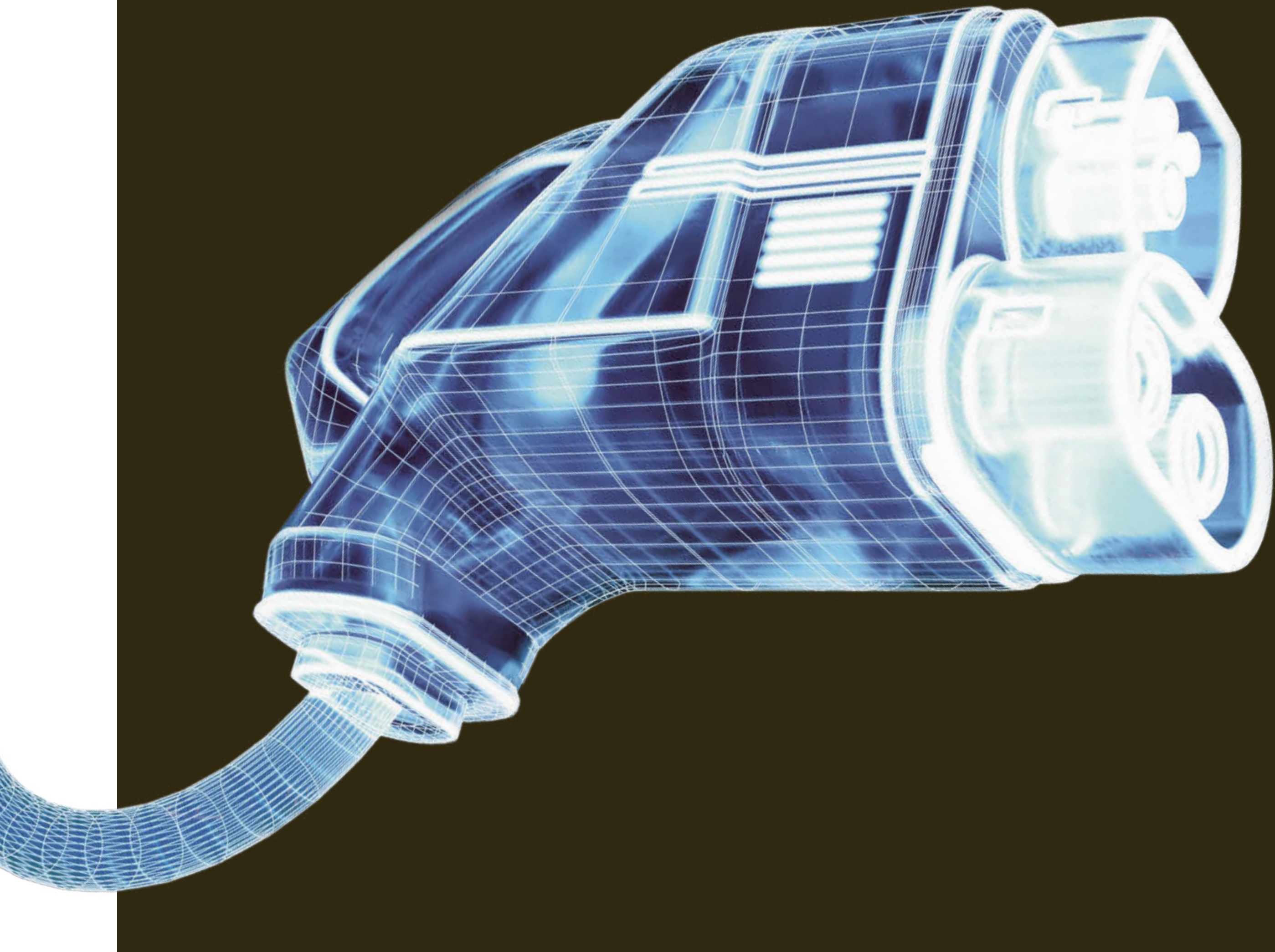




CONNECTED TO THE CLOUD
PEVIOT

The PE IoT edge platform (PEvIoT) connects devices to the cloud, such as the measurement technology in the vehicle or the PCs on HiL (hardware-in-the-loop) test benches. It runs on a vehicle-based PC that is connected to the Internet (via 5G, for example). PEvIoT can be used not only to transmit measurements, but also to install or update other tools such as AMDA V2 in the vehicle—easily and fully automatically. Docker containers are used to dispatch the tools; these package software together with all dependencies such as operating system libraries, software frameworks or databases. This ensures smooth operation in a wide range of computer environments.

PEvIoT enables the use of different tools in the vehicle and significantly reduces the time required for commissioning them. At the same time, updates can be distributed flexibly and entire vehicle fleets can be managed conveniently from a remote location.



Porsche Engineering offers its customers complete development and validation of high-voltage charging management systems. The solution enables automotive manufacturers to enter the market quickly with intelligent charging functions for electric vehicles. At the same time, the system can be used worldwide because all relevant charging standards have been factored in. The central function of the software is charge planning.

Text: Richard Backhaus

Charging ahead

High-voltage charging management (HV charging management) is a key criterion for customer satisfaction when it comes to plug-in hybrid and electric vehicles. It detects the charging power, authenticates the vehicle with the charging station, communicates with the infrastructure, controls the charging flap, and provides the data for the customer's mobile end device, where the charged energy is displayed in an app. This ensures that the charging process proceeds conveniently for the user and functions reliably in all everyday situations and environmental conditions.

Porsche Engineering has been developing advanced charging management concepts since 2011 and has built up extensive development and validation expertise in the process. "When developing the charging management software, we cover all tasks involved in the V model—from requirements analysis to validation. This enables our customers to enter the market quickly and cost-effectively," explains Dominik Langen, Deputy Project Lead for Charging Systems at Porsche Engineering.

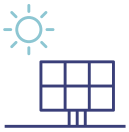
In this way, Porsche Engineering supports the development of passenger cars with plug-in or electric powertrains within the Volkswagen Group—as a central development partner for high-voltage charging management. "Our team handles every step from defining the requirements to designing the software architecture, modeling the software functions, writing the code, and integrating it into the control unit, all the way to test bench validation," says Langen.

Advanced charging management:

Reliably charged: HV charging management ensures that charging functions conveniently and reliably.

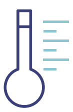
"When developing the charging management software, we cover all tasks involved in the V model."

Dominik Langen
Deputy Project Lead for Charging Systems
at Porsche Engineering

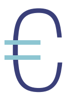


Yielding to the sun:
If possible, the charging software uses free energy from the home solar power system.

Charging worldwide:
The software supports all charging standards so that electric vehicles can be used globally.



An eye on the temperature:
Even at very high and low temperatures, the charge planning is highly accurate.



Saving costs:
The forecast-based procedure helps minimize charging costs.

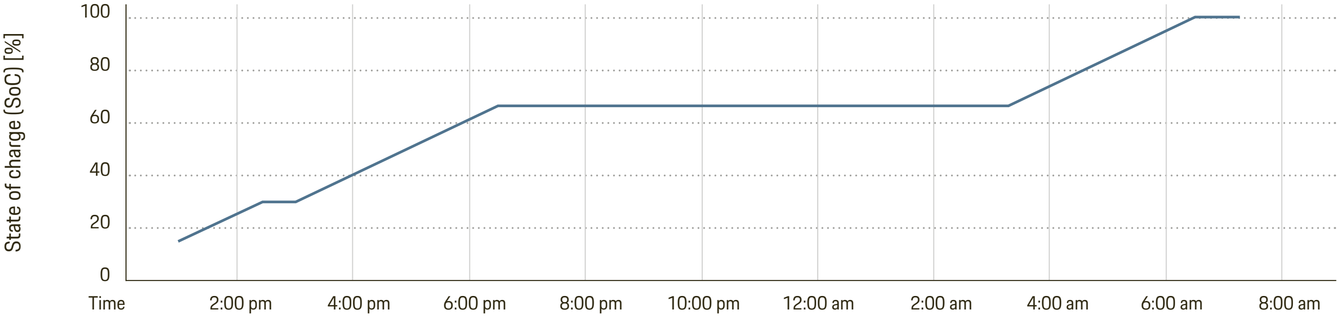
To date, 13 vehicle variants from diverse platforms within the Volkswagen Group have already been equipped with individually tailored charging management solutions. A single software system that can be flexibly adapted to the respective vehicle model and target market always forms the basis for this. Programming into the control unit is carried out easily and reliably via adjustable software parameters. "This makes it easier for automotive manufacturers to manage variants, as the same software is uploaded to the charging control for all electric and plug-in vehicles. It is only during vehicle production that the employee makes the adaptation by setting specific parameters," says Langen. Another advantage of the concept is the efficient implementation of software updates: A new program code only needs to be developed, tested, and released once for all models.

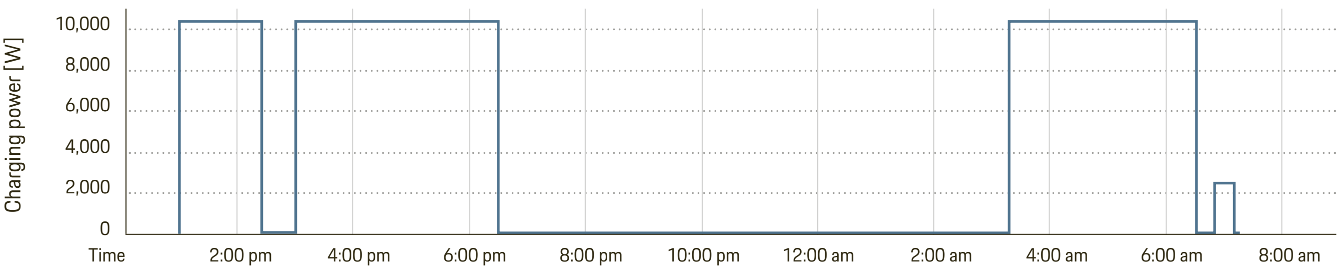
The software system itself has a modular structure and consists of six program modules, each of which performs defined tasks: High-voltage charging management (HVLM), intelligent charging function (ILF), high level communication (HLC), control and display protocol (BAP), charging management safety function (CMSF), and value added services (VAS). "Through modularization, we factor in the numerous requirements made of charging management during development and are able to optimally coordinate these with each other," says Narendra Kumar Boorlagada, Project Lead for Charging Systems at Porsche Engineering. Some of the requirements are determined by the technical hardware components. The status of the battery—for example, its temperature and residual capacity when charging starts—has a significant impact on the energy that can be stored, and therefore the course of the charging process. To put it simply, the energy flow slows down if the battery is too cold or warm or almost fully charged. What's more, the charging management system offers functions that make charging easier for the end customer and improve the customer experience. For example, the HVLM program module opens the charge port door so that the driver can plug in the charging cable. It also enables the vehicle electronics for charging. Customers no longer need a credit card for authorization at the charging station, as the secure automatic identification is carried out using the HLC program module by means of the "Plug & Charge" function.

IN DIALOG WITH THE INFRASTRUCTURE

During charging, the system detects the maximum available charging capacity, exchanges information with the infrastructure, and supplies the data for the customer's mobile end device via the control and display protocol program module, which can be used to display information such as the battery charge state and the planned charging time in an app. The possible charging performance of the system includes AC charging with low power, charging at the DC charging station, and even high-power charging (HPC) with several hundred kilowatts of power. If the vehicle is charged at home using a wallbox, automatic data exchange between the HLC and the home energy system ensures that the house connection is not overloaded.

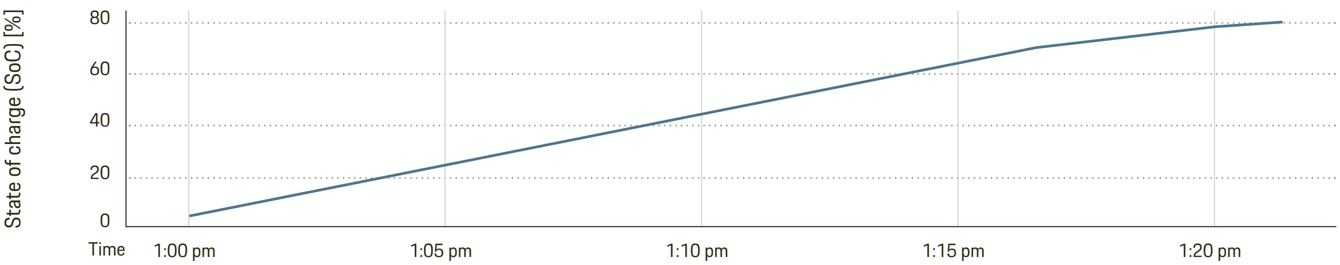
CUSTOM PROCESS
COMPARISON OF WALLBOX AND FAST CHARGING

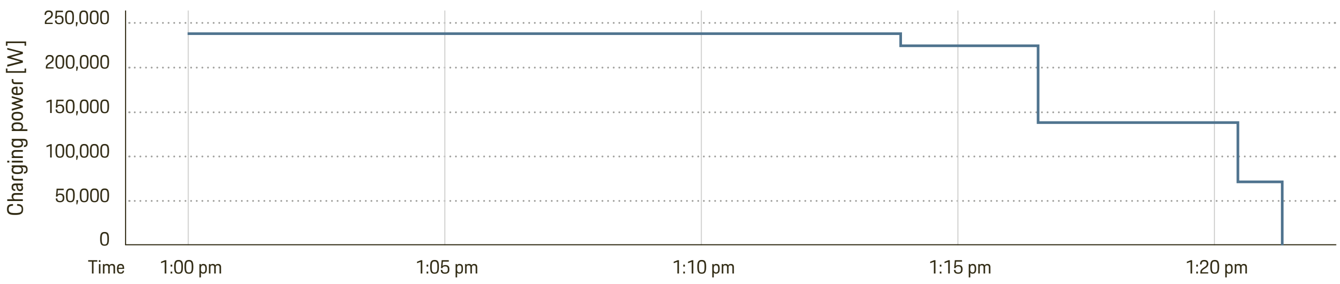




Wallbox charging

The battery is initially charged to a **minimum SoC** as quickly as possible so that the vehicle is ready for unexpected journeys. The second phase starts when the **preferred time window** is reached—for example, a time with particularly low electricity tariffs. The battery is only fully charged shortly before the planned end of charging. **Auxiliary consumers** such as the air conditioning system are also supplied from the power grid. Since the home network can only provide low power, charging always takes place with the **maximum value** (in this case 10 kW).





Fast charging

Fast charging is all about getting **as much energy as possible** into the battery in the shortest possible time—without damaging it. This is why the HV charging management constantly adapts the power to the battery's characteristics. After all: The higher the state of charge, the lower the permissible charging capacity. The **battery management system** calculates exactly where the current maximum is—based, among other factors, on the temperature of the battery. In this example, the charging power gradually drops from 250 kW to only 75 kW.

No grid overload: The charging software takes the current grid load into account and prevents overloads.

Full transparency: The charging management system provides data to mobile end devices, such as the amount of energy charged.

Identity on board: The software automatically verifies the electric vehicle at the charging station (PnC).

Modular approach: The software can be flexibly adapted to the vehicle model and the target market.

"A high degree of flexibility in the charging connection was one of our most important development goals. The HLC program module supports all charging standards worldwide, including GBT, GBT+, Chaoji, Chademo, ISO 15118 or DIN EN 62196, and enables customers to use their electric vehicle in all regions around the world," explains Boorlagada. One development challenge is the imprecise specifications of some charging standards, which leave room for interpretation in the technical implementation. Boorlagada: "In individual cases, the charging system may comply with the standard, but communication between the vehicle and the infrastructure does not function smoothly. We validate these cases with a compatibility mode that guarantees the basic function of the charging process." If a malfunction occurs during charging, the CMSF program module detects this and switches the system to a safe state. VAS offers functions such as an interface to the in-cable control and protection device (ICCPD), which can be used to charge the vehicle using a standard home electrical socket.

The central component of Porsche Engineering's charging management system is the creation of the charging plan. This determines the time curve for the energy input into the battery within the total charging time. The default is for the charging management system to charge the vehicle battery as quickly as possible to a minimum 25 percent state of charge after connection to the charging station, so that a sufficient amount of energy is available for unplanned journeys. "After that, our forecast tool for creation of the charging plan comes into play. It consists of individual time intervals for which an electrical charging capacity is defined. The overall charging plan is obtained by arranging the individual intervals into a sequence," explains Norbert Melinat, Technical Project Manager for Charging Planning at Porsche Engineering. The charging management system must ensure that the most favorable electricity tariff is used while simultaneously ensuring that the vehicle is fully charged at the desired point in time.

USING SURPLUS ENERGY

The charging plan takes various factors into account, such as current grid utilization, the availability of environmentally friendly energy from the home solar power system, and the vehicle's charging requirements. In a specific example, surplus energy from the solar power system can be transferred to the vehicle when capacities are available, thereby storing it. The charging management system receives up-to-date information on dynamic electricity tariffs via communication with the infrastructure. By using intelligent algorithms and real-time data, this matrix is used to create a dynamic charging plan that can react flexibly to changes—for example, if the infrastructure can provide less energy in the short term than predicted. The user is shown the calculated charging process and the expected charging time via a smartphone app. "The forecast-based procedure helps to minimize charging costs while reducing the grid load, which also makes charging management very complex," says Melinat.

"A high degree of flexibility in the charging connection was one of our most important development goals."

Narendra Kumar Boorlagada
Project Lead for Charging Systems at Porsche Engineering

"The forecast-based process helps to minimize charging costs while reducing the grid load."

Norbert Melinat
Technical Project Lead for Charging Planning at Porsche Engineering

HIGH PLANNING QUALITY DURING CHARGING

One particular challenge is the calculation of precise charging plans at very low or high outside temperatures, as the chemical reactions in the battery are particularly volatile under these conditions. This is mitigated during charging plan execution by a monitoring function that starts running additional calculations parallel to the actual charging planning and compares the results. "This increases the planning quality over the course of the charging process, and the charging time specifications successively become more precise," says Melinat. As practical experience in the development of charging management has also shown, focusing on a single optimized charging plan is not expedient, as the charging strategy may have to be adapted during charging.

If the user has specified a fixed departure time using "timer charging", the charging management system must ensure that the vehicle battery reaches the required state of charge in the predefined period of time under all circumstances. In this case, the total charging time is therefore divided into subphases. The main phase comprises the regular charging planning. The end of this phase is limited by the departure time specified by the user, minus a time buffer of typically 30 to 60 minutes. This serves as additional charging time in the event that the charging goal could not be reached within the main phase. In the subsequent third phase, the vehicle is pre-climatized. In this phase, the charging planning makes calculations using a reduced charging capacity, as the charging system must cover the required energy for the air conditioning at the same time.

For the validation, dedicated hardware-in-the-loop (HiL) test benches were set up on which the software is tested in an automated process. "From 2021 to 2024, our experienced international team also implemented the next milestone development in charging management: The complete redesign of the software," says Boorlagada.

While the old software structure had evolved over the years and been successively expanded, the new code now includes a compact summary of all functions of the charging management system, including charging planning, so that the already-low memory requirement on the control unit of the on-board charger as well as the computing speed could be further minimized.

SUMMARY

Porsche Engineering has extensive expertise in the development and validation of HV charging management systems, which enables vehicle manufacturers to enter the market quickly and cost-effectively. Intelligent charging planning always uses the most favorable electricity tariff and at the same time reliably ensures that the vehicle is fully charged at the required time.

In the same orbit

How can automotive development service providers and aerospace benefit from each other? In this interview, ESA astronaut Dr. Matthias Maurer and Dr. Christoph Roggendorf from Porsche Engineering talk about material research, autonomous systems, and virtual test methods.

Text: Heike Hientzsch
Photos: Max Brunnert

Collegial atmosphere: Dr. Christoph Roggendorf (left) and Dr. Matthias Maurer meet at the Columbus module at ESA's European Astronaut Center in Cologne.

Dr. Matthias Maurer
was the second German ESA astronaut to fly to the ISS, as part of NASA's Commercial Crew Program in the fall of 2021. During his 177 days in orbit, he conducted numerous scientific experiments with researchers and partners around the world.

Mr. Maurer, you are a passionate scientist and spent six months conducting research on the International Space Station ISS in 2021/2022 with the Cosmic Kiss mission—including extra-vehicular activity. Now you are in charge of setting up the LUNA Analog Facility in Cologne, the ESA and DLR simulation facility for future lunar missions. Are you satisfied with the pace of this lunar approach?

— **MM:** I am very satisfied with our LUNA moon training facility—I would even go as far as to say that it is the most advanced facility in the world. Even NASA recently visited us in Cologne to conduct measurements here. Its employees tested a new camera here which will be used on the moon—I was then allowed to test it in the extreme conditions simulated here. We're very proud of that. We will also soon be testing a new lunar station here. You can imagine a high-tech container in which we will spend weeks living in realistic conditions. A tunnel will then connect this container to the LUNA training facility. This also means that we will not leave these connected areas during the simulated operation—and therefore won't see any sunlight either. On the surface of the moon there is high abrasive volcanic dust to deal with. Rock on the moon hardly moves, since there is no water and no wind either due to the lack of an atmosphere. This is why the shape of the sand grains is sharp edged and also the sand is very sticky, much like flour. Added to this are craters whose depth is difficult to estimate and icy temperatures as low as 150 degrees below zero. In the shady areas of the moon, in the deep craters, into which sunlight never penetrates, temperatures can plummet as low as 250 degrees below zero. Another challenge is the low-lying sun, which casts tricky shadows. This is what awaits us in the polar region of the moon—and this is where we intend to go.

That all sounds very concrete—what are the remaining challenges?

— **MM:** What we don't have at the moment is our own rocket and capsule. The challenge this involves is that both the rocket and the capsule must be certified for transporting people. The special consideration here is that the capsule must return at some point, and must not burn up when it re-enters the Earth's atmosphere. This is due to the high speed and the frictional heat that is generated upon re-entry. In the past, we relied heavily on international engineering and partnerships here. However, it is time for Europe to step up its resilience in this respect—this certainly applies to several sectors, but aerospace is a key one.

Mr. Roggendorf, you come from the world of mobility systems, and yet you have long been working in all domains: from the road to space. How is it possible, as a development service provider, to succeed in dealing with such a broad spectrum—not least in visionary projects with many unknowns?

— **CR:** This broad spectrum is exactly what drives us and inspires us as engineers. In our interdisciplinary teams, for example, a large proportion of developers have a background in aeronautic and aerospace technology. These skills help us with a wide range of technical challenges in a wide range of industries. We are currently developing a complete energy system for satellite applications. The requirements in low-earth orbit are very similar to those in the automotive sector, for example with regard to temperature profiles or vibrations during a rocket launch.

Mr. Maurer, ESA is an aerospace agency and has a very different setup to commercial companies. What ways of thinking and working are crucial to allow people to be able to actually live and work on the moon one day?

— **MM:** ESA operates with taxpayers' money, which means that we use this money in a very responsible manner. It also means, however, that we face quite a lot of bureaucracy and have to deal with delays that private companies in industry do not have to the same extent. We often say: Let's do a study—and then a second and a third. The aim is to meet legal requirements and to proceed very correctly. The main task of ESA is to specify the direction, to define programs, and to outsource them to industry. If the industry itself could define goals and address them at its own risk and with its own capital, supported by ESA as a reliable anchor customer, this would certainly introduce more speed and agility. And at this point, we also need more players.

Mr. Roggendorf, how do you see the future in this regard?

— **CR:** We have always had the drive to venture beyond the automotive industry and into other industries. It is exciting for us to combine knowledge from different industries and to make a contribution with our engineering services. Process-efficient—from proof of concept and testing of physical limits at an early stage, through to the fastest possible approach to a solution that is ready for series production.

"Even NASA recently visited us in Cologne to conduct measurements here."

Dr. Matthias Maurer
astronaut at the European Space Agency (ESA)

Of course, research and progress cannot be achieved without setbacks. As a development service provider, how do you deal with failure? How do you succeed in boldly developing new technologies and at the same time validating processes for customers?

— **CR:** This depends entirely on the stage of development and customer expectations. There's a Ferry Porsche quote that fits perfectly here: "We are not

Difficult terrain: The surface of the moon has sharp-edged sand and treacherous shadows, which have been realistically reproduced at the LUNA training facility in Cologne.

afraid of setbacks. On the contrary, we expect them. If you don't fail from time to time, then you didn't really challenge yourself." This is the motto that we apply to our work every day. As an engineer, I have to and want to test the limits of what is technically feasible, especially in pre-development phases. If everything always goes smoothly, then I have learned too little. We have to promote an error culture that allows mistakes to be made in these phases. Of course, this is different in the series phase. At that point, we have to have an absolutely functionally reliable, error-free, and high-quality product.

Mr. Maurer, in manned space flight in particular, the reliability of a development is a matter of life and death. How do you strike a balance between "better safe than sorry" and the courage to take risks?

— **MM:** Up to now, aerospace agencies have always carried out an extremely large number of tests in order to rule out as many errors as possible before launching a rocket—this is, of course, very time consuming. And you can learn a lot from it, in particular when something goes wrong. In the meantime, a new error culture has taken root in aerospace due to the influence of industry: "Fail early, fail often." This happens to a certain extent in large-scale rocket projects—a rocket explodes and employees cheer because they weren't expecting a total success in the first place. It's hard for me to imagine that happening at ESA, but it's a direction we need to take. Of course, only as long as there are no people sitting in these rockets and no one is harmed on the ground. As soon as we start talking about manned space flight, we must have an absolute zero-error policy—and a reliable fallback system. If a rocket has a problem, the astronauts in the capsule are ejected and come back down to earth with the parachute. And this fallback system has actually already been needed, and resulted in the astronauts landing safely.

To what extent can aerospace benefit from industrial and commercial achievements in terms of cost-effective manufacturing and profitable development timeframes? And what can space research specifically do for companies?

— **MM:** I'm very keen on the idea of "spin-in". That is to say, to ensure that we incorporate industrial capabilities and innovations into aerospace projects. The automotive industry is so innovative and so fast in development that an incredible amount of technology is either already in use, almost ready for series production, or at least in the drawer. I dream of opening this drawer and tipping its contents into the aerospace sector. The prerequisite for this is establishing a dialog between the two worlds. After all, something has shifted in terms of innovation drivers. In the past, the entire IT system had to be developed for the Apollo mission. That was a driver

"Especially in pre-development phases I have to and want to test the limits."

Dr. Christoph Roggendorf
Director Energy System at Porsche Engineering

Just like on the moon:
Dr. Christoph Roggendorf lets the sand slide through his fingers at the LUNA training facility.

Workstation in space: Dr. Matthias Maurer and Dr. Christoph Roggendorf examine the interior of the Columbus module.

Dr. Christoph Roggendorf has been Director of the Energy System division at Porsche Engineering since 2023. His main areas of activity include electric mobility, charging infrastructure, and HV systems, such as components for battery storage and power electronics.

of innovation, if you look at the patents that emerged from that. However, in today's aerospace, we have highly established processes and make use of a lot of heritage. Using new technologies means overcoming new hurdles—and the technologies must be certified. As a result, we use very old systems and even older computers on the ISS. I hope that we will increasingly introduce new technology—and dialog, as we are engaging in here today, is essential for this.

Mr. Roggendorf, to what extent can industry and you, as a development service provider, benefit from aerospace programs?

— **CR:** The topic of material research is always very exciting for us, and also one of Mr. Maurer's pet passions. Historically, many high-end materials from which industry has benefited have come from aerospace applications. And that's where these two worlds are growing together. New business areas are emerging—we are now also involved in the satellite sector, for example. Traditionally, virtually every satellite has been a one-off. The objective now is to see how such systems can be standardized and constructed in a modular way. This means our experience allows us to provide assistance in the industrialization of products and thereby enable our customers to scale up in the new business areas.

— **MM:** Autonomous systems are also a major issue that exhibits an overlap. On Earth, the focus is on autonomous driving with artificial intelligence. In space, we are now also reaching a level of traffic density in which individual people will soon no longer be able to control all of the satellites. There are more than 12,000 satellites in orbit, some of which are no longer active and therefore no longer controllable. So there are lots of wrong-way drivers up there in space, which we either have to sidestep or capture. These satellites have been controlled by people on Earth, but this will no longer be possible given the sheer number of satellites. This control

Intensive dialog: The two technology experts talk in the entrance hall of the LUNA building, a plan of which is displayed behind them on the wall.

must be replaced by artificial intelligence—the satellites must use it to operate autonomously. The terrestrial and cosmic challenges and questions are pointing in the same direction. Aside from the fact that we don't need a reverse gear in space. (laughs)

— **CR:** When we think about autonomously controlled satellites, the question of precision also arises. And we have a lot of experience with that. In the automotive industry, we're talking about centimeters—for satellites, we are talking about many kilometers. However, the intervention mechanisms are comparable. And we can also make a valuable contribution to fleet management—given increasing numbers—with our methods and tools in the areas of control and automation, and even artificial intelligence.

Staying on this topic: Mr. Roggendorf, how can this knowledge—for example, with regard to development processes, virtual test methods or high integration—be applied to aerospace projects?

— **CR:** I think these are exactly the methods that need to be used in the aerospace sector. Virtual testing methods are a great example. We are working on digital twins of entire systems. Let's take a vehicle battery as an example. Through a digital twin and live data transmission, we come to know and understand the system in great detail during development. I can get the most out of it and extend the service life of the battery. Virtual methods and processes like these are, of course, even more important in space. After all, I can't repair things or refuel as easily. Every gram of fuel and everything I have to bring up there costs an immense amount of money.

— **MM:** In fact, we also use VR technology with twin models here at the LUNA training facility, because we cannot reproduce every device as a physical model. Instead, we wear VR glasses in our spacesuit and display different devices, measuring instruments or another space station in order to interact with them.

"Space flight is such a vast undertaking, and no single country in Europe can manage it alone."

Dr. Matthias Maurer
astronaut at the European Space Agency (ESA)

— **CR:** If you take this idea in regard to the methods a step further, we invest a great deal of effort in achieving end-to-end solutions—that is, from the product definition to automation of requirements and the generation of test cases with the support of AI, to efficient evaluation of live analysis data. In the case of highly individualized products in particular, where these development phases take an extremely long time, we can become significantly faster with an end-to-end toolchain.

Another common feature of your two fields of activity is the global orientation. How important is the international network?

— **MM:** Space flight is such a vast undertaking, and no single country in Europe can manage it alone. As already mentioned, we in Europe as a whole are not yet in a position to fly our own astronauts. We could do that in terms of content, but the financing is unresolved. We have incredible strengths thanks to the huge wealth of experience of different European cultures and different fields of engineering expertise. We can generate potential from this—and we can significantly expand this potential by opening the doors and working together with experts who come from outside the aerospace industry. This will enable us to put Europe in the pole position.

— **CR:** For us at Porsche Engineering, internationalization is very important and a key factor for our success. In Europe, we operate a number of different locations: apart from Germany mostly in Czechia and Romania. We also have a large test facility and an engineering hub in Italy. Our asset is the engineers, the brains of the operation. In order to attract the best talent, the most motivated and highly trained engineers, cooperation with universities in various regions of the world is extremely important. We also have development locations in the US and China. Above all, because they have very different requirements for vehicles than in Europe. Thanks to our local presence, we understand much better what the specific market needs. In terms of connectivity alone, we are dealing with completely different ecosystems, entire app worlds on smartphones, particularly in China. Vehicles are simply used differently there. The right ideas won't occur to you while you're sitting in an office in Germany. In addition to the purely technical side, intercultural cooperation is extremely instructive and fruitful in regard to other ways of working.

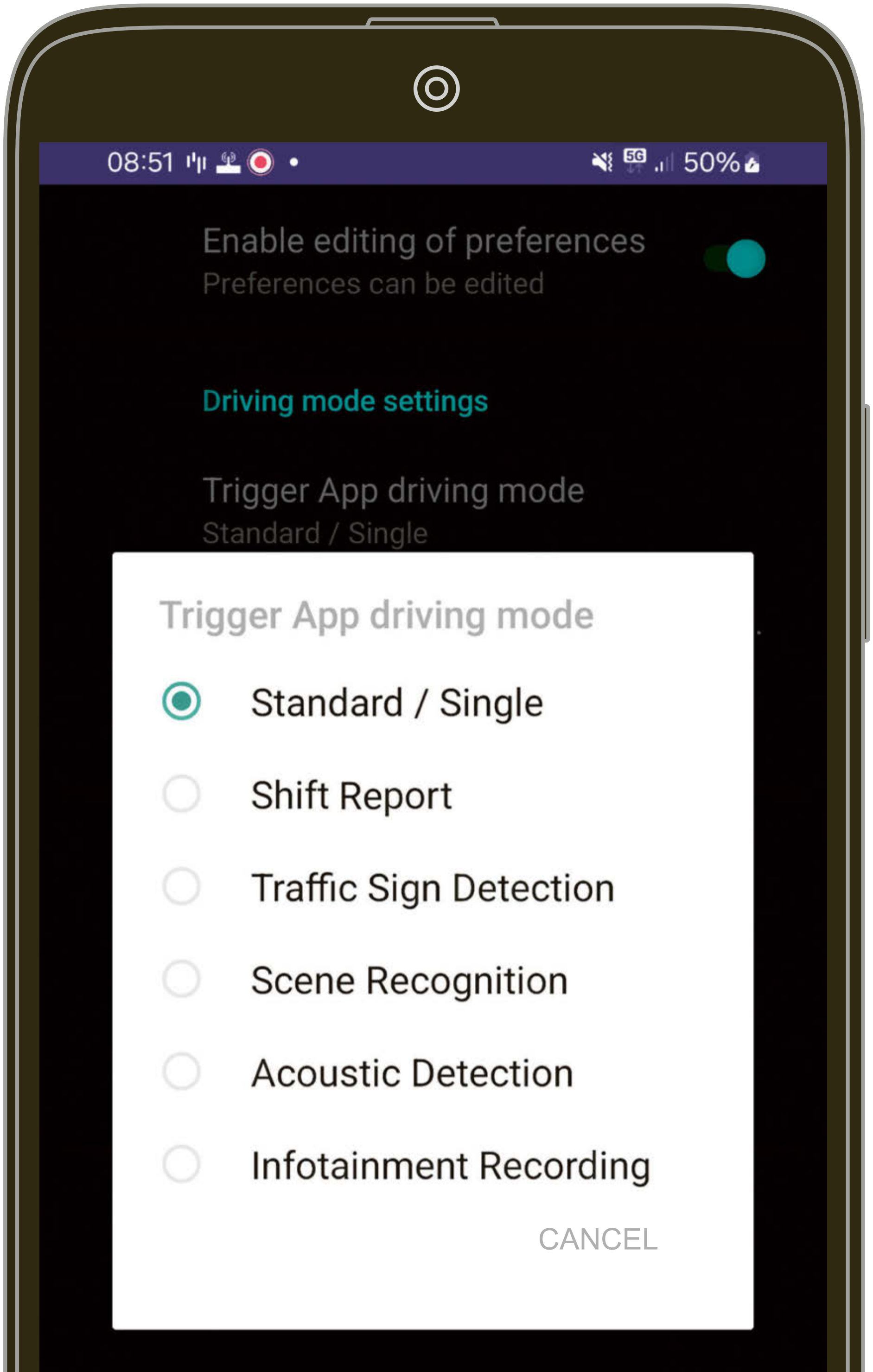
Finally, a personal question for both of you: What drives you?

— **CR:** It was clear to me at an early stage: I will become an engineer because of my passion for technology. I love trying things out, developing things, refining innovations. And that inspires me every day. We have a highly motivated team to tackle and implement truly novel ideas together. I originally come from the energy sector. It was always a matter of first integrating renewable energies into the grids and ultimately enabling today's electric mobility. My focus is on advancing new technologies for our planet. I also look at my children, for whom I want things to go well later on. That's why I get up every day and enjoy going to the office.

— **MM:** As an astronaut, of course, you are someone who is led by your dreams. All I need is to gaze into the night sky every evening and to marvel at how much there is still to discover out there. There are so many places where I want to go and where I want to learn something. The fundamental question here is: How did all that out there come about? How did life come to Earth and how did our solar system come about? Are we alone in the universe or are there other intelligent beings out there? And how might they live? These questions have a lot to do with dreams, but also with a sense of adventure and the drive to discover new things. In addition to my enthusiasm for technology as an engineer, from a science standpoint I am fascinated by the fact that I am allowed to do new experiments every day in space and look over the shoulders of the best researchers in the world. That really energizes me. And then there is the dream of flying to the moon itself. We are looking through the glass here at an Apollo situation—I would like to go there. And another motivation is to share knowledge and inspire the next generation.

Much in common: In the view of the two experts, the aerospace sector and industrial engineering can benefit greatly from each other.

Evaluation at the touch of a button

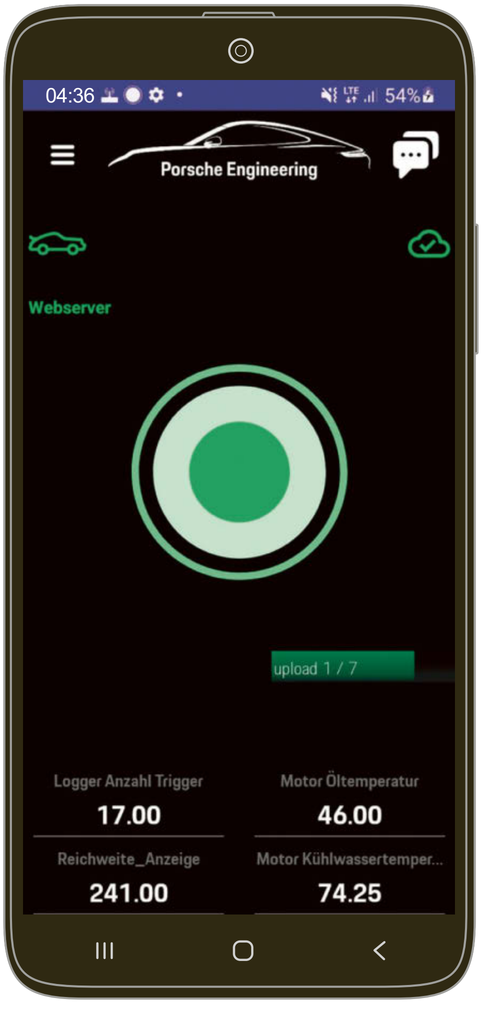


Versatile: The ComBox app provides users with six modes that make their work much easier. They can be easily selected upon launching the app.

The ComBox app from Porsche Engineering records relevant measurements in test vehicles, evaluates them with the help of AI—on the spot in some cases—and automatically sends the results and measurement data to the cloud. This reduces the manual workload for test drivers and increases the efficiency when developing and validating new vehicle functions.

Text: Christian Buck

Standard/Single service: A single press of the button is all it takes to trigger a measurement. All vehicle data in a time frame of six minutes is loaded into the cloud—for example, from three minutes before to three minutes after triggering.



Drivers of development vehicles already have their hands full identifying, documenting and reporting technical abnormalities of new vehicle functions to the respective development departments during their test drives. "We welcome any simplification of our work, especially with regard to ADAS and drive issues, the validation of which is particularly time-consuming," reports Jan Wörner, Project Manager in Data Driven Testing & Vehicle Functions at Porsche Engineering. "That's exactly why we developed the ComBox app: It's the engineer's companion and serves as a kind of digital assistant during the testing. It also performs many calculations directly in the vehicle and identifies important scenarios in the measurement data without the driver having to intervene. This edge computing means we have to send significantly less data to the cloud for evaluation."

SIX MODES TO CHOOSE FROM

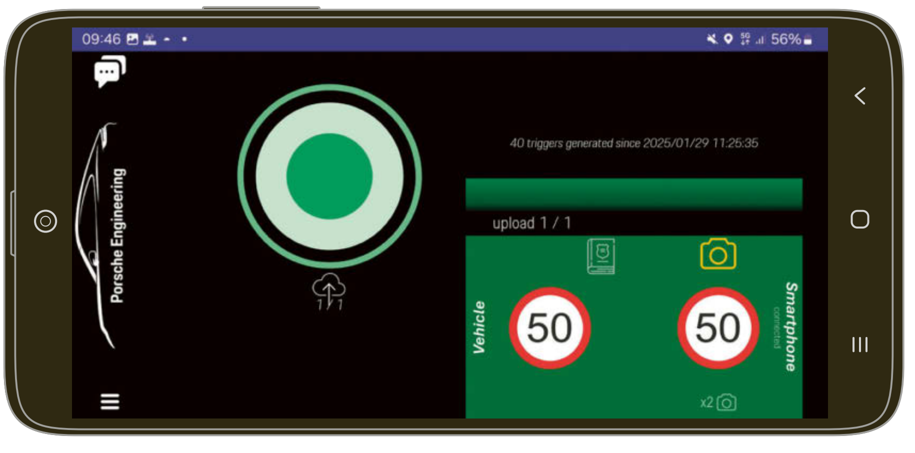
A commercially available high-end smartphone serves as the platform for the ComBox app. Most of the computing resources of this smartphone are available to the assistance software developed by Porsche Engineering. After launching the app, the user can select from six different modes: "Standard / Single" can be used to trigger measurement of vehicle control unit data at any time in order to record this measurement data and upload it to the cloud. "Scene Recognition" mode can record general traffic scenarios that are relevant for ADAS functions, for example. "Acoustic Detection" mode uses AI help to find distracting noises, while "Infotainment Recording" offers support with correcting display problems. "These four modes have one thing in common: After a manual or automatic trigger, they record patterns or errors and send the corresponding data to the cloud," says Wörner. "Shift report" mode is used after the test drives and reduces the work involved in creating the log. "All modes reduce the manual workload, which increases efficiency and cuts human errors in the testing and fault elimination process," explains Wörner.

ACCESS TO THE VEHICLE BUSES

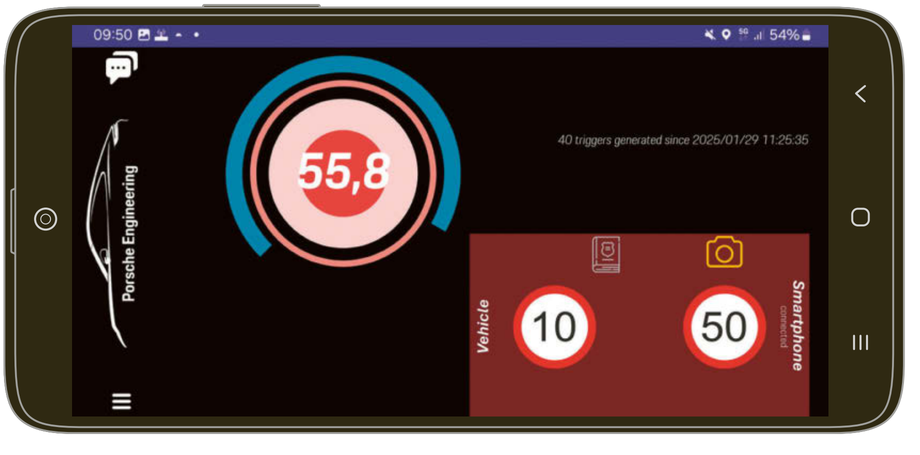
The prerequisite for this is that all modes have access to the relevant vehicle buses and data. The ComBox app obtains this data from a data logger in the test vehicle, such as Porsche Engineering's Car Data Box. "The data logger has full access to all bus systems such as CAN, LIN, FlexRay, and Automotive Ethernet, which it uses to provide information about the current status of all vehicle systems," explains Wörner. "It forwards this data to the smartphone with the ComBox app—either via cable using an Ethernet-to-USB adapter or via Wi-Fi, if there is a wireless access point in the vehicle that is connected to the data logger."

With the ComBox app's Standard / Single service, the driver can trigger a measurement manually if any abnormality occurs. "This means that all measurement data from the vehicle is recorded within a defined timeframe around the trigger time and loaded into the cloud. The timeframe could be, for example, from three minutes before the trigger time to three minutes after it," says Wörner. "The driver can also input a voice explanation into the smartphone, which is then automatically converted into text and sent to the cloud together with the measured data via a 5G network. With this method, detailed additional information can be recorded immediately and thereby be made available without delay for the downstream error analysis. The other modes also offer this option."

"Acoustic Detection" mode automatically identifies certain unwanted noises in the vehicle and, under certain framework conditions, provides support with identifying the cause. "The ComBox app uses the smartphone's high-quality microphone to detect the

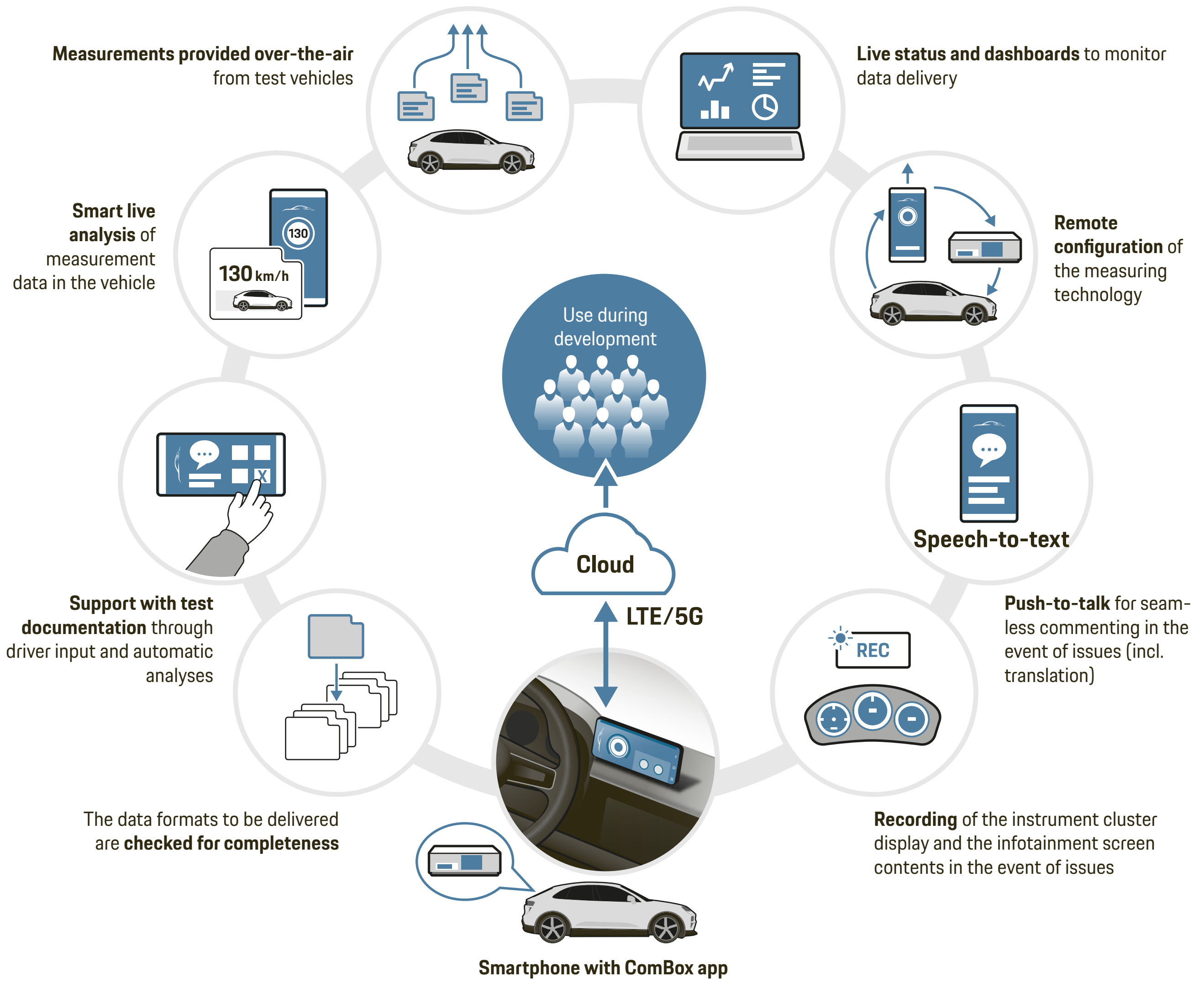


Traffic signs correctly detected: Green areas indicate that the results of the vehicle and the ComBox app match.



Traffic signs incorrectly detected: If the results do not match, the color changes to red. The measurements are also transferred to the cloud.

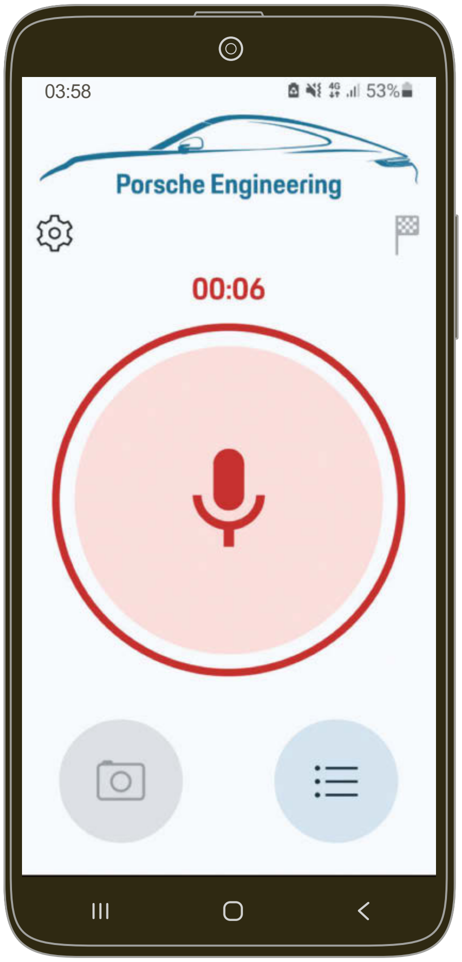
BETWEEN THE MEASUREMENT TECHNOLOGY AND THE CLOUD
THE COMBOX APP IS THE DIGITAL ASSISTANT FOR TEST DRIVES



The ComBox app has access to the vehicle buses via a **data logger**. Its **six modes** use this data to **detect anomalies**, for example. These anomalies are transferred to the **cloud** together with the associated measurements and can also be commented on via **speech-to-text**. Conversely, the **measuring technology can also be configured** in the test vehicle via the ComBox app.

background noise. This makes reliable detection possible that is as cost-effective as it is space-saving—and without any additional equipment. However, those who wish to can still connect special microphone technology," Wörner explains. "Artificial intelligence is used to analyze the audio recording directly in the vehicle: We use a neural network that we have trained with noise interference patterns." If the ComBox app detects an unwanted pattern, it automatically generates a message to this effect and loads it into the cloud together with the relevant audio file. Other measurements such as the current speed of the vehicle, the gear engaged, and the engine speed are also transmitted. This extensive automation significantly reduces the workload required.

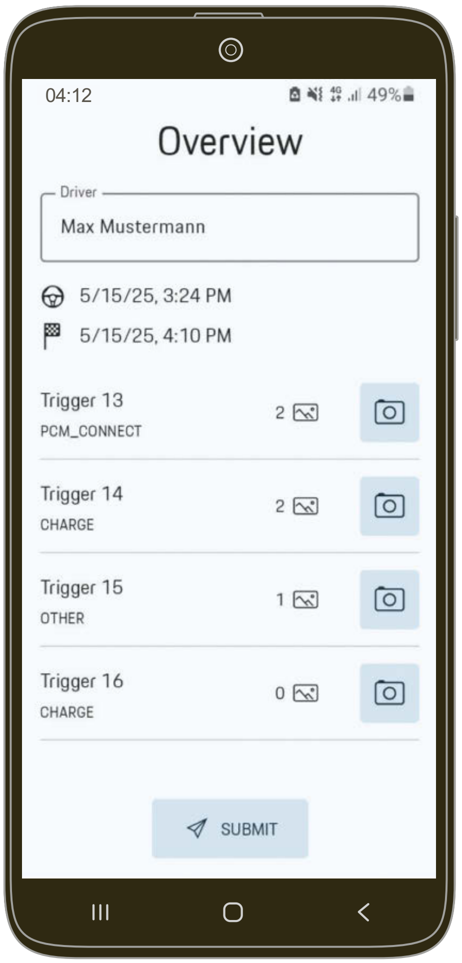
For example, "Acoustic Detection" mode can automatically detect the signature howling noise of turbochargers, as well as certain intrusive wind noises. The list of automatically identifiable noise types will be expanded to include further noise categories in the future. In addition, the neural network has also learned



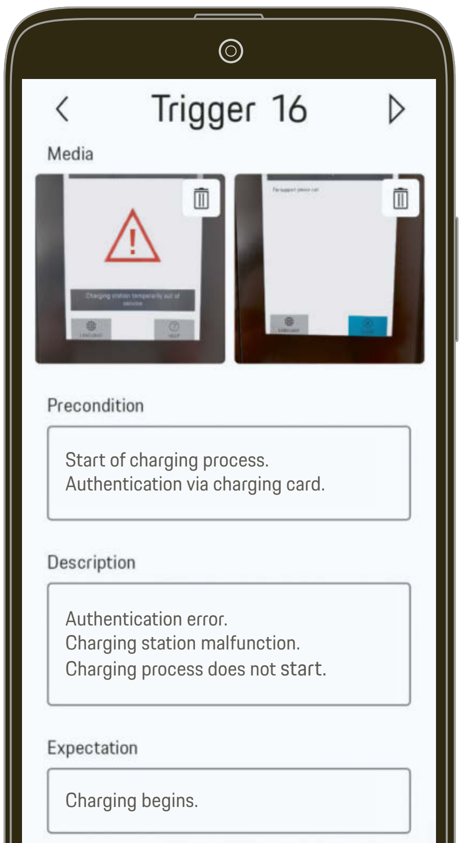
Automatic test reports: The ComBox app supports report creation during and after the test drive. Pressing the microphone button suffices to enter comments via speech-to-text. It is also possible to take photos or videos and to display a list of all issues.

how normal driving sounds as a reference. Using the ComBox app can significantly reduce the effort involved in detecting and analyzing acoustic issues. "In the past, there was often no suitable measuring equipment in the vehicle when such anomalies occurred," reports Wörner. "We therefore first had to equip a vehicle with the measuring technology and then deliberately recreate the fault. This was very time-consuming and associated with high costs."

Abnormalities in the infotainment system can also be logged using the ComBox app. This is where "Infotainment Recording" mode comes in. This mode records the content of the screens (driver, central, and passenger display) while the vehicle is moving. If



Evaluation complete: At the end, the ComBox app displays an overview of all recorded issues and enables the report to be sent using the "SUBMIT" button.



Filling out a report: Pressing the chequered flag button leads to a list of all issues; the list can be supplemented with comments and photos.

the test driver notices a problem, a simple press of a button in the app will suffice to automatically upload a short video to the cloud. The video also contains the screen content from a few seconds before the function was triggered," says Wörner. "Abnormalities such as misaligned text, an incorrectly placed icon in the navigation system or the wrong element being overlaid usually only appear for a few seconds, which is why we were often unable to record them in time in the past. 'Infotainment Recording' mode gives us a lot more room to identify and flag such issues."

AUTOMATIC SCENE RECOGNITION

"Scene Recognition" mode is still under development. It aims to automatically detect typical traffic scenarios that are relevant for testing a new ADAS function, such as being cut off by a vehicle in front—an incident that the ACC function, for example, may need to counter by braking. Such scenarios are described by the signals that occur in the vehicle and the order they occur in. These signals include the current speed, the brake pressure, and the distance to the road user in front. Edge computing directly within the app allows even complex scenarios and test cycles to be detected intelligently and automatically, without the driver having to intervene.

"We can send a specific scenario pattern—containing the sequence of events and the combination of signals—from the cloud to all vehicles equipped with the ComBox app," says Wörner. "As soon as the pattern you are looking for appears somewhere, the ComBox app sends the current measurement data to the cloud. This allows developers to see whether the new vehicle function has responded as desired." The big advantage here is that, in the future, all vehicles in a test fleet that are running the ComBox app can be used to search for the relevant patterns—and not just those vehicles that are, for example, specifically on the road for ADAS testing purposes. "This saves a lot of time," says Wörner, "because we no longer have to carry out certain dedicated test drives separately. They are done by other vehicles along the way, so to speak."

"Shift report" mode greatly facilitates the documentation of test drives and measurement results. For quality assurance purposes, new vehicles undergo extensive endurance tests that include many repetitions—for example, opening the luggage compartment and sliding the sunroof several times or repeatedly charging the battery. This mode uses vehicle measurement signals to partially fill out the reports automatically—with data such as the number of repetitions performed. The reports need only to be checked after the journey and corrected if necessary. What's more, the driver can record all errors that occur while driving directly in the ComBox app and add photos if necessary. "After each journey, the driver fills out a report and indicates how often they have carried out which action," explains Wörner. "Completing these reports manually means a great deal of work and, as with any manual activity, errors can creep in. This is where the app effectively remedies the problem and we can increase the quality of the reports."

The six modes of the ComBox app have already proved themselves in practice and are constantly being enhanced. "The ComBox app thus serves as a reliable assistant for testing and, at the same time, functions as a central data interface," Wörner sums up. "Another advantage is its ability to be used seamlessly and comprehensively for more or less all vehicle derivatives." In the future, Porsche Engineering plans to offer this tool, including the backend in the cloud, to its industrial customers as a self-contained product. The app's different modes can be added on individually depending on customer requirements.

"The ComBox app serves as a reliable assistant for testing and, at the same time, functions as a central data interface."

Jan Wörner
Project Manager in Data Driven Testing & Vehicle Functions at Porsche Engineering

Combinational explosion: The depth and breadth of possible operating scenarios for automated driving functions is the greatest challenge that SOTIF addresses.

Mastering complexity

Functional safety and the safety of the intended functionality are essential pillars when it comes to developing safe, modern vehicle systems. Due to increasingly complex assistance systems and autonomous driving, functional safety is becoming increasingly important. The experts at Porsche Engineering put their many years of experience into practice helping customers develop modern, safety-conforming systems from the initial draft to release.

Text: Ralf Bielefeldt

The relationship between functional safety (FuSa) and the safety of the intended functionality (SOTIF) can be understood as two sides of the same coin: The two together result in one valuable whole. Both sides play a decisive role in modern driver assistance systems, or ADAS (advanced driver assistance systems) for short, as well as in autonomous driving (AD).

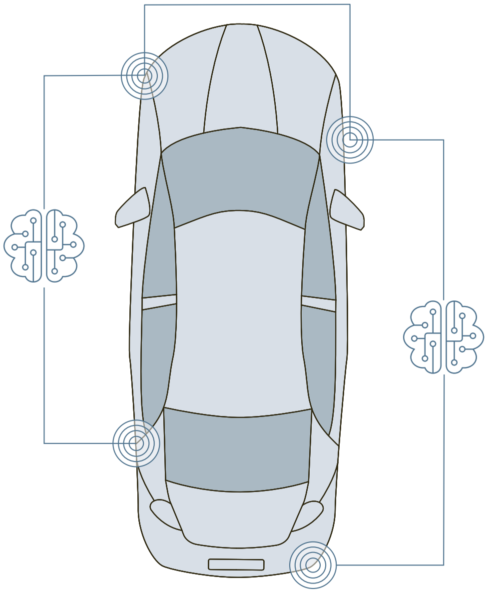
FuSa addresses the classic question: What happens if a software or hardware component fails? The idea of functional safety ensures that the system does not cause an unacceptable risk if internal malfunctions arise, such as a sensor failure or a software error. This is based on a process of structured analysis in which all relevant software and hardware errors are examined and evaluated for their effects. Effects rated as safety-critical are mitigated by technical and procedural measures. The functional safety methods are applied consistently, this being both during the concept phase and in the series implementation phase.

SOTIF, the safety of the intended functionality, addresses another, equally important question: What happens if the system operates without failures but fails to master a real operating situation? This concerns the acceptability of risks that arise from the limitations of the function itself, for example when a vehicle camera is blinded by the sun or an algorithm does not detect a cyclist in a complex driving scene. SOTIF is an exploratory discovery process in which iterations are the central tool for gradual improvement of the function design and knowledge generation.

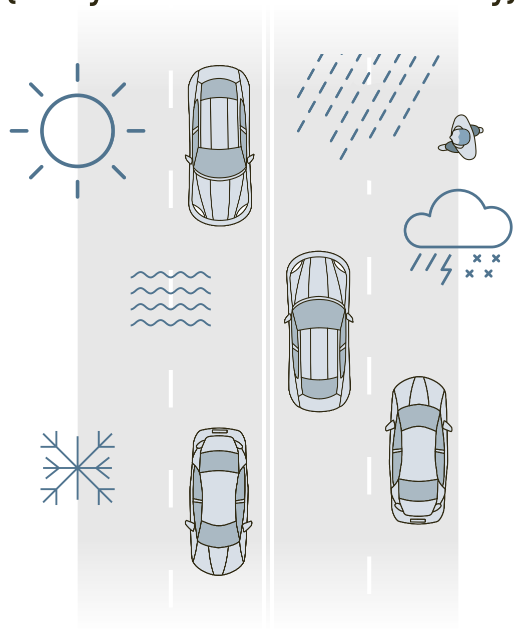
In order to achieve the overall safety of the system, FuSa and SOTIF are systemically interconnected and complement each other. “FuSa ensures that hardware and software work reliably. SOTIF ensures that the

INTEGRATED SAFETY PROCESS
V-MODEL

FuSa (functional safety)



SOTIF (safety of the intended functionality)



FuSa	Step	SOTIF
Definition of the system, its limits and functions. What should the system do?	**1. Definition and specification**	**Function and system specification:** Description of the intended function and its known performance limits (e.g. camera performance at night).
Hazard analysis and risk assessment (HARA): Identification of hazards due to system malfunctions—Evaluation of the risk (severity, frequency, controllability)—Derivation of the ASIL level (automotive safety integrity level, A–D) and the safety objectives.	**2. Hazard and risk analysis**	**Identification and evaluation of hazards:** Identification of hazards caused by functional insufficiencies in known and unknown scenario assessment of the risk based on scenarios—not an ASIL level, but with a focus on risk acceptance.
Functional and technical safety concept: Definition of safety requirements and mechanisms (e.g. redundancy, fault detection, safe state) to achieve the safety objectives.	**3. Concept and design**	**Definition of measures and function modification:** Improvement of system behavior to minimize SOTIF risks (e.g. adapt algorithm, sensor data fusion, driver warning in corner cases).
Hardware and software development: Implementation of safety requirements in accordance with strict, ASIL-dependent methods and processes.	**4. Implementation**	**Implementation of improvements:** Implementation of the functional adjustments and system performance improvements defined in the previous step.
Test and integration verification: The safety mechanisms are working correctly—Focus: Testing of error detection and reaction (e.g. through fault simulation/fault injection).	**5. Verification and validation**	**Verification and validation:** Evidence: The effectiveness of risk mitigation measures—Focus: massive, scenario-based testing (simulation, HiL, real trips) to evaluate known and discover new unsafe scenarios.
Safety case: Argument that the residual risk due to potential malfunctions is acceptable.	**6. Release and safety case**	**Release argument:** Argument that the residual risk from uncovered or non-critical scenarios is acceptable.

capabilities of these reliable components are sufficiently specified and proven to operate safely in the real world," explains Marek Hudec, Senior Manager of System Safety at Porsche Engineering. "This is because a system can be safe from the traditional FuSa standpoint, but still not safe enough from a SOTIF standpoint due to performance limitations."

ITERATIVE APPROACH FOR SOTIF

Despite the similarity, there are differences in the process steps between FuSa and SOTIF, because an iterative approach with exploratory analysis and test methods is generally preferred to achieve SOTIF (see box on page 38). "What that means is that the developers specify, test and revise the system design until an acceptable residual risk is reached," reports Dennis Müller, Development Engineer at Porsche Engineering.

Porsche Engineering offers its customers a comprehensive solution portfolio that includes both safety methods—SOTIF and FuSa—to manage the complex development and verify and validate of driver assistance systems and autonomous driving functions. "Among other services, we support our customers in applying the relevant standards such as ISO 26262 (FuSa) and ISO 21448 (SOTIF). This includes their implementation in existing development processes, execution of the hazard and risk analyses, drawing up safety concepts, and supporting the entire safety lifecycle," explains Müller. "At Porsche Engineering, we ensure safety-conformant development in accordance with FuSa and SOTIF through clearly defined, integrated processes with clearly dedicated responsibilities. This guarantees conformity to standards and provides traceability."

Porsche Engineering has many years of expertise throughout the entire development chain: From drawing up requirements to simulating and testing real vehicles, Porsche Engineering uses state-of-the-art simulation and test methods, including ones for developing warning functions, parking systems, and (partially) autonomous driving functions. As an example, one out of many results of this expertise is the modular software component called "Guardian". It is designed to facilitate the transition from advanced Level 2 systems to highly automated Level 3 driving. It offers a robust, safe, and standard-conforming solution for the implementation of safety components for autonomous driving systems. By analyzing real driving data, potentially critical situations and special cases—referred to as corner cases and edge cases—are identified exploratively and used for data-driven scenario generation.

As the responsibility of the system increases, the challenges the system is facing also become bigger. As far as functional safety is concerned, these challenges primarily consist of the fact that degradation and warning concepts can no longer rely solely on the driver, who bears sole responsibility for all vehicle maneuvers during assisted driving (Level 1) and semi-automated driving (Level 2). This will change from Level 3 on: In this case, the systems must be able to handle failures autonomously, as the driver will no longer have a constant duty of attention. Only if the systems reach their limits must it be possible to intervene after an appropriate warning period. In principle, therefore, safe operability must continue to be guaranteed when failures occur, at least for a certain period of time—this makes the leap from Level 2 to Level 3 challenging. As a side effect, the number of redundancies in vehicle electronics is increasing rapidly—and so are the associated development workload and costs.

With regard to SOTIF, the challenge lies in the depth and breadth of the set of all possible operating scenarios that the function needs to be able to master. "These include the continuously changing vehicle environment, the behavior of road users, and unforeseeable events, which are referred to as unknown unsafe scenarios," says Hudec. To deal with this complexity, systems

"A system can be functionally safe, but still not safe enough from a SOTIF standpoint due to performance limitations."

Marek Hudec
Senior Manager of System Safety
at Porsche Engineering

are initially designed for a defined operational design domain (ODD). The scenarios to be safely mastered are thus restricted to a systematically derived space, which is divided into discrete individual scenarios by means of a scenario portfolio. The system must ensure that the approach to the boundary of this space is detected at an early stage so that either control can be handed over to the driver or the vehicle can be stopped safely within the boundaries of the ODD. "This approach is extremely important for driver assistance development: The more responsibility a system assumes for the actual driving, the more critical it becomes to consider the safety aspects of FuSa and SOTIF," explains Müller.

IMPROVED SAFETY DUE TO REDUNDANCY

One example from practice that illustrates the different but complementary approaches of FuSa and SOTIF is an SAE Level 3 situation for automated driving on the highway in which the driver completely relinquishes responsibility. When it comes to managing hardware or software failures, FuSa is required: Suppose that the radar sensor that measures the distance to the vehicle in front has a hardware defect and is no longer providing data. This example of a fault could lead to the function relying on outdated or invalid sensor data and possibly risking a rear-end collision. That is why the experts at Porsche Engineering use deductive and inductive safety analyses to identify such failures; the analyses must be verified by safety mechanisms. In this specific case, for example, redundancy would be useful to prevent this local individual failure from leading to "global unavailability" of the sensor data, at least until the point in time when the driver again takes responsibility for driving.

SOTIF comes into play when it is a matter of mastering performance limits for automated driving on the highway. For example, vehicle detection must be designed in such a way that all other vehicles around or approaching the vehicle, including all motorcycles, are detected. However, due to the general, technically inherent performance limits of the sensors used, the vehicle may not correctly detect certain narrow silhouettes and approach trajectories under unfavorable light or weather conditions. Although the hardware and software are working flawlessly, this could cause the function to initiate a lane change that could result in a collision risk with an overtaking motorcycle. In this case, the SOTIF processes stipulate that the design must be analyzed and validated across all operating scenarios and that the weaknesses identified are corrected with the next design iteration (specification update followed by implementation update). For example, additional cameras and lidar sensors could be installed in the rear section or the sensor fusion algorithms could be optimized.

"The biggest challenge is no longer just in the system itself, but in the almost infinite complexity of reality. It is not possible to test every conceivable scenario in advance, but it is necessary to achieve sufficient coverage of the range of operation. The development process is just as complex as one would expect. SOTIF provides the framework for understanding the limits of the system and designing them safely even when all system components are functioning perfectly," Müller explains.

Providing qualitative and quantitative evidence that a system is safe requires large amounts of test data, a considerable amount of which is generated through simulations. The biggest challenge is dealing with unknown unsafe scenarios—dangerous situations that were not taken into account during development

"The more responsibility a system takes over for the actual driving, the more critical it becomes to consider the safety aspects of FuSa and SOTIF."

Dennis Müller
Development Engineer at Porsche Engineering

SOTIF: Mastering performance limits

In rare **corner cases**, even a correctly implemented drive function may work incorrectly. In this example, a motorcyclist approaches the vehicle from behind. In most cases, the motorcyclist would be detected correctly and a **lane change would be prevented**, but this is more difficult when the sun is low in the sky, as in this picture. The SOTIF processes stipulate that a weakness like this **should be addressed in the next design iteration**—for example, by adding sensors to the rear section or by optimizing algorithms.

due to insufficient specifications or that could occur due to changes in operating conditions. To discover and minimize these is the core objective of SOTIF and represents a great challenge when developing the systems.

"At Porsche Engineering, we offer our customers not only individual test services, but also close and long-term cooperation to meet the enormous demands placed on ADAS/AD development and to put safe, robust, and reliable functions on the road," promises Hudec. Methods such as AI-based recognition of corner cases or specially trained AI models will increasingly provide developers with support for this in the future. It is already clear today the use of AI in safety-critical systems will require even more complex verification procedures in the future. This topic is addressed by the new international standard draft ISO/PAS 880, which deals with the safety of AI when it is part of the end product. Another innovation is the international draft standard ISO/TS 5083, which focuses specifically on the topic of safety of autonomous driving functions of the vehicle and takes into account not only the vehicle on-board components, but considers also the off-board components and its effect on the overall safety. This is referred to as holistic safety.
The safety-oriented V2X communication between vehicles and with the infrastructure not only brings with it new safety-enhancing possibilities, but also new potential sources of faults and new dependencies. These too must be safeguarded with the same consistency—a demanding process that the experts at Porsche Engineering devote themselves to on a daily basis. — ●

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SUMMARY

The requirements placed on the functional safety of vehicles are increasing significantly due to he widespread use of assistance systems. The performance of the correctly implemented system in corner cases is the main focus of SOTIF. Among other things, Porsche Engineering uses data-driven and AI-based methods to master complexity and thus bring reliable systems on the road.

ANY QUESTIONS?

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

How do you actually recreate the moon?

Text: Ralf Bielefeldt
Illustration: Julien Pacaud

1972 was the last time a human was on the moon. There are plans to return soon. To ensure that astronauts and lunar robots are optimally prepared to do so, the German Aerospace Center (DLR) and the European Space Agency (ESA) have jointly built the LUNA research facility. It is a kind of mini earth satellite, a training ground as “true to life” as possible.

At the heart of the showcase project in Cologne is a 700 square-meter simulated moon surface, something that not even NASA has in this form. Sand, stones, and rocks are modeled on the moon’s geology, while a light simulator creates solar conditions similar to those found on Earth’s natural satellite, which is about 400,000 kilometers away. The position of the sun and the light conditions therefore change only minimally over the course of the training units—a day on the moon lasts about four weeks. The lack of an atmosphere is also taken into account. Since sunlight is not scattered and strikes the Earth’s companion at a very flat angle, it casts long shadows—and they are extremely dark. If an astronaut, say, puts a tool down on the moon, it is very hard to find it again. The tasks and motion sequences involved in these areas therefore require specific practice.

The budding lunar explorers step onto the surface of the Rhineland’s moon model wearing astronaut suits that can also be secured to the ceiling using a sophisticated cable system. This is intended to realistically simulate the lower gravity on the moon, which is only one sixth that of Earth. However, the cable equipment is still a prototype; the series system is expected to be installed in 2026. However, the biggest challenge facing lunar travelers might be the sand on the surface: Very fine and just as sticky as flour, it is highly abrasive and downright destructive. Its destructive power is due to the fact that it can settle in almost any crack and damage technical instruments.

The developers have collected sand and rock all over the world for the training facility to be able to reproduce the properties of the moon as precisely as possible. The sand for the bright zones of the moon comes from Norway and Greenland, while the dark, volcanic sand comes from the local region and the volcanic rocks come from Mount Etna on Sicily. The rock that represents the impact craters has had the shortest journey as it comes from the Nördlinger Ries, an impact crater in the depression between the uplands of the Swabian and Franconian Jura. A meteorite struck there about 14.6 million years ago.

LUNA is also an ideal terrain for lunar rovers, which are drivable robots. In the simulated lunar landscape, prototypes can learn tasks such as how to use camera

images to decide which path they should take and how they should move. Black, shadowy hollows should be avoided at all costs.

In order to prepare astronauts for the upcoming moon landing as realistically as possible, an additional research module can be connected to the training facility. This means that a lunar operation will be simulated for several weeks without the future lunar researchers glimpsing the Cologne sun.

A lunar surface in Rhineland: Straight from the coffee machine in ESA's office to the moon—in the LUNA training facility, astronauts can simulate lunar living and working.

PERFORMANCE AND EXPERTISE

FRAUSCHER X PORSCHE

ELECTRIC POWER TO THE WATER

From an SUV to an eBoat: Porsche AG, Porsche Engineering, Studio F. A. Porsche, and boat-building company Frauscher have jointly developed the 850 Fantom Air—a sports boat with an electric powertrain that is based on standard components of the Porsche Macan Turbo. The project shows how Porsche Engineering is transferring automotive expertise to other sectors in order to establish innovative powertrain systems there as well.

Text: Richard Backhaus

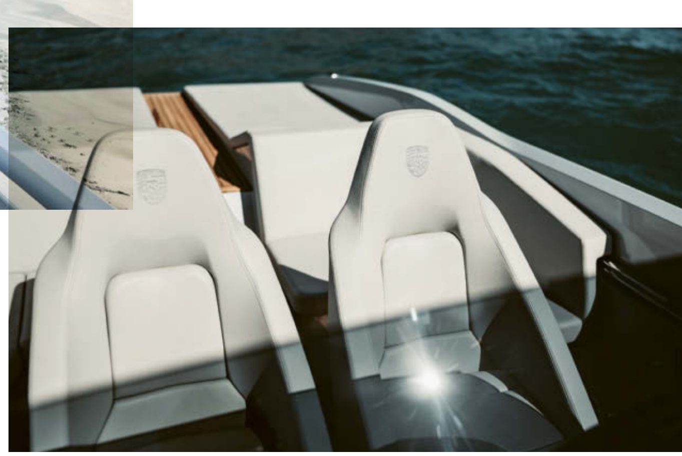
Powerful yet quiet: The electric powertrain of the 850 Fantom Air brings the boat up to maximum speed in just a few seconds (left)—thanks to components from the electric vehicle sector. The throttle also borrows from Porsche sports cars by offering the familiar Sport and Sport + driving mode buttons (bottom right).

850 Fantom Air

Battery capacity (gross): 100 kWh
DC charging capacity: > 250 kW
AC charging capacity: 11 kW
Charging time: Under ideal conditions, SoC (state of charge) from 10 to 80 percent in well below 30 minutes
CE category: C
Continuous/peak power of electric motor: 170/400 kW
Range at cruising speed: 45 km

Macan Turbo

Power consumption (combined): 20.7–18.9 kWh/100 km
CO_2 emissions (combined): 0 g/km
CO_2 class: A



Quietly crossing Lake Garda: Jörg Kerner, Vice President Product Line Macan at Porsche AG (far right), was most surprised by the boat's pleasant soundscape. The Porsche-quality leather armchairs (image below) were also impressive.

"Only through close and trust-based cooperation with the individual specialist departments of Porsche AG have we succeeded, in just two years, in implementing a development that is ready for series production."

Thomas Warbeck,
Specialist Project Manager at Porsche Engineering

Michael Frauscher "hooks up". That's the phrase among motorboat skippers for when you're at full throttle. The bow rises out of the water and the boat accelerates to its maximum speed of more than 85 km/h within a few seconds. The powertrain is not only powerful, but also barely audible. Frauscher, co-owner and Managing Director of the Austrian boatyard of the same name, is more than satisfied with the result of the maiden voyage on the local lake, Traunsee. It took less than a year for the development team from Porsche Engineering, Porsche AG, and Frauscher to jointly develop the 850 Fantom Air from the design stage to the first prototype. Porsche AG took the lead in the project, and Philip Ruckert was appointed eBoat Project Manager by the Executive Board of Porsche AG. The technical foundation was laid together with Porsche Engineering. A short time later, the decision was made to integrate the project into the Macan model series and bring it to series production. Porsche Engineering was responsible for the technical implementation of the project content. "Only through close and trust-based cooperation with the individual specialist departments of Porsche AG have we succeeded, in just two years, in implementing a development that is ready for series production," explains Thomas Warbeck, Specialist Project Manager at Porsche Engineering.

The special feature of the 850 Fantom Air is hidden in the hull: Instead of the usual petrol or diesel engine, this boat has a powerful electric powertrain. As in an all-electric vehicle, the powertrain delivers high torque from a standstill and at the same time makes the boat extremely quiet. The main components of the 800-volt powertrain—including the battery and drive module—originate from the rear-axle drive of the Macan Turbo. The passenger car components have been specifically adapted for marine use, as each sector has individual requirements that must be met by specific solutions. "In the automotive sector, we have built up in-depth know-how in technologically state-of-the-art developments. We use this as a basis to analyze the requirements for the vehicle and compare them with the specifications for the new target application. This shows us the changes needed to the system integration for both components and software, and we implement these changes on the development side," says Warbeck. Differences between use on the road and on the water can be seen, for example, in the driving profiles: While dynamic load requirements are the main focus of the car, the boat tends to have high continuous loads. As a result, this means that high-performance cooling must be provided. This was achieved on the 850 Fantom Air by means of optimized pump actuation. When building a boat, the limited space in the hull must also be taken into account when it comes to the powertrain and the battery. Additionally, there are specific requirements for vibration resistance and media compatibility due to the fact that the system can come into contact with salt water, for example. What's more, the E/E architecture of the 850 Fantom Air has been reduced to the most necessary components and supplemented by a specially developed control module.

"LOOK AND FEEL" OF A PORSCHE

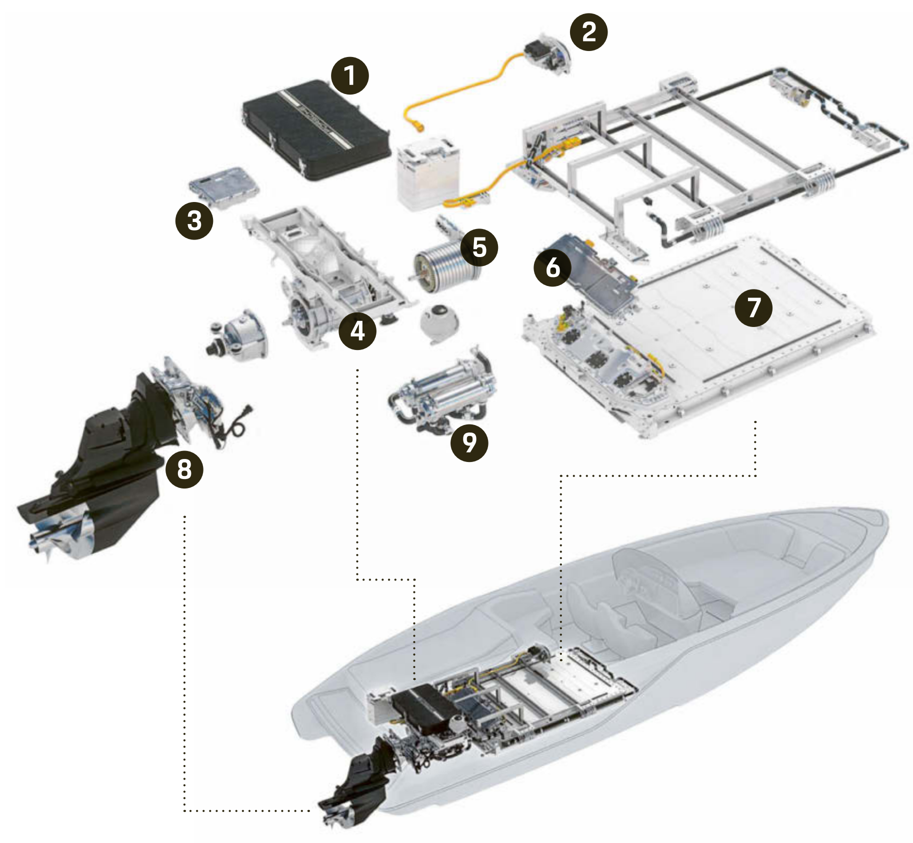
In the development project, Porsche Engineering was responsible, among other things, for requirements management, mechanical design, electrical system and ECU development, as well as testing. Moreover, there was a close cooperation with Studio F. A. Porsche, Porsche AG, and Frauscher when it came to component selection and design. "Our aim was to bring a typical Porsche 'look and feel' on board so that Porsche drivers would feel right at home on the boat. For example, we developed a throttle with the familiar Sport and Sport + driving mode buttons, car-like display graphics, and a boat steering wheel in a Porsche look," reports Project Manager Ruckert.

The permanently excited synchronous electric motor (PSM) installed on the rear axle of the Macan Turbo impresses with its high efficiency and power density. In the 850 Fantom Air, it delivers up to 400 kW. The electrical components of the car engine, such as the stator and rotor, were adopted for the boat project unchanged. However, the motor housing has been newly developed. In cars, a gearbox is integrated into the motor casing to reduce the high engine speeds. In the boat, in contrast, the motor runs at a significantly lower speed of 6,000 rpm instead of the more than 16,000 rpm in a vehicle, which is why internal reduction was not required. "We have developed and tested the new housing specifically to marine standards in terms of material selection and pairings, for example by means of adapted tests for salt spray, corrosion, and leaks," explains Sebastian Riesbeck, Specialist Project

"We have transferred our quality expectations from the road to the water without compromise."

Philip Ruckert,
eBoat Project Manager
for Porsche AG

HIGH VOLTAGE, HIGH POWER



Equipped with the drive technology of the all-electric Porsche Macan, the electric sports boat offers outstanding handling characteristics. **1** The **control unit** contains all the control modules of the drive. **2** The **fast-charging connection** guarantees short charging times. **3** The **inverter** supplies the motor with the electrical power it needs at any given moment. **4** The **motor housing** has been specially developed and tested to marine standards. **5** The **synchronous electric motor** boasts impressively high efficiency and power density. **6** The **integrated Power Box** uses a CCS2 socket for charging with AC and DC voltage**.** **7** The **high-voltage battery** is mounted directly in the hull using a support frame. **8** The **Z-drive** transfers the power of the electric motor to the propeller in the water. **9** The **heat exchanger** prevents excessive temperatures in the battery, inverter and electric motor.

Partners: Michael Frauscher (left in left picture) and Jörg Kerner examine sketches of the eBoat. The lithium-ion battery adopted from the Macan is located under the sun deck in the rear (image on the right).

Up to

400 kW

of power are delivered by the eBoat's permanently excited synchronous electric motor (PSM). It is normally found on the rear axle of a Porsche Macan Turbo.

100 kWh

is the capacity of the eBoat's lithium-ion battery. A support frame with steel cable damping cushions harmful excitations.

Engineer at Porsche Engineering. The only gearbox in the powertrain is the standard boat Z-drive in front of the propeller, which reduces the speed to around 3,000 rpm. "The necessary adjustments included the actuation for the marine powertrain, meaning that we could produce a combustion engine-like behavior with the advantages of an electric drive, in particular when it came to the torque characteristics," says Riesbeck. The connection between the motor and the Z-drive was a challenge. A slip clutch was used in the first prototypes, however it could not withstand the high engine torques of up to 700 Nm and high torque gradients. The current configuration consists of a robust jaw coupling with elastomer insert. In addition, the torque curve of the motor was adapted to the load limits of the clutch, allowing a long-lasting solution for series use to be presented.

The electric powertrain draws its energy from a lithium-ion battery with a capacity of 100 kWh. The wave impacts on the water cause the boat to vibrate, which can be transmitted to the battery and result in damage. "In order to quantify the problem and derive suitable technical countermeasures, we carried out reference measurements in the car and compared them with the values in the boat," says Warbeck. The boat now uses a load-bearing mounting frame with steel cable damping for the battery to cushion harmful excitations. "With the low central positioning of the powertrain and the batteries in the hull, we have achieved unique handling characteristics. What's more, there is a pleasant soundscape on the boat. That surprised me the most," says Jörg Kerner, Vice President Product Line Macan at Porsche AG.

ADAPTED CABLE HARNESS

The electric cables also had to be adapted to the conditions on the water and to marine standards: The low-voltage cable harness has been almost fully reconfigured to meet the specifications regarding cable cross-sections and protective sheathing. The changes to the high-voltage wiring harness compared to the car relate to extended charging cables with a modified charging socket. In addition, all components had to be certified for use in the marine sector.

One obstacle to the integration of electric drives into motor boats is the often high level of intricacy involved in integrating the individual components into the boat's hull. The development team therefore implemented a modular concept that consists of a drive unit

with cooling, control modules, and other subsystems as well as the battery unit with the support frame. Both modules can be mounted directly in the hull in the boatyard using defined mounting points. “This modularization represents a solution that is unique worldwide, being one that leads to lower development costs for the manufacturer of the boat and considerably simplifies the installation of the drive in the boatyard,” says Riesbeck.

In the Macan Turbo, the control module architecture of the drive is aligned with the data connections and communication protocols of the vehicle. Porsche Engineering has developed a special gateway control module to bring the worlds of cars and boats together on board. “Here, too, we have taken into account the special marine requirements, such as those of EN 55016-2-3 and EN 6094, for example with regard to electromagnetic compatibility (EMC), compass deviation or bus disturbances due to overvoltage,” says Dietmar Luz, Electrical/Electronics Senior Expert at Porsche Engineering. The gateway control module is where devices such as the throttle and the marine-specific displays are connected, but above all it forms the interface to the electronics of the individual drive components.

Using what is called a rest-bus simulation, the control module supplies the components with information and signals, for example, that come from the ESP brake system in the car, something that is not needed in the boat. “Because you can’t record wheel speeds on the water, or because you don’t have a parking brake, for example, there were many empty interfaces. To continue with this example, the Macan only charges when the parking brake is applied. We had to find a way to generate that and other missing signals,” Kerner explains. “We were able to draw on our extensive expertise in the development and validation of sophisticated electronic architectures to analyze the signal flows in the car and to set up a suitable rest-bus simulation. It was also only possible to implement this through our detailed technical knowledge of the Porsche components and with the support of those responsible for the components at Porsche,” reports Luz.

When implementing the software of the gateway control module based on AUTOSAR, the team of Porsche Engineering experts from Germany, Romania and the Czech Republic entered uncharted territory, as there were no standards for linking the boat-side bus system with the powertrain from the car. The close cooperation between the sites allowed the challenging development task to be implemented in a short time despite the small team. It was possible to transfer the high requirements of functional safety and software quality from the automotive sector to the motorboat sector.

AWARD-WINNING PROJECT

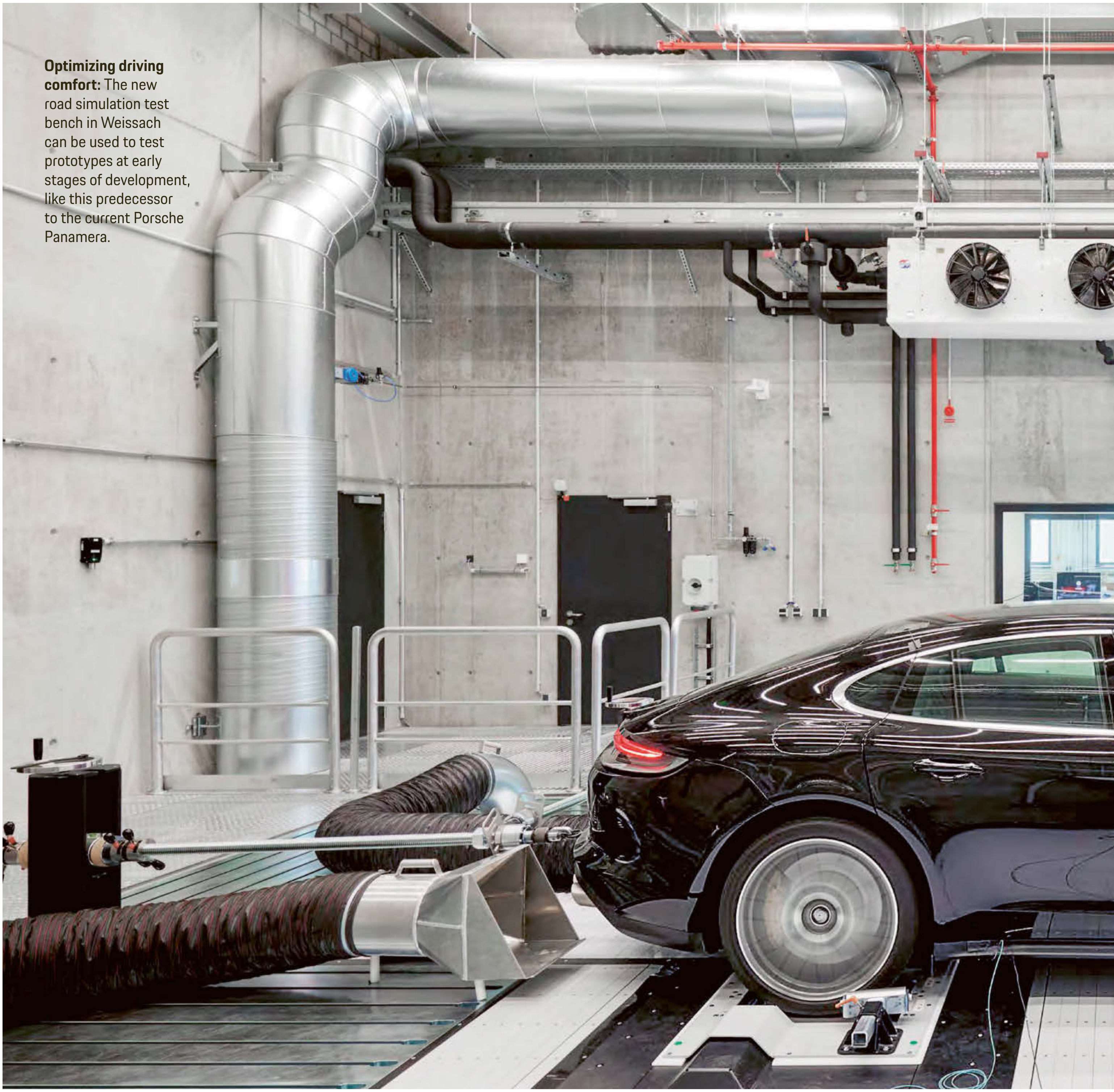
“A success story needs fascinating products. The Porsche name has always stood for performance, quality and design. We have kept this promise with our eBoat project, too,” as Kerner sums up the success of the project. Ruckert adds: “We have put the boat through its paces and transferred our quality expectations from the road to the water without compromise. This is only possible if everyone involved is passionate about the project.” The series-production model of the 850 Fantom Air was crowned “Powerboat of the Year 2024” prize at the Boot Düsseldorf trade fair in 2024 and was named “Best of Boats 2024” in the eBoat category at the “Boat & Fun” trade fair in Berlin. The boat manufacturer Frauscher is wholly satisfied with the result of the joint project. “Due to the high level of interest from customers, we have now started to manufacture a small series of 25 boats,” says Florian Helmberger, Director Sales & Marketing at Frauscher. “The first boats in the limited edition have already been delivered and are making customers around the world happy.” However, the powertrain developed by Porsche Engineering can also be easily integrated into other boats of different sizes and classes. For larger boats of more than ten meters in length, a drive with several parallel powertrains is even conceivable. “Our proven development methodology for transferring technology from cars to other sectors is universally applicable and can be used in many other areas such as the construction machinery sector,” says Warbeck.

“The first boats in the limited edition have already been delivered and are making customers around the world happy.”

Florian Helmberger,
Director Sales & Marketing at Frauscher

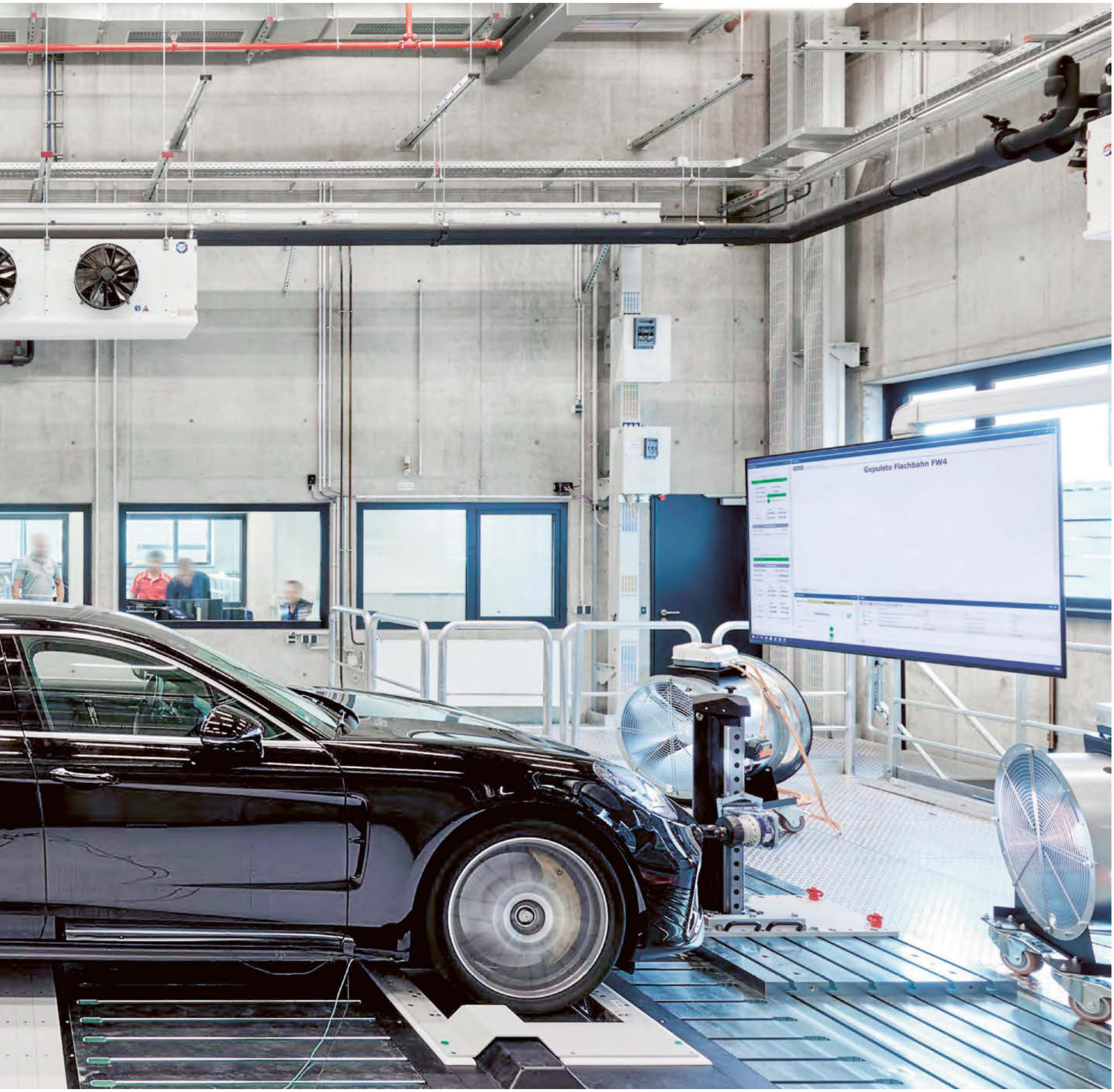
SUMMARY

Porsche Engineering, Porsche AG, and the Austrian boat manufacturer Frauscher have jointly developed the 850 Fantom Air. The eBoat has a powertrain that essentially uses standard components of the Porsche Macan. They have been adapted to the requirements of the marine sector.



Optimizing driving comfort: The new road simulation test bench in Weissach can be used to test prototypes at early stages of development, like this predecessor to the current Porsche Panamera.

Vibrations under scrutiny



Porsche's new road simulation test bench makes it possible to accurately reproduce real road conditions. This means that vehicle characteristics can be optimized and validated early in the development process—for Porsche sports cars and in other vehicle projects.

Text: Constantin Gillies

The humming is barely audible; it feels like a slight pressure on the ears. To find out where it's coming from, the test engineer picks up his tablet. Using a slider, he minimizes the vertical excitation of the vehicle. The humming seems to be more prominent. To further home in on the source, the engineer taps the tablet again. He switches off the excitation of the front axle so that only the rear axle is excited in the longitudinal vehicle direction.

This is possible because the test is not taking place on the road, but rather on the new road simulation test bench (FaSiP) at the Porsche Development Center in Weissach. The simulator makes it possible to realistically reproduce road characteristics with a view to optimizing driving comfort. It also enables the individual control of axles—for example, to find the source of the humming. Shutting down the front axle quickly clarifies the matter: The noise is still present because the rear lid is being stimulated to vibrate by the rear axle. "In this case, a specially tuned absorber can be attached to the rear lid, which dampens these vibrations," explains Dr. Sebastian Ihrle, Senior Manager Verification NVH in the Complete Vehicle Validation Characteristics and Simulation department at Porsche AG.
The acoustic and vibration characteristics play a decisive role in driving comfort. Regardless of the speed and the surface being driven on, no unpleasant noises, vibrations, or harshness, called NVH for short, may occur. This is a challenge for a manufacturer like Porsche with a wide range of products, as each model should have a characteristic vibration behavior that the driver experiences as positive—experts refer to this as the dynamic fingerprint. "With a sporty vehicle, customers expect relevant and significant feedback from the road surface and the driving situation, and with a more comfort-focused vehicle, they expect greater decoupling," explains Rainer Gebhardt, Senior Expert Driving Comfort at Porsche AG. In a comfortable sedan, for example, a slight chattering would be much more unpleasant because it is not masked by the road excitation.

TESTING AT AN EARLY STAGE

In order to optimize the NVH properties of a vehicle, many real test drives are required in addition to virtual tests. However, in the past, these could only begin once a complete vehicle with driving clearance was available. At this relatively late stage in the development process, however, fundamental design changes are usually very costly to implement. Both of these limitations are eliminated by the test bench. Here, prototypes can be tested for their vibration characteristics in the early stages of the development process, so that even extensive adjustments can still be made without difficulty. Even individual components or modules can be tested (hardware-in-the-loop tests, HiL). For example, engineers can send a single axle, clamped into a special frame, on a test drive. "As a result, we get 'on the road' much earlier in the development process," says NVH expert Ihrle.

Complex technology is used to accurately reproduce real drives: The vehicle is flexibly mounted on the FaSiP—in straight-line driving—with all wheels standing on four independent belt units. Each tire rolls on a 0.4-millimeter-thick steel belt driven by a highly dynamic electric motor. By changing the belt speed, longitudinal forces are applied to the tire, causing the vehicle to vibrate in the longitudinal direction (forward and back). In addition to this, servo-hydraulic cylinders below the belt units generate vertical impulses (up and down). The interplay between these factors can precisely reproduce forces as they occur in real driving conditions, whether due to a poor road, a change in road surface, or manhole covers.

It is crucial for the wheels to be turning during the test—in contrast to test benches where the forces are supplied by hydraulic pistons while stationary. There are, after all, numerous physical differences between a stationary and a rolling vehicle. "The tire stiffness is

↓

250

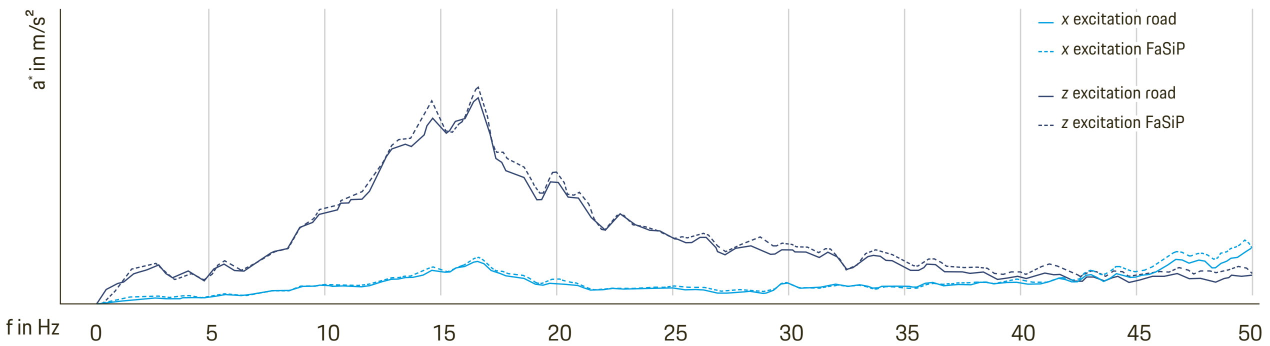
km/h is the maximum speed that can be reproduced on the road simulation test bench.

"Using the FaSiP, we get 'on the road' much earlier in the development process."

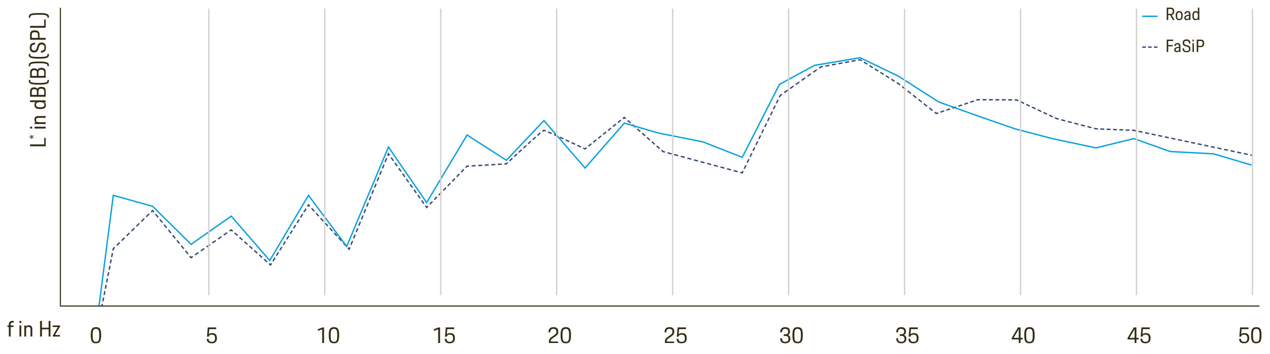
Dr. Sebastian Ihrle
Senior Manager Verification NVH in the Complete Vehicle Validation Characteristics and Simulation department at Porsche AG

INVESTIGATING CAUSES ON THE ROAD SIMULATION TEST BENCH

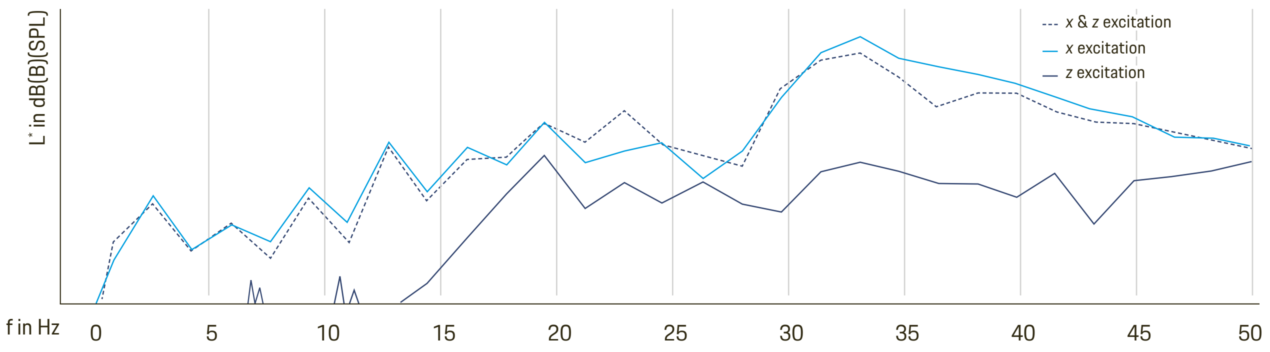
Excitations: Comparison of road—FaSiP



Interior noise level/humming: Comparison of road—FaSiP



Interior noise level/humming: Directional dependency



* a stands for acceleration / L stands for sound pressure level

A comparison between measurements and the test bench show how precisely the FaSiP can reproduce the accelerations on the wheel carrier (top). In both the longitudinal (*x*) and vertical (*z*) directions, the curve measured on the road and the one measured on the test bench are almost exactly the same. Driving on the FaSiP is also very close to reality (center) when it comes to measuring the noise level in the vehicle interior. By selectively switching excitations on and off in a longitudinal or vertical direction, the developers are able to identify the cause of the humming: It is, contrary to expectations, caused by the longitudinal excitation. The vertical excitation does not play a role in this phenomenon.

Excitations between

0

and

50

hertz can be generated on the road simulation test bench.

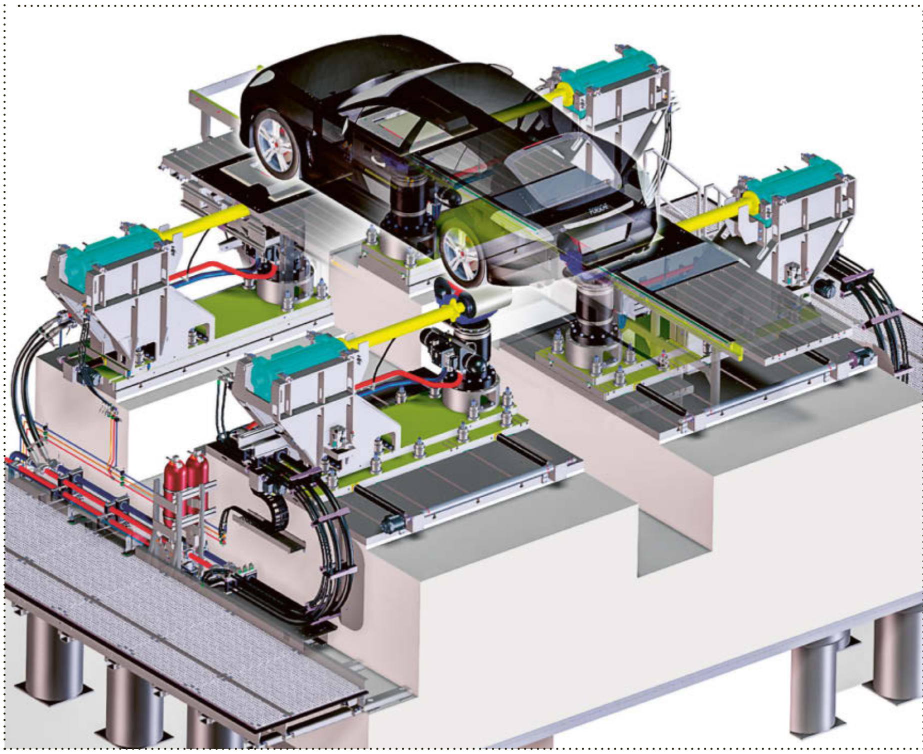
different when the wheel is stationary, and the resonances also shift," explains expert Gebhardt. The FaSiP realistically reproduces driving in both dimensions.

What's more, it's also easier for engineers to focus on individual aspects. While driving on the road always provides an overall acoustic profile, the FaSiP allows a vibration range to be controlled precisely and reproducibly, just like in a recording studio. The test bench functions something like a magnifying glass. "For example, we can specifically test the imbalance behavior of the wheel and tires," explains Ihrle. If a factor remains constant, the best technical solution can be found more quickly through experimentation.
Without a precise tool like the FaSiP, the development and validation of driving comfort would be much more complex in the future. This is because the interaction of the technology in cars is becoming increasingly complex, for example due to intelligent mechatronic systems that ensure an optimal balance between performance and driving comfort—such as variable current supply to the dampers depending on the driving situation. Checking all possible combinations and their effects on road test drives would involve a great deal of effort. "Tools such as the FaSiP are particularly useful in managing the conflict between the need for systemic validation in the face of increasing complexity and the simultaneous shortening of development times," says Ihrle.

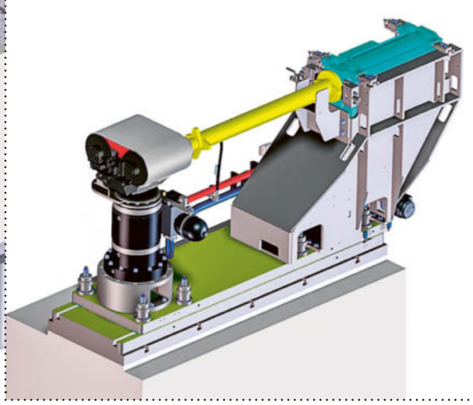
IDENTIFYING NOISE PROBLEMS

The test bench is also ideally suited for what is known as "firefighting" in the technical jargon: An industrial customer books the FaSiP because a problem with the acoustics has unexpectedly occurred on a model that is ready for series production. When sitting in the vehicle, the development engineer can use the control tablet to modify or remove specific excitation components and frequency ranges in order to pinpoint the disturbing problem with the acoustics. The subjective perception is then transformed into objective parameters based on the recorded data, which helps solve the problem in a systematic and efficient manner. The location at which the disturbance originates is irrelevant, as the test route of the industrial customer can easily be "recreated". "On the FaSiP, we can reproduce any vibration phenomenon that has occurred on the vehicle anywhere in the world, analyze the causes, and optimize it," says Gebhardt.

PRECISE REPRODUCTION OF ROAD SURFACE EXCITATION



Four independent belt units form the heart of the road simulation test bench. Each of them consists of a 0.4-millimeter-thick steel belt (silver) driven by an electric motor (light blue) via a drive shaft (yellow) and on which the tires of the test vehicle roll. Changes in belt speed produce longitudinal vibrations while servo-hydraulic cylinders (black) generate vertical impulses.



“We can reproduce any vibration phenomenon that has occurred on the vehicle anywhere in the world, analyze the causes, and optimize it.”

Rainer Gebhardt
Driving Comfort Senior Expert at Porsche

Plus/minus

40 mm

vertical movements are possible on the road simulation test bench.

The new road simulation test bench has been in operation since mid-2024 and is used by Porsche AG for development. It can also be booked by industrial customers, such as other vehicle manufacturers, through Porsche Engineering. Two factors make the test bench unique worldwide: One is that speeds and road excitations can be simulated up to 250 km/h, which is essential for sports car development. The other is that vertical movements of the belt units of up to plus/minus 40 millimeters are possible. The excitation can be applied across a broad frequency spectrum ranging from 0 to 50 hertz. “Ranges as large as this are important in order to observe the movements of the vehicle body,” explains expert Ihrle. The convenient operation of the system in real time using a tablet is also unique. The new test bench is an important link in vehicle development, which is becoming increasingly virtual, especially in its early stage. When there is a distinct virtual early phase, it is expedient to check the acoustic and vibration behavior in detail under real conditions and make any corrections necessary before the results of test drives become available in a later phase. This is now possible on the new road simulation test bench. With the help of this early “hybrid testing”, it will be possible to develop driving comfort characteristics even more efficiently in the future, which ultimately saves time and money.

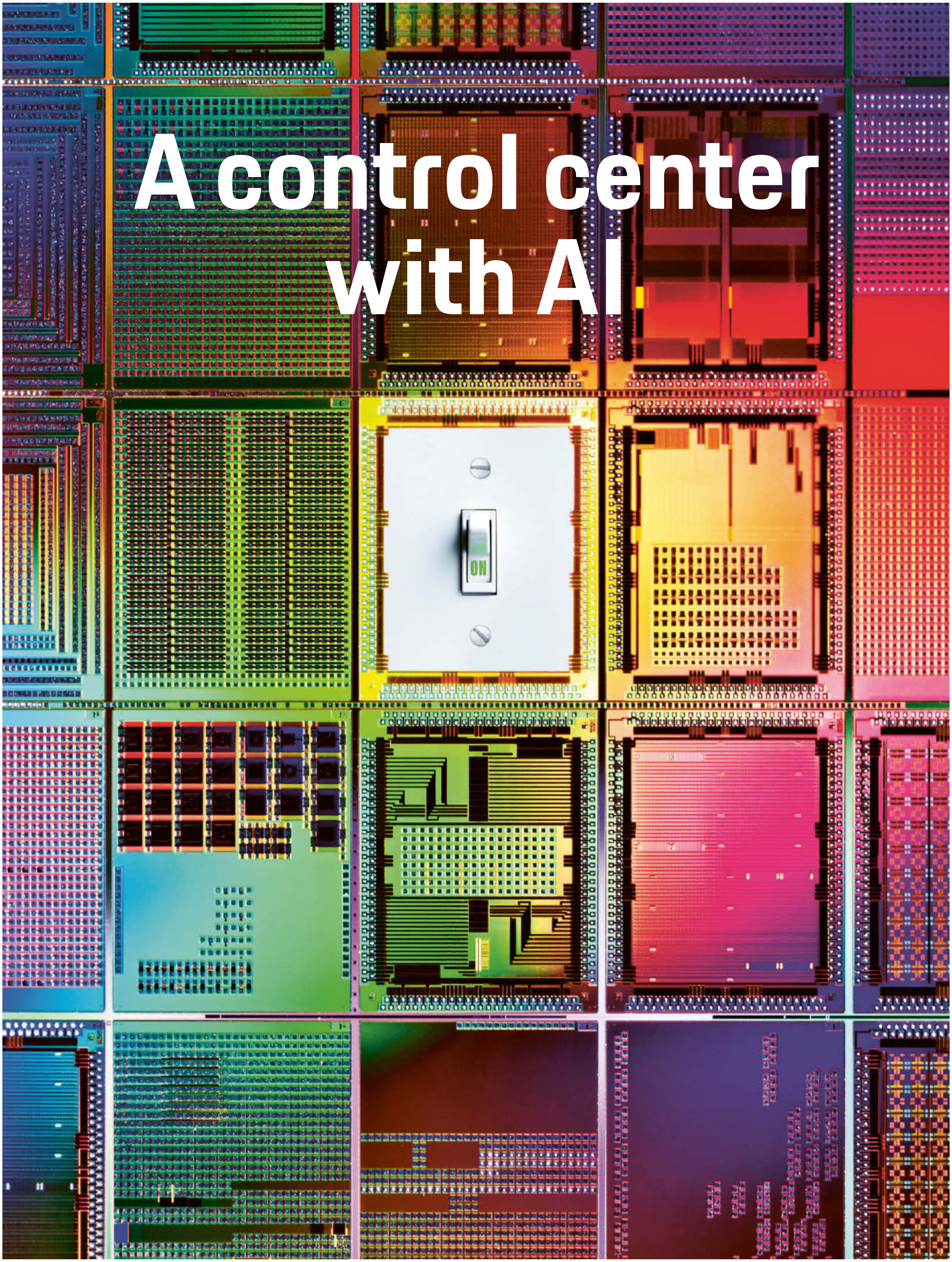
Above all, the test bench demonstrates its strengths where vehicle parts behave in a complex manner due to their material properties and are therefore difficult to simulate on the basis of virtual methods. This includes elastomers, for example, which are plastics that return to their original state after being deformed. “With these materials, double the force does not mean double the deformation,” explains Ihrle. To explore their behavior in the complete vehicle, testing is the key.

COMBINING TESTING AND SIMULATION

In view of this complexity, the development engineers have two options: Either they put a great deal of effort into refining the simulation model—or they test with physical hardware. In practice, a hybrid solution is increasingly emerging. “Physical checks are made on everything that is complex or highly nonlinear, the rest is simulated,” says Ihrle. In doing so, the findings from the real and digital worlds complement each other. Porsche uses data from the FaSiP, for example from axle tests, to make computer simulations even more precise.

In addition, the FaSiP could be supplemented in the future with a completely new approach: AI-supported optimization of driving comfort. Porsche Engineering is currently developing neural networks that have learned through intensive training to objectively assess driving comfort. Together with the FaSiP, they enable more automated development, which in turn is associated with lower costs and input: After basic tuning based on a fully virtual application, the vehicle would repeatedly drive the same route on the test bench—without a test engineer on board—with specially installed acceleration sensors recording the vibrations that occur. Using this data, the AI could then evaluate comfort according to defined characteristics. The chassis parameters of individual systems are then changed—and the test is repeated. In the final step, the driving dynamics experts come into play and get to work on the fine-tuning that characterizes the brand.

A control center with AI



Gently does it: Losses in the inverters of electric vehicles can be significantly reduced by intelligent actuation of the transistors.

Intelligent soft switching with AI support promises to reduce switching losses in power transistors by up to 95 percent. Porsche Engineering is already testing the new approach in simulations.

Text: Christian Buck

Range is one of the most important criteria when it comes to purchasing an electric vehicle. It is therefore crucial that all available options to increase powertrain efficiency are used. The inverter offers a lot of potential here, because noticeable losses occur in the inverter's power transistors during switching. These losses can, however, be significantly reduced by intelligent actuation of the transistors.

In principle, two primary types of losses occur in the inverter of an electric vehicle: Line losses and switching losses. Line losses are a physical property of the transistors, and one that cannot be influenced by the inverter's circuit design. For physical reasons, a power transistor does not behave like an ideal switch that would conduct current without loss. Instead, even when it is switched on, the transistor still exhibits a low residual resistance, which leads to losses and heat generation.

Switching losses occur during the transition between the "On" and "Off" states. A voltage is present at the power transistor for a short time, even while a noticeable current is already flowing through it. The product of this current and the applied voltage is the undesired power loss. While switching on and off, this power loss forms characteristic peaks that lead to energy losses—which ultimately reduces the potentially achievable range. "The more often the transistors are switched over, the greater the problem," explains Volker Reber, Senior Manager Function & Software Development at Porsche Engineering. "Then again, high switching frequencies are welcome in the inverter, because this can improve the quality of the alternating current that is generated, among other things."

The way out of this dilemma is called "soft switching". While the power transistors in the inverter are switched on and off directly during "hard switching", the changeover points are varied in real time so intelligently that the product of voltage and current at the transistor—and thus the power loss during switching—is minimized. There are essentially two ways of doing this: Zero Current Switching (ZCS) and Zero Voltage Switching (ZVS). With ZCS, the transistor is switched while almost no current is flowing through it. With ZVS, switching takes place when the voltage at the transistor is close to zero.

REDUCED LOSSES THANKS TO ZVS

Porsche Engineering uses ZVS to improve inverter efficiency. ZVS leads to lower losses in silicon-carbide and gallium-nitride power transistors, as are used in electric vehicles. In addition, it exhibits better efficiency at higher frequencies than ZCS, while disruptive electromagnetic interference is lower. Above all, ZVS is the better choice for inductive loads such as electric motors.

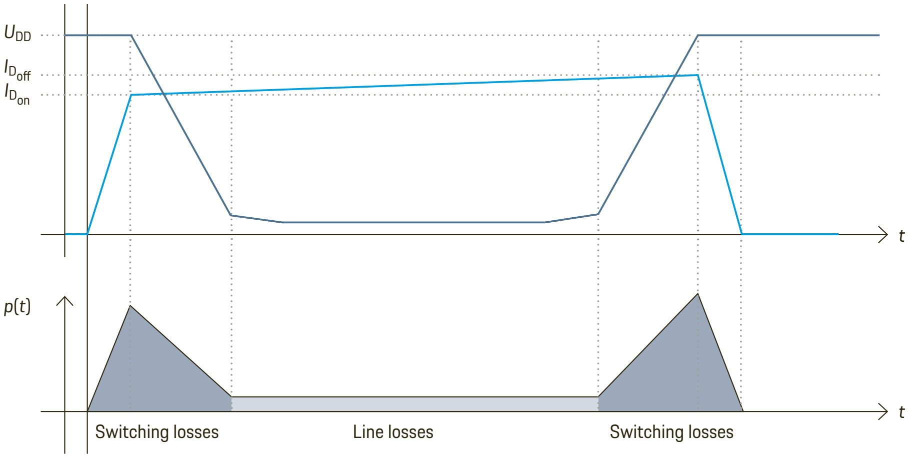
"Around the power transistors, we place an additional electronic circuit consisting of transistors, coils, and capacitors," reports Souhaib Touati, Specialist Project Engineer Function & Software Development at Porsche Engineering. "This inverter topology has long been referred to as the auxiliary resonant commutated pole, or

"We achieve full soft switching with minimal losses and, as a result, higher ranges."

Volker Reber
Senior Manager Function & Software Development at Porsche Engineering

SMART TRANSISTOR SWITCHING
HOW SOFT SWITCHING INCREASES A VEHICLE'S RANGE

Hard switching

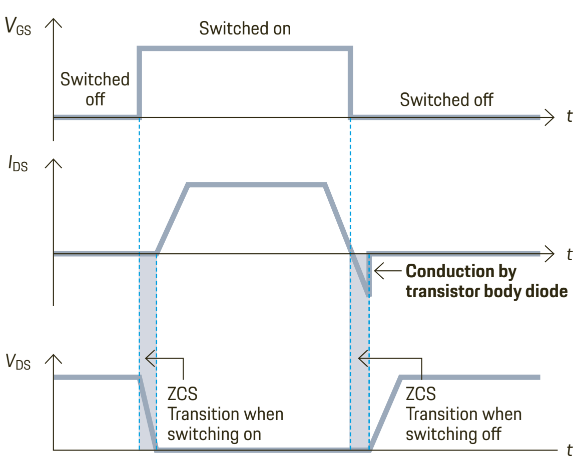


Hard switching leads to typical peaks in power loss at the power transistors. The cause: During a transition period, a voltage U_{DD} is still present at the transistor while current I_{DD} is already flowing. The product of both results in the power loss.

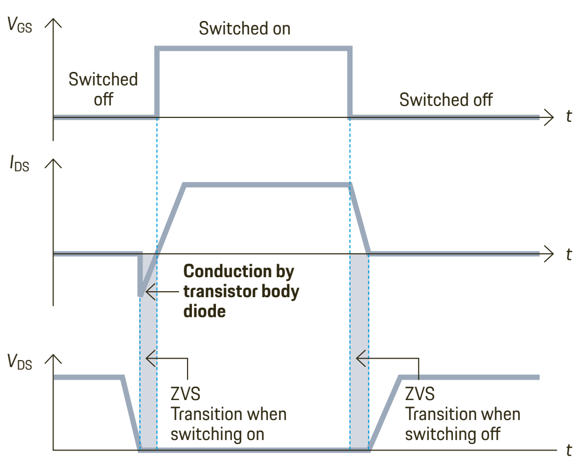
With **soft switching with Zero Current Switching (ZVS)**, switching occurs when there is hardly any current flowing through the transistor—which significantly reduces the power loss. **Soft switching with Zero Voltage Switching (ZVS)** has the same effect. Here, switching occurs when the voltage at the transistor is close to zero—which also minimizes the power loss.

By **using AI**, Porsche Engineering optimizes the switchover times depending on the current operating conditions.

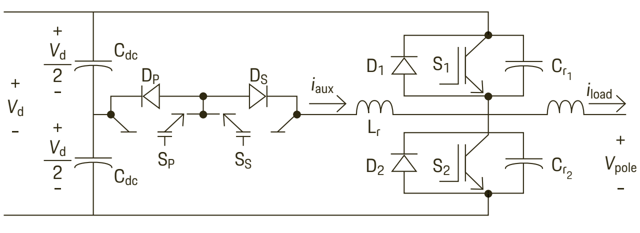
Soft switching with ZCS



Soft switching with ZVS



Auxiliary resonant commutated pole (ARCP)



The operating principle of an **auxiliary resonant commutated pole (ARCP)** is based on the use of resonance circuits to minimize switching losses in power electronics systems. The ARCP uses a resonant circuit that allows an interaction between inductances and capacitances. This resonance helps to control the voltage or current during the switching process. The switches (e.g. transistors) are controlled in a way that ensures that they are only switched on or off at zero voltage. This significantly reduces switching losses, as the switches do not switch under load. The switches are controlled using variable timing control, which takes into account the live load current in order to determine optimum switching times.

ARCP." What's new about Reber and Touati's approach is the use of artificial intelligence to control the ARCP: A pre-trained AI algorithm processes several dozen live measurements from the electric vehicle in real time, such as load, torque, and temperature, from which it calculates the optimum switching times of the power transistors in fractions of a second.

SWITCHING OPTIMIZATION WITH AI

"An electric vehicle operates under constantly changing loads, which is why soft switching has not yet been applied in any other way due to the wide variety of rapidly changing operating conditions," says Reber. "We were able to change that by using artificial intelligence to optimize transistor switching: Our algorithm predicts the optimum moments for controlling the ARCP, even under changing conditions. This allows us to achieve full soft switching with minimal losses and, as a result, higher ranges."

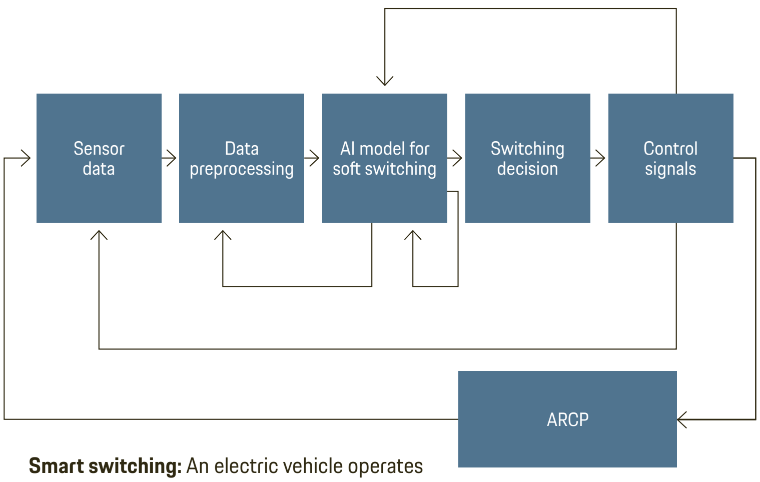
Reber and Touati are currently investigating recursive neural networks and reinforcement learning as AI methods for intelligent soft switching. "Each has its own respective advantages: Recursive neural networks are characterized by high predictive accuracy and high performance," says Touati. "Reinforcement learning increases the speed of calculations and is therefore particularly well suited for very demanding real-time requirements."

The efficiency increase offered by the new approach is significant: Soft switching with AI support reduces switching losses in the power transistors by 70 to 95 percent. The range of an electric vehicle can thereby be increased, depending on how the vehicle is being used, by a high single-digit percentage. Soft switching also reduces heat generation in the pulse inverter due to the lower switching losses, resulting in lower cooling requirements and more compact components. Various filter components found in existing circuits can also be omitted, which further optimizes the printed circuit board (PCB) layouts. Overall, the volume of the pulse inverter decreases by 20 to 50 percent. What's more: The hard switching used up to now places a heavy load on the power transistors in the inverter, thereby reducing their service life. This problem is also alleviated by AI-based soft switching.

The new AI control algorithm for inverters is already at an advanced stage of development. As soon as it has been fully developed, Porsche Engineering will offer its customers AI-based soft switching as a complete software solution. "We will thereby offer OEMs and Tier-1 suppliers a big advantage: AI-based soft switching is implemented purely via software libraries and can therefore be integrated into existing control units in the same way as a plug-in," says Touati. "The cost of modifying the hardware should be relatively low based on existing designs. AI-based soft switching could therefore be best implemented as part of a model update or new development."

"AI-based soft switching is implemented purely via software libraries and can therefore be integrated into existing control units in the same way as a plug-in."

Souhaib Touati
Specialist Project Engineer Function & Software Development at Porsche Engineering



Smart switching: An electric vehicle operates under constantly changing loads. This is why the AI model continuously determines the optimum switching time based on current sensor data.

ICON OF COOL

Back in the 1970s: The 911 Spirit 70 is a tribute to the design tradition of Porsche. At the same time, the exclusive collector's item impresses with the latest technology.

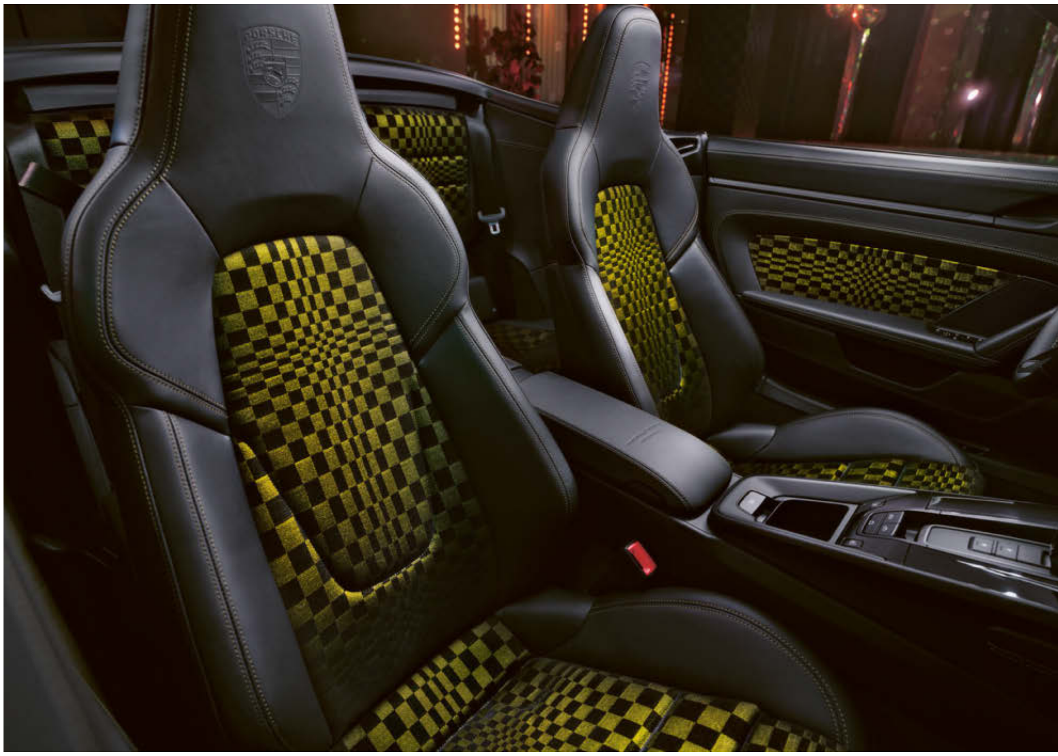
Text: Dr. Ing. h.c. F. Porsche AG

911

PORSCHE AND PRODUCT

Exclusive collector's item: Porsche produced just 1,500 of these cabriolets that encapsulate the essence of the 1970s and early 1980s.

Interior highlights: The iconic fabric pattern Pasha in Black/Olive Neo hints at a waving chequered flag.



Exceptional detail: At the rear you will find the gold-colored Porsche logo and the model designation, with galvanically gold-plated Porsche lettering and model designation.

Exclusive shade Olive Neo, three decorative stripes in various shades of the same color, and the legendary Pasha pattern in the interior: Porsche presented the 911 Spirit 70 in April 2025. This Cabriolet, limited to just 1,500 cars, encapsulates the 1970s and early 1980s. Built within the bounds of the Heritage Design strategy, the collector's item is the third 911 model that Porsche has used to breathe new life into an era, using iconographic design elements of earlier cars. Porsche Exclusive Manufaktur implemented this exceptional concept alongside the design department Style Porsche, bearing in mind the slogan "Icons of Cool."

All Heritage Design models emphasize the Lifestyle dimension that is at the heart of the Porsche product strategy for particularly emotive concepts. The first individual model in the series was the 911 Targa 4S Heritage Design edition in the styles of the 1950 and early 1960s, presented in 2020. The 911 Sport Classic was the second collector's item from the Heritage Design strategy, presented by Porsche in 2022. This small series, limited to 1,250 vehicles, revived the style of the 1960s and early 1970s.

"The Heritage Design models occupy a special position within our product strategy from a design perspective" says Michael Mauer, Vice President Style Porsche. "The limited sports cars encapsulate what makes the Porsche brand so special. The design of each of our cars draws on our brand history – these take it a step further. They show how we reinterpret historical design elements in a state-of-the-art sports car."

"The Heritage Design models occupy a special position within our product strategy from a design perspective."

Michael Mauer
Vice President Style Porsche

The designers and paint experts at Porsche created the color Olive Neo specifically for the 911 Spirit 70—a rich, deep green with a modern undertone. Bronzite forms an exciting contrast to this. The rear underbody, front apron and Sport Classic wheels in Fuchs design are painted in this slightly more golden shade of gray. Alternatively, the new 911 Spirit is also available in solid Black or GT Silver Metallic, in addition to the large selection of around 140 shades from the Paint to Sample program. The roof is Black, as is the windscreen frame, which underlines the unmistakable visual presence of the 911 Spirit 70.

TRADITION AND INNOVATION

Three decorative stripes in Black (satin gloss) stretch over the bonnet. This detail is reminiscent of the safety stickers from the 1970s: At that time, racing drivers applied horizontal stripes to the bodies of their fast cars so that they could be better identified at high speeds in the rear-view mirror, on the motorway or on the race track. The stripes continue onto the convertible roof in various shades of the same color. The racing tradition of the brand is also reflected in the decorative graphic on the side with Porsche logo and round start number field ('lollipop') in Black (satin gloss) as well as individual start number.

One example of the contrasting pair "tradition and innovation" can be found in the center of the bonnet: The 911 Spirit 70 has a Porsche crest that is almost identical to the historical crest from 1963. Gold-plated Porsche Exclusive Manufaktur badges can be seen on the front wings, and a Porsche Heritage badge is on the grille of the rear lid. The design is reminiscent of the Porsche 356 badge that was awarded in the 1950s when a vehicle reached the 100,000 kilometer mark. Other exceptional details include the gold-plated Porsche logo and the model designation at the rear. The logos receive their extraordinary brilliance from the galvanically gold-plated surface.

The 911 Spirit 70 drives on 20-inch wheels at the front and 21-inch wheels with central locking at the rear. The "wing" or "clover leaf"-style of the design is a reference to the Fuchs rim, one of the most famous Porsche wheels. Porsche and Otto Fuchs KG presented the first forged light-alloy wheel for the 911 S in 1967. From a technical perspective, the 911 Spirit 70 is based on the 911 Carrera GTS Cabriolet. Its 3.6-liter, six-cylinder boxer engine with an especially lightweight T-Hybrid system and electric turbocharger delivers 398 kW (541 PS). The maximum torque is 610 Nm. Power is transmitted via an eight-speed dual-clutch gearbox (PDK) with integrated electric motor.

↓

1967

was when Porsche and Otto Fuchs KG presented the first forged light-alloy wheel for the 911 S. The 911 Spirit 70 is a link to this.

Tailor made: The designers and paint experts created the color Olive Neo especially for the 911 Spirit 70. The decorative graphic on the side with a round start number field is reminiscent of racing tradition at Porsche.

541 PS

is what the 3.6-liter, six-cylinder boxer engine with an especially lightweight T-Hybrid system and electric turbocharger delivers.

610 Nm

is its maximum torque.

The standard sports exhaust system provides a stirring sound experience. The deceleration power also matches the high performance: Like the 911 Carrera GTS, the 911 Spirit 70 relies on the high-performance brake of the 911 Turbo. The Porsche Ceramic Composite Brake (PCCB) is available as an option.

The Porsche Active Suspension Management (PASM) high-tech chassis with rear-axle steering is available at no extra charge. It meets high performance requirements because the dampers respond to dynamic changes at astonishing speed. The PASM is combined with the sports chassis, which is lowered by 10 millimeters. The design with helper springs on the rear axle also originates from the 911 Turbo models. This means that the main springs are under tension in all driving states.

ASSISTANCE SYSTEMS AS STANDARD

The instrument cluster combines historical design with state-of-the-art technology. The high-resolution 12.65-inch display has white hands and scale lines in an analog display. Green numbers are reminiscent of the Porsche 356—the first series-produced sports car from Porsche. The model logo is elegantly integrated into the fully digital rev counter. White hands and green numbers also mark out the special design of the Sport Chrono stopwatch.

Design classics: The wing or clover leaf-style of the design is how the 911 Spirit 70 references the legendary Fuchs rim.

As standard, the current 911 offers a range of assistance systems that make driving and parking more convenient and safer, especially in everyday traffic. The camera-based warning and brake assistant significantly reduces the risk of collisions with vehicles, pedestrians and cyclists.

The 911 Spirit 70 also features the sixth generation of Porsche Communication Management (PCM). One of the most important functions is the deep integration of the streaming services Apple Music and Apple Podcasts. Android Auto is also integrated. In addition, the language assistant Voice Pilot understands instructions in natural speech. Instead of using predefined commands, simply say “Hey Porsche” and give instructions in natural speech. The hardware and software architecture of the PCM 6.0 allows the navigation system to perform very quick calculations, taking real-time traffic information into account.

The highlight in the interior is the iconic Pasha fabric pattern in Black/Olive Neo. The graphic design of the textile is reminiscent of a moving chequered flag. A sense of movement is created in the pattern through the cleverly arranged rectangles in different sizes. Instead of Jacquard velour, the 911 Spirit 70 combines a textile with flocked yarns. This gives the pattern an even more dynamic flair, an improved feel and more comfort, especially on longer journeys.

The Pasha pattern is used to cover the central panels of the 18-way-adjustable Sports Seats Plus, the wing mirrors, and even the inside of the glove compartment. The decorative inlays for the seat backrests and the dashboard trim are also available in Pasha as an option. In addition, the standard product includes a reversible luggage compartment mat in Pasha. The elegant Club Leather interior in Basalt Black with decorative stitching in Olive Neo and the Club Leather Basalt Black interior package are also fitted as standard.

The dashboard trim features a gold-plated badge with 911 logo, model designation and personal limited-edition number. The crest, which is almost identical to the historic crest from 1963, is located on the steering wheel and embossed on the headrests and leather key pouch. The Porsche Exclusive Manufaktur logo is embossed on the lid of the storage compartment and in the standard, leather in-car folder.

The door projectors cast the first-ever animated “Icons of Cool” logo directly onto the ground as soon as the doors are open. The illuminated door entry guards are made of aluminum with black anodized finish and feature a 911 Spirit 70 logo. Another detail is the Heritage Design floor mats with a leather border in Basalt Black and decorative stitching.

Owners of the latest Heritage Design small series can get a mechanical masterpiece for their wrist: the handmade Chronograph 911 Spirit 70. The limited-edition number of the vehicle is engraved on the base of its housing, inextricably linking the watch and sports car.

Historical references: The 12.65-inch instrument cluster has white hands and scale lines in an analog display. Green numbers are reminiscent of the Porsche 356.

Attention guaranteed: Three decorative stripes stretch over the bonnet and are reminiscent of the safety stickers from the 1970s. The aim at the time was to make the cars more visible in the rear-view mirror.

"For our customers across the globe, the limited-edition collectors' items are particularly desirable."

Alexander Fabig
Vice President Individualization and Classic

Naturally, the car served as a model for the design of the timepiece: The glossy black Pasha pattern of the dial is inspired by the seat center of the 911 Spirit 70. In addition, the colors Phosphorus Green and Traffic Red have been adopted from the tachometer.

DELIGHTED CUSTOMERS

Porsche also offers the Lifestyle collection that accompanies the 911 Spirit 70. It allows the 1970s to be rediscovered in style and with authenticity. The range of very special collector's items includes daywear, lifestyle accessories, model vehicles and sportswear that was designed in cooperation with the sporting goods manufacturer Puma. The matte "Icons of Cool" badge, the woven Porsche logo, the legendary Porsche Pasha pattern, and the black Nappa leather of the Heritage Bag—all details have been carefully selected.

"The limited collector's cars are particularly desirable for our customers worldwide" says Alexander Fabig, Vice President Individualization and Classic. "The first two models of the Heritage Design strategy brought back the lifestyle of past decades and generated great enthusiasm. We are delighted with their success and are proud to be able to now present the third highly exclusive model."

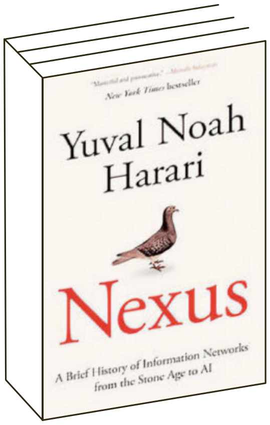
911 Spirit 70

CO_2 emissions (combined): 246–242 g/km
Fuel consumption combined: 10.9–10.7 l/100 km
CO_2 class: G

Deeper knowledge

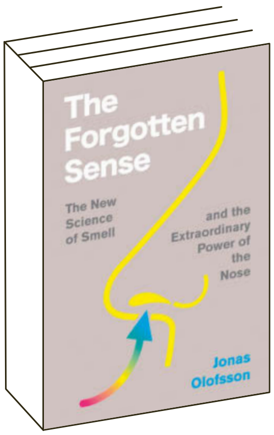
BOOK

The history of information networks



Yuval Noah Harar shows how the flow of information has shaped our world—from the Stone Age to populism.

Nexus
Yuval Noah Harari
Penguin



BOOK

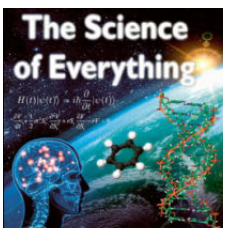
The power of the nose

The sense of smell is indispensable for our survival—and yet it is paid little attention. This book finally puts it center stage.

The Forgotten Sense
Jonas Olofsson
William Collins

PODCAST

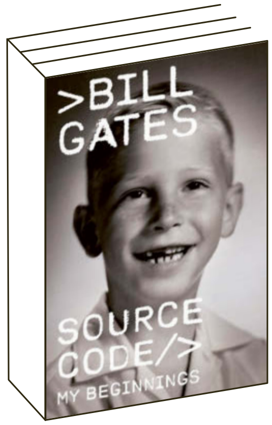
The Science of Everything



In this podcast, James Fodor discusses a variety of topics in both the natural and social sciences, exploring the many fascinating insights that the scientific method yields about the world around us.

thescienceofeverything.net
Available wherever you get your podcasts.

The big picture



BOOK

How it all began

Microsoft founder Bill Gates talks for the first time about his childhood, his early passions, and his goals.

Source Code
Bill Gates
Piper

PODCAST

Things were actually very different

Each week, Mike Hobbes and Sarah Marshall take a look at an event, person, or phenomenon that has been misrepresented in public perception.

You're Wrong About
https://yourewrongabout.com
Available wherever you get your podcasts.

For the child in all of us

↓

GAME

Around the world with Lara Croft

In this collection, fans of the game can experience the original adventures of Lara Croft, faithfully remastered.

Tomb Raider 4-6 Remastered
Aspyr Media

GAME

Above the clouds

In this two-person game, you'll fly a jumbo jet together to the world's most famous airports. Awarded Game of the Year 2024!

Sky team—ready for landing?
Kosmos

GAME

The power of friendship

In this split-screen adventure, players must coordinate their actions and their time with each other—and support each other to the end.

Split Fiction
Electronic Arts

Intelligent entertainment

↓

FILM

Ride the volcano

6,721 meters above sea level: no vehicle has ever gone higher. In late 2023, the feat was achieved by a team led by three-time Le Mans winner Romain Dumas in a heavily modified Porsche 911 called Edith. A 50-minute film shows the long and arduous expedition.

Edith: Porsche's Volcano Ascent
Amazon Prime Video

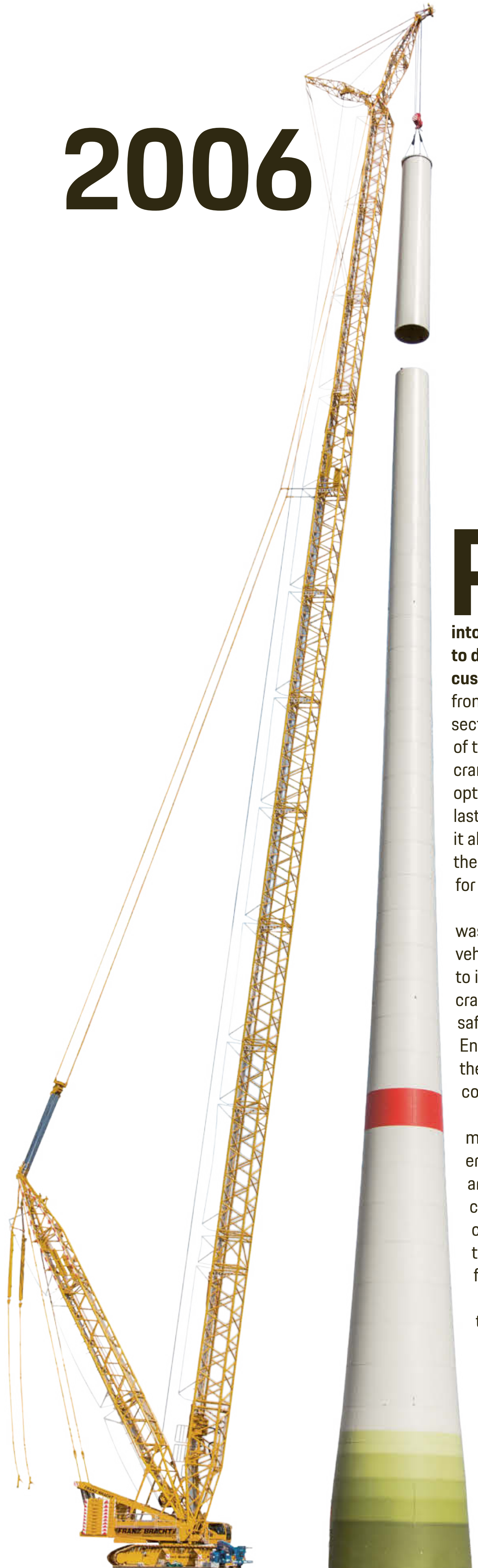
PODCAST

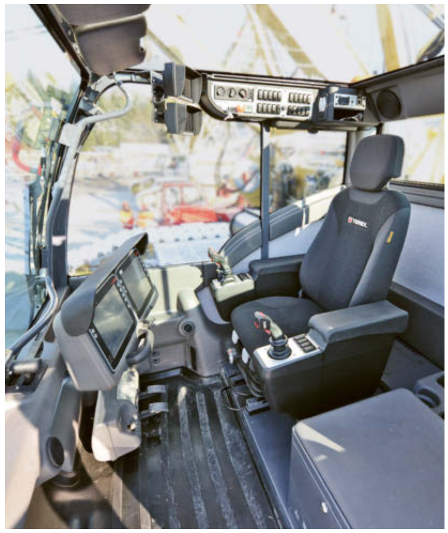
Curious Cases

In this entertaining science format of BBC Radio 4, the presenters—Professor Hannah Fry and comedian Dara Ó Briain—give scientific answers to listeners' questions.

https://bbc.com/curiouscases
Available wherever you get your podcasts.

2006





Functional and aesthetic: Porsche Engineering completely redesigned the interior and exterior of the cabin of the Superlift 3800.

Porsche Engineering likes to move into uncharted territory when it comes to development projects for external customers and transfer its experience from automotive development to other sectors. One successful collaboration of this kind was the optimization of the crane cab design for Terex Cranes. The optimization was not only to have a lasting impact on the brand face of Terex, it also resulted in the company receiving the Rhineland-Palatinate Design Award for its Superlift 3800 model.

The starting point of the cooperation was a comprehensive redesign of the vehicle and crane cabins. The aim was to improve the working conditions for crane operators and thereby increase safety, operability, and comfort. Porsche Engineering's remit was to redesign the interior and exterior with the aim of combining functionality and aesthetics.

Discussions with Terex customers made it clear early on that comfort and ergonomics are not a luxury—but rather are crucial factors to ensure safety and concentration during operation. This collaboration therefore focused on three areas: ergonomics, mobility, and functionality.

At the beginning of the project, the requirements for all controls were examined and their ideal position determined. The aim was for all components to be easily accessible and user-friendly following the redesign. During the concept design, the development team placed particular emphasis on intuitive operation, ergonomically optimized controls, and individually adjustable equipment details. An ergonomic joystick was to enable precise and error-free control processes, and the display would be individually configurable. The seat was to be adjustable to suit the weight and height of the crane operator, while adjustable air vents for heating and air conditioning were to increase the cabin comfort.

The exterior of the cabin was also redesigned: New grip positions and an optimized step width made it easier to enter the Superlift 3800. Adjustable and heated exterior mirrors, a roof panel wiper, and tinted safety glass ensured optimum visibility in all weather conditions. A newly developed lighting system provided the best possible illumination—both in the interior and in the crane's operating environment.

The redesigned cab celebrated its premiere at the bauma trade fair in Munich in 2007. Feedback from Terex customers there confirmed that the new development was already being well received by users. The innovative design was then used for several other crane models and went on to shape the face of the Terex Cranes brand.

The collaboration between Porsche Engineering and Terex Cranes shows how cross-industry thinking can lead to extraordinary solutions. The result: Crane cabins that combine ergonomics and mobility, enable concentrated and safe work, and offer a design that is both technically and stylistically impressive.

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