Porsche Engineering MAGAZINE

A COLORFUL MIX

ISSUE 1/2014

Porsche Engineering
MAGAZINE

CUSTOMERS & MARKETS Porsche Engineering optimizes crane cabins for Terex Cranes
PORSCHE UP CLOSE Sports Car in the Compact SUV Segment: The Porsche Macan
ENGINEERING INSIGHTS Networked World with Porsche Car Connect

ISSUE 1/2014

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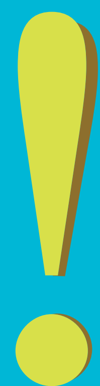
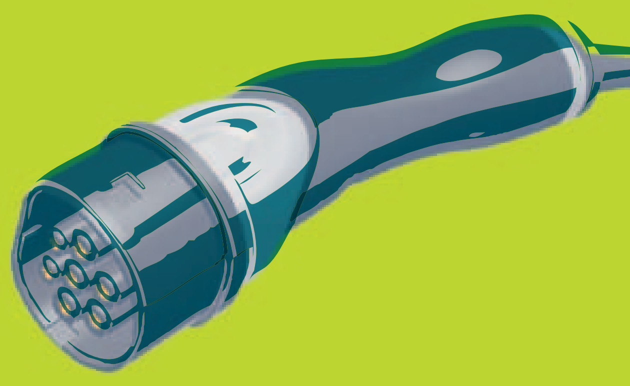


Powertrains of the Future

A COLORFUL MIX



Malte Radmann and Dirk Lappe,
Managing Directors of Porsche Engineering

Dear Readers,

_____ How will we get around in the future? What energy carriers will we use to do so? And where will the energy come from? Our answer to these questions: the solutions will be a *colorful mix*. There won't be just one ideal source of propulsion, but a variety of solutions adapted to specific needs.

Electricity and fuels will increasingly be generated in CO_2-neutral processes. We will get around with a mix of different powertrain technologies and energy carriers—be it with fuel cells, batteries, plug-in hybrids, or optimized combustion engines—and thus create, step by step, CO_2-neutral and sustainable forms of mobility.

So much for the seemingly simple theory. What about the practice? We'll show you in this issue: for example, our expertise in designing and simulating e-drives. You'll be "electrified" by our article about testing on the electric motor test bench. And you can't talk about powertrains of the future without mentioning the Porsche 918 Spyder. The super sports car combines the advantages of a conventional drive and those of a purely electric concept to a degree unmatched by any car in its class. Finally, the article "Networked World" explains how the modern connection between the vehicle and the driver works and what goes into the development process.

Powertrains of the future move and inspire us to work on innovative mobility concepts. The result is a rich array of solutions for a mobile future that is environmentally sound and sustainable.

We're on the way. What about you?

We hope you enjoy this issue
of the Porsche Engineering Magazine.

Sincerely,
Malte Radmann and Dirk Lappe

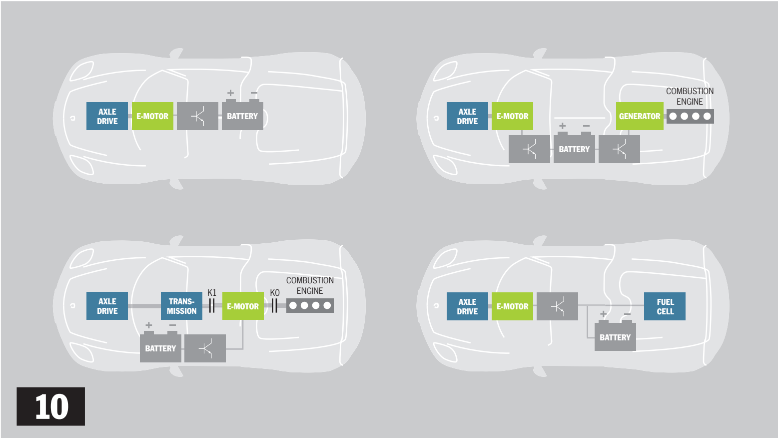
About Porsche Engineering

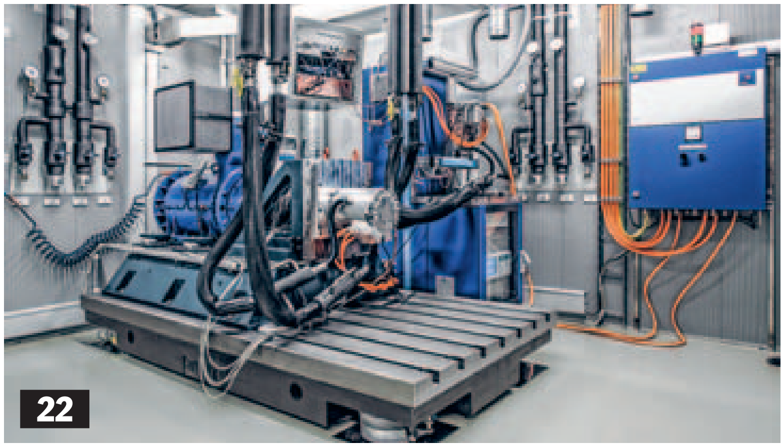
Creating forward-looking solutions was the standard set by Ferdinand Porsche when he started his design office in 1931. In doing so, he laid the foundation for today's engineering services by Porsche. We renew our commitment to that example with each new project that we carry out for our customers.

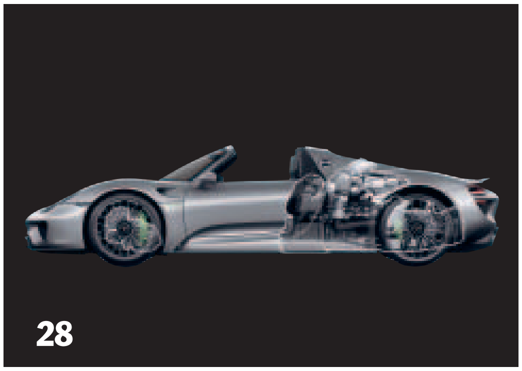
The scope of services provided by Porsche Engineering ranges from the design of individual components to the planning and execution of complete vehicle developments, and is also transferred to other sectors beyond the automotive industry.

918 SPYDER Fuel consumption (combined): 3.1 – 3.0 l/100 km; CO_2 emissions (combined): 72 – 70 g/km; electrical energy consumption (combined): 12.7 kWh/100 km/h


TEREX







PANAMERA S E-HYBRID Fuel consumption (combined): 3.1 l/100 km; CO_2 emissions: 71 g/km; energy consumption: 16.2 kWh/100 km; efficiency class: DE/CH A+/A

MACAN Fuel consumption (combined): 9.2–6.1 l/100 km; CO_2 emissions: 216–159 g/km

918 SPYDER Fuel consumption (combined): 3.1–3.0 l/100 km; CO_2 emissions (combined): 72–70 g/km; electrical energy consumption (combined): 12.7 kWh/100 km/h

News

TECHNICAL UNIVERSITY IN PRAGUE HONORS COOPERATION

___ The mechanical engineering department at the Czech Technical University (CTU) in Prague recognized Porsche Engineering for their successful cooperation between the research business communities. At a festive ceremony, the department presented an honorary medal to Malte Radmann, managing director of Porsche Engineering Group GmbH. Christoph Gümbel, chairman of the shareholder's committee of Porsche Engineering Services s.r.o. in Prague, received the Prof. Hýbl medal, named after a distinguished former CTU professor. Dr. Miloš Polášek, managing director of Porsche Engineering Services s.r.o. in Prague, received a medal from the department as well. Porsche Engineering's collaboration with the university, which began in 1996, has contributed significantly to the institution's ongoing development. The collaboration focuses on research and development projects for the automotive industry. ■

Malte Radmann, managing director of Porsche Engineering Group GmbH, receives the honorary medal from the Department of Mechanical Engineering.

News

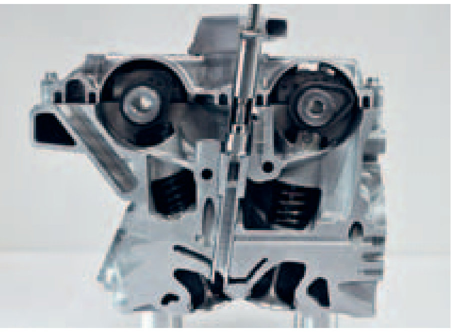
MERCEDES-BENZ LOOKS BACK ON RECORD DRIVE IN NARDÒ IN 1983

CUSTOMER EVENT

___ It's no secret that some record-breaking drives have made history on the test track of the Nardò Technical Center. One of those milestones was set by the Mercedes-Benz 190 E 2.3-16 in August 1983. In just 201 hours, 39 minutes and 43 seconds, the predecessor of today's C-Class covered a distance of 50,000 kilometers on the 12.6-kilometer ring circuit—a world record. For the 30th anniversary of the event, Mercedes-Benz sent one of its three original world-record-setting vehicles back to the testing grounds in southern Italy. Together with some of the originators and witnesses of the record-setting drive, some 25 journalists had the opportunity to admire the display vehicle and test-drive the "Baby Benz" at the site of its remarkable success. A most extraordinary event. ■

NO-TOUCH TEMPERATURE MEASUREMENT OF ENGINE COMPONENTS

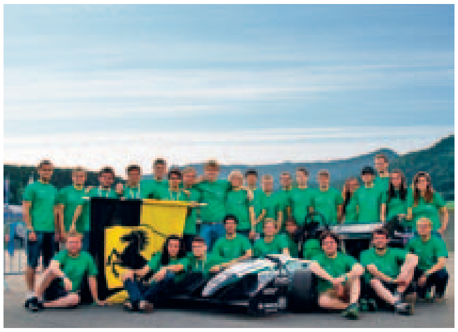
NEW MEASUREMENT METHOD



___ With no-touch temperature measurement, Porsche Engineering offers a new method of examining highly stressed engine components. This method of measurement enables transient function evaluation of thermally and mechanically highly stressed engine valves in which various factors such as geometries, materials, and ambient conditions are tested in real time to determine their impact on the local component temperature. The impact of different application statuses of the engine control is also analyzed and evaluated immediately. The measurements are conducted with high frequency and are suitable both for the test bench and in-vehicle testing. This method of measurement was first presented to potential customers at the Aachen Colloquium in Beijing last autumn and was very well received. ■

PORSCHE ENGINEERING SUPPORTS UNIVERSITY OF STUTTGART'S GREENTEAM

SUPPORTING THE UP-AND-COMERS



___ Every year, the GreenTeam, a group of ambitious students at the University of Stuttgart, builds its own fully electrical e-race car and enters it in the international Formula Student competition to test its mettle against other students. The team is actively supported through partnerships with manufacturers and other companies. Porsche Engineering, which has been an official sponsor since 2011, supports the GreenTeam with valuable knowledge and experience in the team's ongoing development activities. The team is granted access to Porsche Engineering test benches for testing to help the team continually advance its fully electric drive technology and set the stage for a successful season of racing. ■

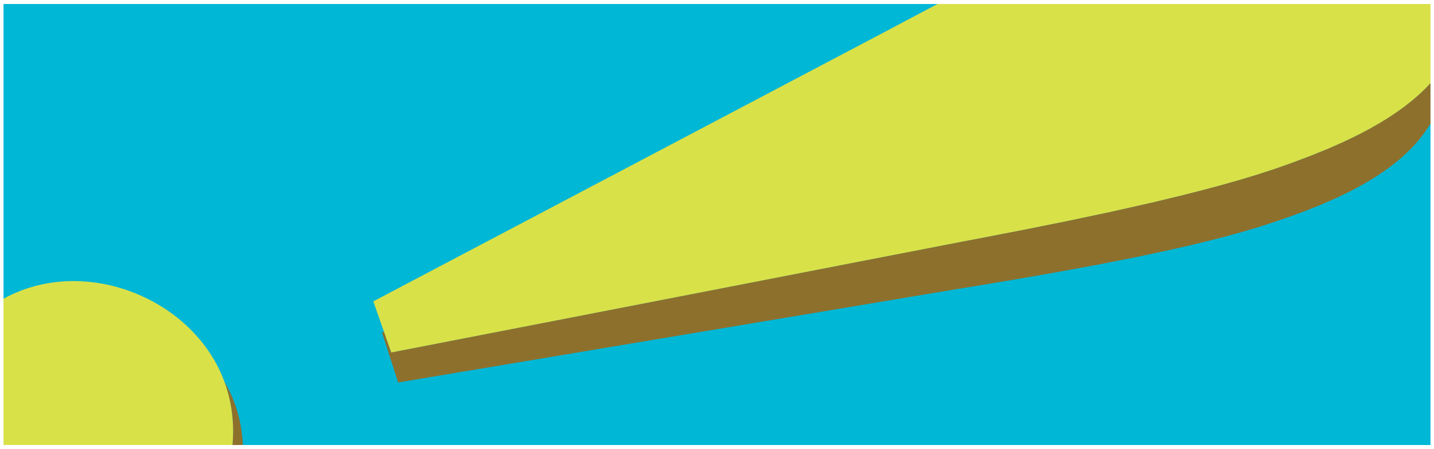
Powertrains of the Future

____ A colorful mix. That's the watchword. The future of powertrain technology will be diverse. CO_2-neutral mobility is the overarching long-term objective. Achieving it will require a balanced mix of powertrain types and energy carriers. All variants are being continuously refined—batteries, plug-in-hybrids, hybrids, fuel cells, and combustion engines.

As we do so, we take account of applicable regulations as well as political, business, and societal factors. And not only that: first and foremost is our own commitment to continuous improvement and technological progress. That's how we shape the future.

How exactly? We'll explain in our articles "Identified," "Optimized," and "Electrified," among others. Learn more about the theoretical foundations and special issues, as well as the design process and testing of electric motors. And the Porsche 918 Spyder demonstrates how combustion engines and electric motors can harmonize efficiently at the very pinnacle of performance.

Exciting times in the world of powertrain technology—we can look ahead to a diverse future with optimism.

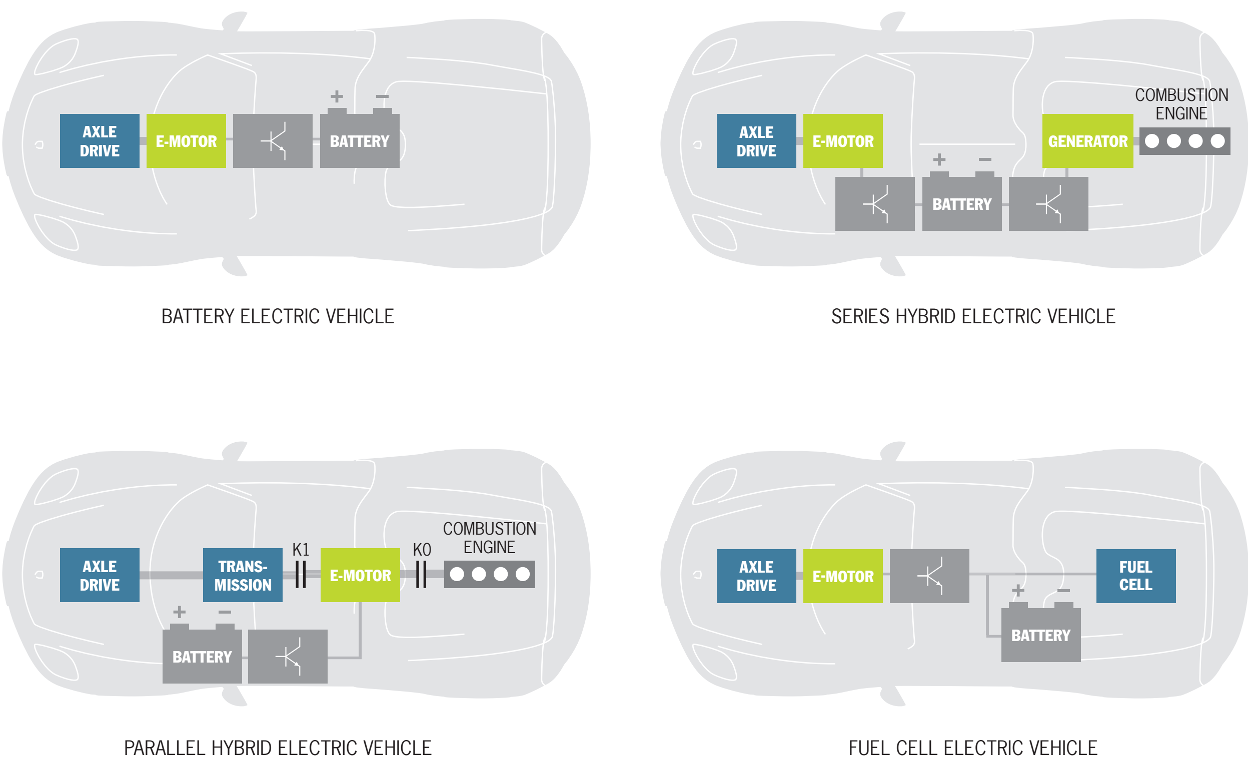



IDENTIFIED

Electric Motors—the Heart and Soul of Tomorrow's Powertrain

____Electric mobility is playing a key role in future drivetrain technology. Step by step, it is leaving its niche and becoming reality—a serious challenge for vehicle manufacturers used to dealing with gasoline, pistons, and spark plugs. Porsche Engineering is uniquely positioned to benefit from this radical and disruptive shift in technology by providing the type of closely integrated expertise new vehicle architectures demand. In this article we take a first look at the theory and functionality of the device that is central to tomorrow's powertrain.

By Dr. Malte Jaensch



Topologies of electric powertrain systems

More than 150 years ago, James Clerk Maxwell laid the foundation for the development of the electric motor by devising a set of governing equations commonly known as Maxwell's equations (see below). These equations capture both the beauty and the challenges inherent to electric motors: a machine with only one moving part—the rotor—described by only four short equations seems deceptively simple. Yet, working with electric motors can still be confusingly complex.

Operating principles

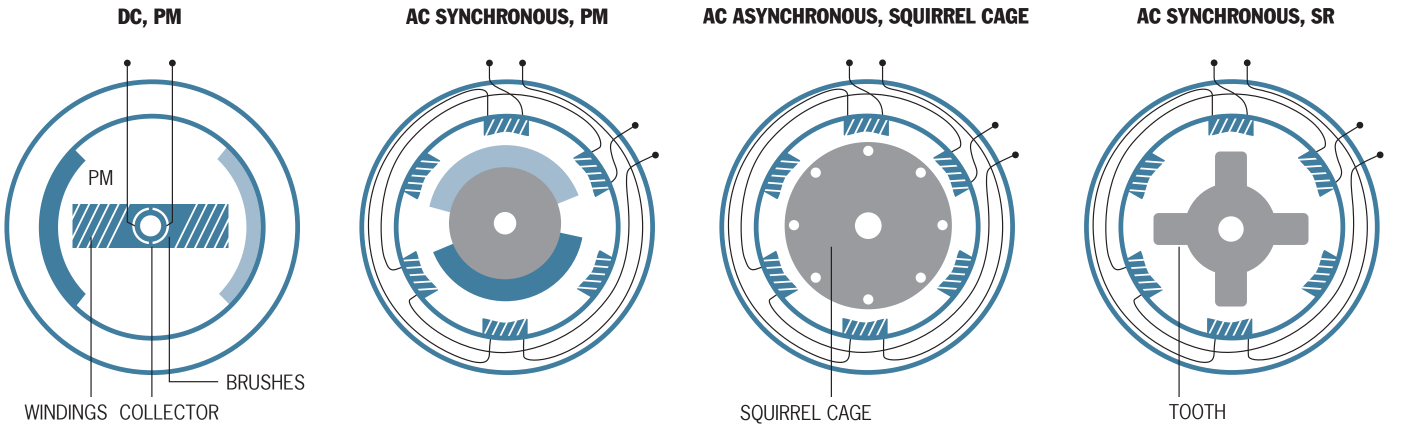
Within a vehicle environment, electric motors are part of a larger system: the electric powertrain. Battery electric vehicles have the simplest type of electric powertrain: a high-voltage battery pack provides direct current power (DC), which is converted by a frequency inverter into three-phase alternating current power (AC) of variable frequency. The electric motor finally converts the electric power into mechanical power, which is then used to propel the vehicle. Other types of electric vehicles, such as fuel cell electric vehicles or hybrid electric vehicles, exhibit more complex topologies. (see left-hand page).

Most electric motors rely on the interaction of two distinct electromagnetic fields—the rotor field and the stator field—to produce torque. At least one of these fields is established by current injected in the machine by the inverter. ›

E ELECTRIC FIELD
ρ CHARGE DENSITY
ε_0 PERMITTIVITY OF FREE SPACE
B FLUX DENSITY
μ_0 PERMEABILITY OF FREE SPACE
t TIME
J CURRENT DENSITY

Gauss's Law	$\nabla \cdot E = \frac{\rho}{\varepsilon_0}$	Describes the relationship between the electric field and the charge that causes it
Gauss's Law for Magnetism	$\nabla \cdot B = 0$	Magnetic field lines have no start or end; there are no magnetic monopoles
Faraday's Law of Induction	$\nabla \times E = \frac{\partial B}{\partial t}$	Changing magnetic fields can induce voltages, as in an electric generator
Ampere's Circuital Law	$\nabla \times B = \mu_0 J$	Electric currents create magnetic fields, as in an electric motor

Maxwell's equations



Functional principle of an electric motor

The second field might be produced by permanent magnets, (PMs) through induction or by current fed from a second external power source (see above).

It is one of the great advantages of the electric motor that energy conversion is reversible. An electric motor used as a motor turns electric power into mechanical power. The same machine—employed as a generator—converts mechanical power back into electrical power. This characteristic is used, for example, during recuperative breaking, whereby the vehicle's kinetic energy is transferred back into the battery.

Overloading

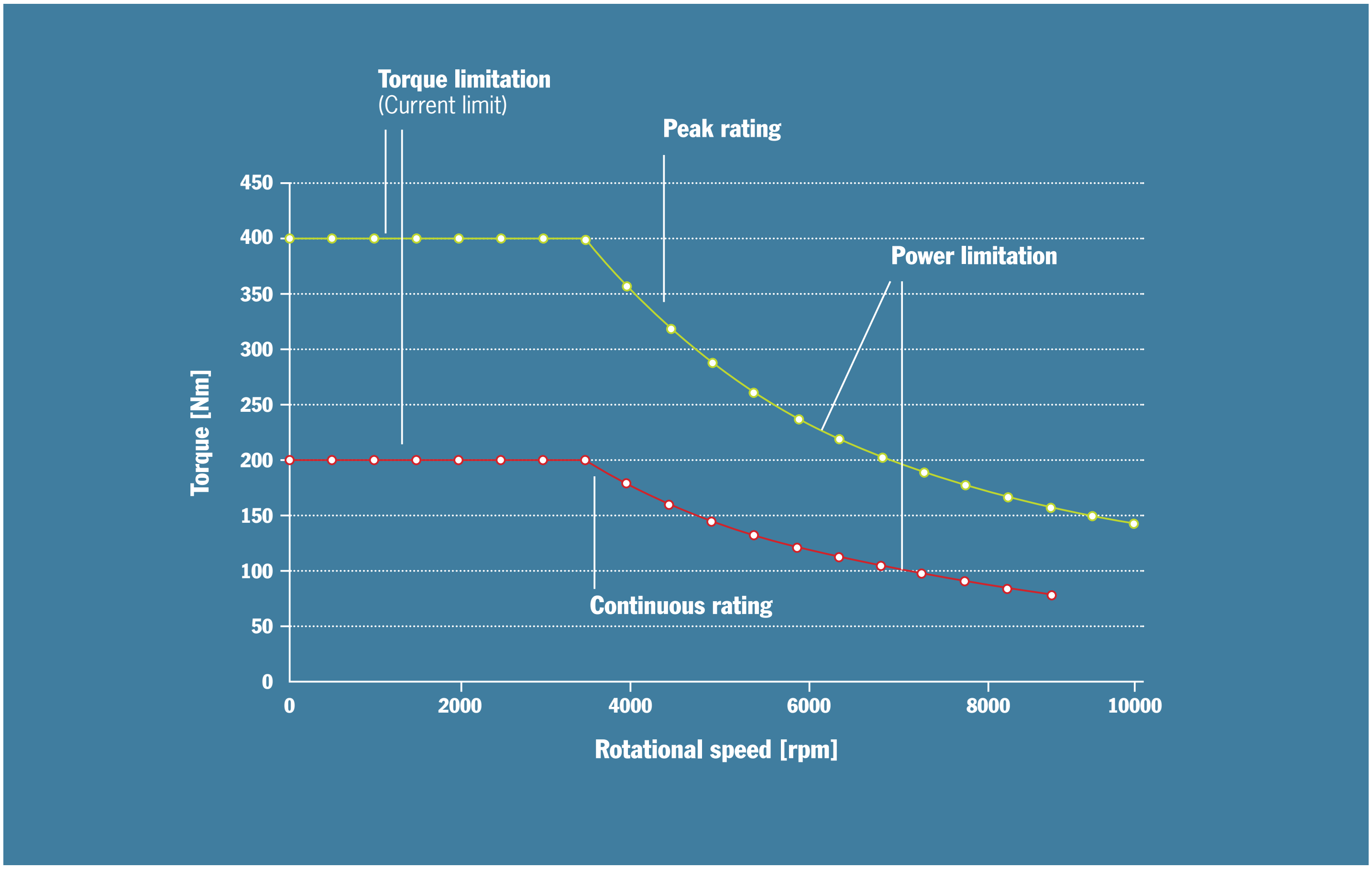
Whereas the performance and power output of combustion engines is generally fixed, an electric motor can deliver short bursts of power at very high levels. Thus, a distinction needs to be made between continuous or "S1" power rating, and the short-term peak power rating of the electric motor.

In some driving scenarios such as sustained uphill driving or driving at high speeds, continuous power is critical. In other scenarios, like overtaking slower vehicles or climbing over a curb when parking, peak power is required. In modern electric motors, peak power ratings can be up to 5 times higher than nominal power ratings, thus inevitably changing the driving characteristics of electric vehicles compared with conventional vehicles.

During a peak power event, the temperature of the copper wires carrying the current rises quickly, eventually reaching the copper wire's temperature limit. At this point, power needs to be reduced to prevent damage to the machine. However, the peak performance depends not only on time but also on other parameters, such as the DC voltage applied to the inverter and the coolant temperature. This gives the electric motor a multidimensional performance characteristic, which is virtually impossible to capture in a single data sheet.

Torque/Speed curves

As is the case with combustion engines, torque/speed curves, plots of torque and power over rotational speed, are useful tools for characterising a given machine (see right-hand page: Torque/speed curve). Torque/speed curves of all electric motors exhibit a certain characteristic: up to a certain speed, the corner speed, torque is constant and power increases.



Torque/speed curve

Beyond the corner speed, torque drops while power stays constant.

In this constant power region, the voltage applied to the machine no longer rises with speed but is kept constant. Keeping voltage constant despite increasing speeds requires an artificial weakening of the electromagnetic fields inside the machine. This can be achieved, for example, by changing the timing of the AC current injected in the machine. However, part of the current is then no longer available for torque production, which is why torque drops beyond the corner speed.

Considering the described complex behavior of electric motors, real-life evaluation on test benches is of paramount importance for identifying the properties of a given machine. Porsche Engineering's electric motor test bench (see article "Electrified," p. 22) thus provides customers with an essential tool for verifying the actual performance of an electric motor.

Performance limits

Electric motor performance is limited by a number of factors. One is the maximum temperature of the copper windings carrying the electric current. Covered with multiple layers of electrically insulating plastic coating, the permissible temperature typically ranges between 140 and 200°C. Since current running through a wire creates losses, the windings heat up, thereby limiting the current applicable.

Permanent magnets, if present, have a temperature threshold as well. Modern neodymium–iron–boron (NdFeB) magnets can withstand temperatures of up to 220°C. If the limit is exceeded, however, the magnets will de-magnetise, irreversibly reducing performance. Magnetic heating is a complex phenomenon, influenced by machine speed, DC voltage, and the magnitude and harmonic content of the AC current waveform. Sophisticated "motor models" are needed to calculate magnetic temperature in situ, since it can be measured only with great difficulty. Predicting the response of an electric powertrain system within a vehicle system therefore requires highly integrated simulation (see article "Optimized").

In addition to the thermal limitations discussed, electric motors face the same constraints as other pieces of rotating machinery: the maximum speed is limited by the rigidity of the rotor and the bearings, while the level of power › supplied by the inverter and/or the battery naturally limits what the machine can deliver.

(A)Synchronous

A large variety of different machine topologies exist in the market, only a few of which are utilised by vehicle manufacturers. Synchronous machines are so named because the electromagnetic field set up by the injected current rotates synchronously with the machine rotor. Most relevant for automotive applications are permanent magnet synchronous machines (PSMs). These machines deliver high torque and power, have a high efficiency and run at high speeds.

The rotor of an PSM can be located either inside or outside the stator. A typical example of an internal rotor PSM is the traction motor powering the front wheels of the Porsche 918 Spyder (see p. 28). External rotor PSMs have an increased torque capability and short axial length. These machines are therefore often used as integrated motor/generators that sit between the combustion engine and the gearbox of hybrid vehicles such as the Panamera S E-Hybrid.

Unlike PSMs, asynchronous machines (ASMs) do not utilise permanent magnets. Torque is produced by the reaction between the stator electromagnetic field created directly by the injected current and a reaction field induced indirectly in the machine's rotor. In these machines, the stator field and the rotor turn asynchronously, i.e. at different speeds. The establishment of the reaction field—as described by Faraday's law of induction—can only happen when there is relative movement or "slip" between the stator field and the rotor.

ASMs are very robust and generally cheaper than PSMs because they don't employ permanent magnets, which are by far the most expensive components of a PSM. However, ASMs are also comparatively inefficient and heavy.

Conclusions

High-power electric motors and generators such as those used in modern electric vehicles are highly complex devices despite their seemingly simple design and elegant physical description. Understanding their true characteristics is therefore essential for integrating them optimally within a complex vehicle system.

A wide range of different types of machines with idiosyncratic and non-obvious advantages and disadvantages populates the market. Choosing the machine most suited for a given vehicle concept therefore necessitates extensive evaluation on an electric motor test bench coupled with advanced simulation of machine and surrounding vehicle system.

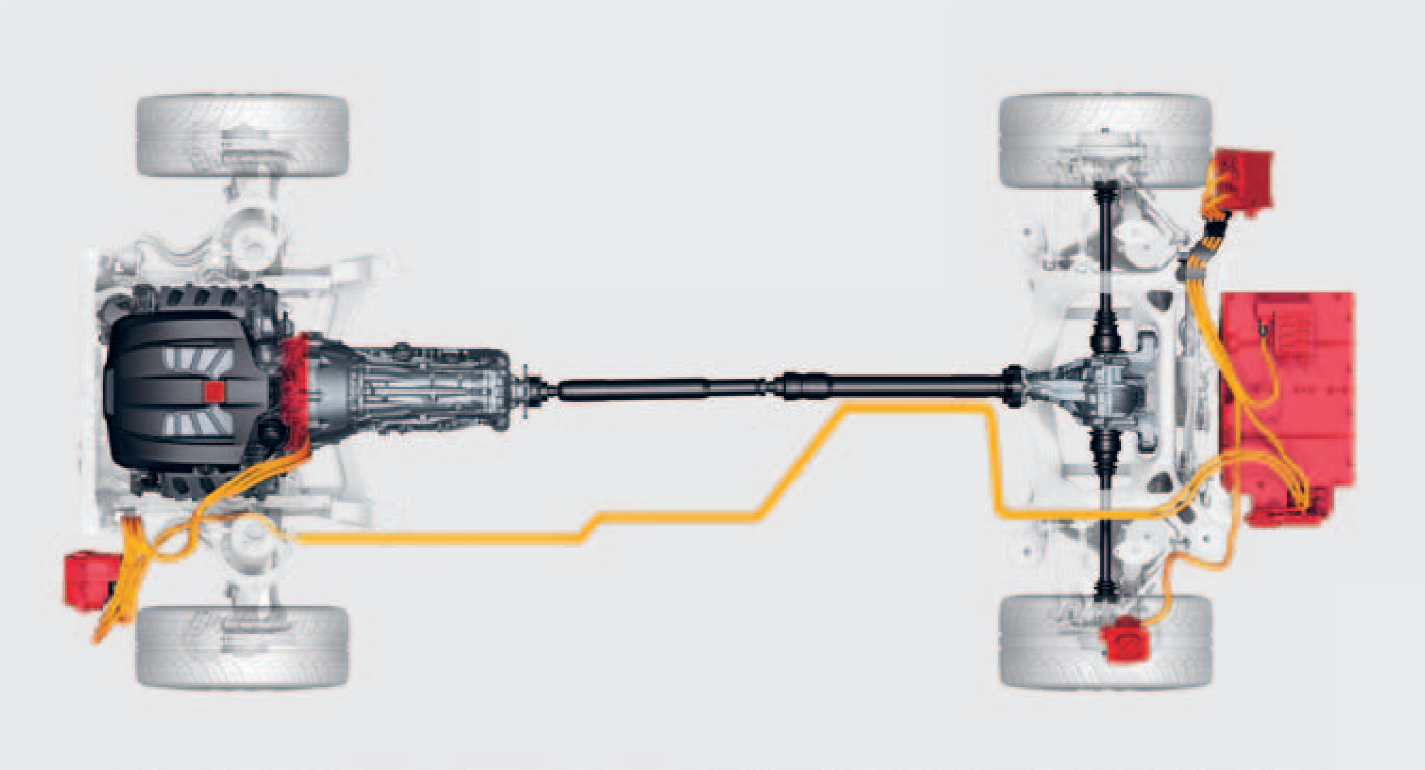
Hybrid Powertrain of the Panamera S E-Hybrid

The seamless interplay between the combustion engine and electric motor forms a drive concept that unites high performance and high efficiency. The new lithium-ion battery can be charged via the vehicle charging connection. The powerful and high-torque electric drive ensures adequate electric performance. The engines are still mechanically connected to the axles, so typical Porsche performance can be called up at any time: via the combustion engine or with extra punch using both drives–also known as boosting.

The increasing prominence of electric mobility is creating considerable pressure on established vehicle manufacturers to develop new products quickly. Porsche Engineering stands ready to accept the challenge and drive new vehicle technologies into the future. ■

PANAMERA S E-HYBRID Fuel consumption (combined): 3.1 l/100 km; CO_2 emissions: 71 g/km; energy consumption: 16.2 kWh/100 km; efficiency class: DE/CH A+/A

The Panamera S E-Hybrid: forward-looking



Hybrid Powertrain of the Panamera S E-Hybrid

OPTIMIZED

Design and Construction of the Optimum Electric Powertrain

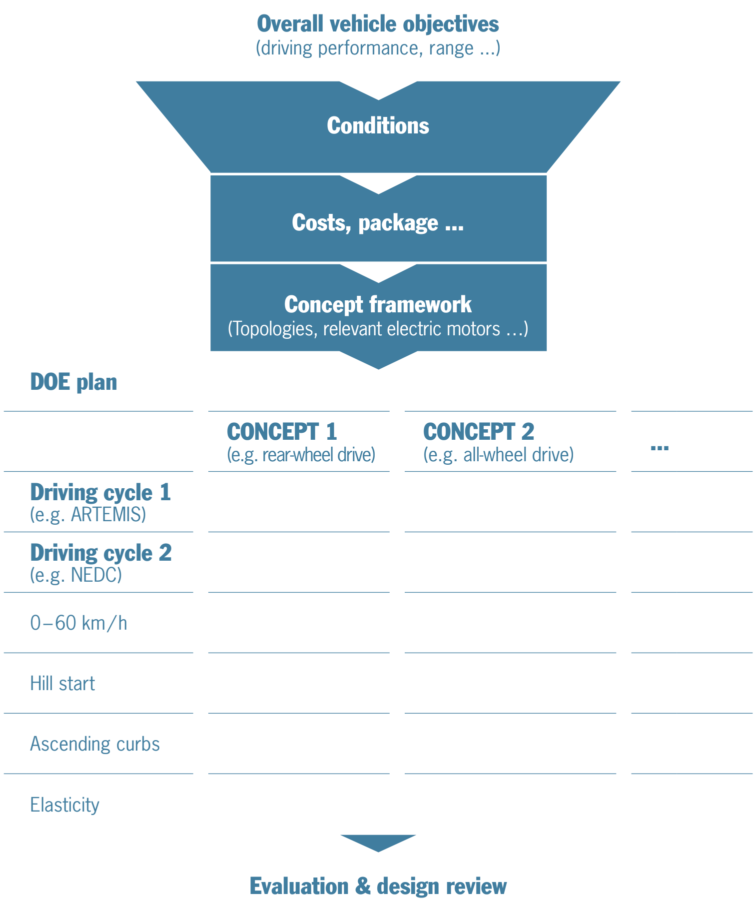
____ Effective design of electric powertrains is, today more than ever, a major focus of vehicle development. Porsche Engineering is therefore working on comprehensive simulations in many fields of electromobility.

By Adam Barák, Thorsten Böger, Torsten Dünninghaus, and Thomas Sadorf

When developing vehicles with electric motors, the conceptualization and design of the powertrain is a central task. It is essential to remain focused on the specifications while optimally harmonizing the functions of the electric motor, power electronics, traction battery, and transmission components. Vehicle concepts under consideration are often highly limited by external factors. For instance, the available space may only allow a certain motor/transmission combination, the distance between axles may limit maximum gear ratios, and the use of multi-stage transmissions and clutches may not be possible.

Another limiting factor is the later production costs, which may preclude the use of highly efficient PSM (permanent magnet synchronous motor) designs from the outset. The same fate can also befall concepts with multiple gears, clutches, and multiple motors. And the time factor cannot be neglected either, because for projects with a high degree of innovation, the available time for development becomes very important. All of this leads to the question of how to best utilize the available resources to develop the best possible powertrain for the car.

Aside from project-specific factors with regard to the package and budget, targets for driving performance, consumption, and range have top priority. The most important maneuvers for determining the driving performance are full-load acceleration from 0 to 100 km/h and hill starts and ascending curbs. The set-up for consumption and range is based on target market-specific factors, legal requirements (for example in the EU the New European Driving Cycle—NEDC) and customer expectations, such as the determination of actual consumption in the CADC (Common Artemis Driving Cycles).

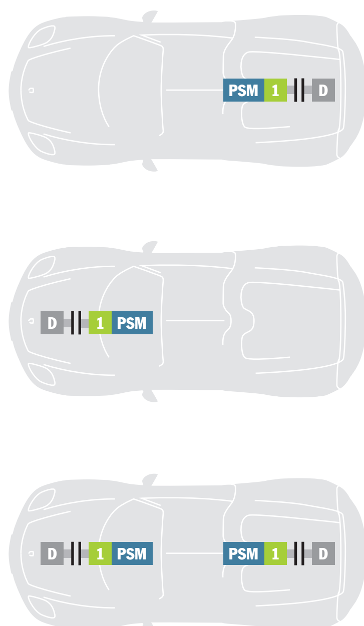


Decision-making process for the effective design of the powertrain

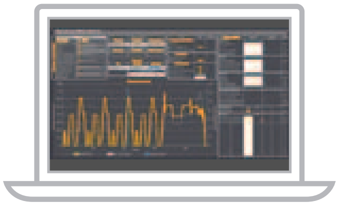
Topology definition

At the beginning of the development process, the target topology for the vehicle must be determined. This is a very complex task, and the result strongly depends on the vehicle type and the technical specifications. There is any number of possible arrangements and combinations of the powertrain components, each of which offers specific advantages and disadvantages. One possible layout is a topology with an electric motor on the front axle and a second one on the rear axle. In terms of propulsion, it offers the benefits of all-wheel drive and the greatest potential for recuperative braking with regard to driving stability. In this topology, it would be possible, for example, to ›

Example of different topologies



Porsche Engineering Simulation Methods



eCruise

In-house Excel-based calculation program for fast preliminary assessments

AVL Cruise

Complete vehicle simulation to determine driving performance and consumption

Matlab/Simulink

Driving performance and consumption simulation in combination with complex subsystem models and rule systems

combine different motor types. One motor with optimal efficiency would assume the majority of driving situations, while a cheaper and less efficient motor would cover the required bursts of high performance. This would enable reduced costs with minimal impact on consumption.

One of the first steps is to convert the factors from the project description into technical characteristics. Here it is crucial to consider the interactions of the system components. Take this example: the desire for a long range could be fulfilled by a sufficiently large traction battery. The great weight of the battery, however, would compromise the vehicle's acceleration behavior. The costs of the larger battery, the package, and the higher energy consumption stand in opposition to numerous other factors.

Simulation of driving performance and fuel consumption

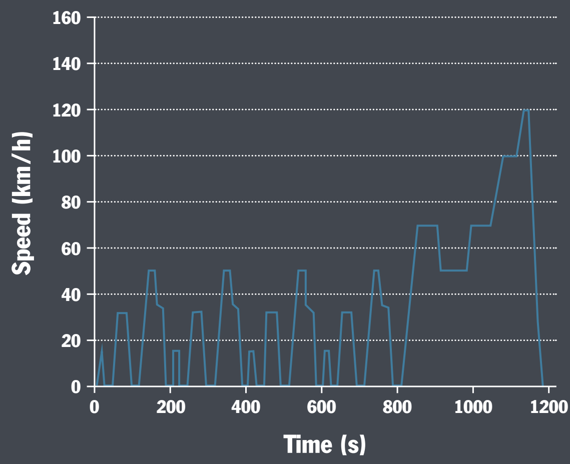
To generate ideas and ultimately decide on suitable concepts, well-known tools are brought into play, such as the morphological box and the decision matrix. Simulation of driving performance and consumption plays a significant role in determining the potential of various concepts and comparing them at the outset. The range of concepts under consideration and the components available for selection is narrowed down at this stage. To evaluate the remaining relevant powertrain concepts, the models are made more detailed at this point. In a DOE (Design of Experiment) plan, these are assessed by simulation. Once the results are in place, the individual concepts can be compared in detail and evaluated. The insights gained and tendencies observed through this process enable a finer granulation of the concepts to determine the optimal design of the powertrain.

At Porsche Engineering, the Matlab/Simulink, AVL Cruise, and eCruise programs are available for this purpose. The eCruise calculation program was developed in-house for simple and quick quantification of consumption and driving performance values in the concept phase.

Definition of the motor size

Once the topology has been defined, the next task is to determine the size and type of the electric motor(s). The minimum required driving power is determined depending on the required driving performance, the applied evaluation cycles, and the motor operating points. In the NEDC, for example, due to the low dynamic response with constant accelerations, decelerations of max. 1.4 m/s², a maximum speed of 120 km/h, and the

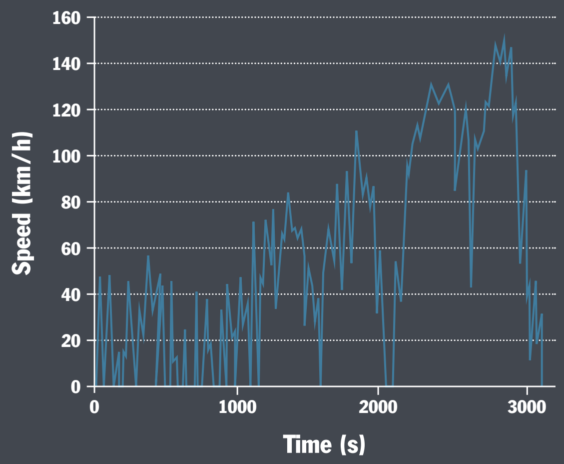
New European Driving Cycle—NEDC



The NEDC is the legally binding consumption cycle in Europe and China. It is comprised of constant speed drives, constant accelerations, braking and idling phases.

Maximum speed	120.0 km/h
Average speed	33.6 km/h
Stopping time	20.0%
Length	11 km
Maximum acceleration	1.0 m/s²
Maximum deceleration	–1.4 m/s²

Common ARTEMIS Driving Cycles—CADC

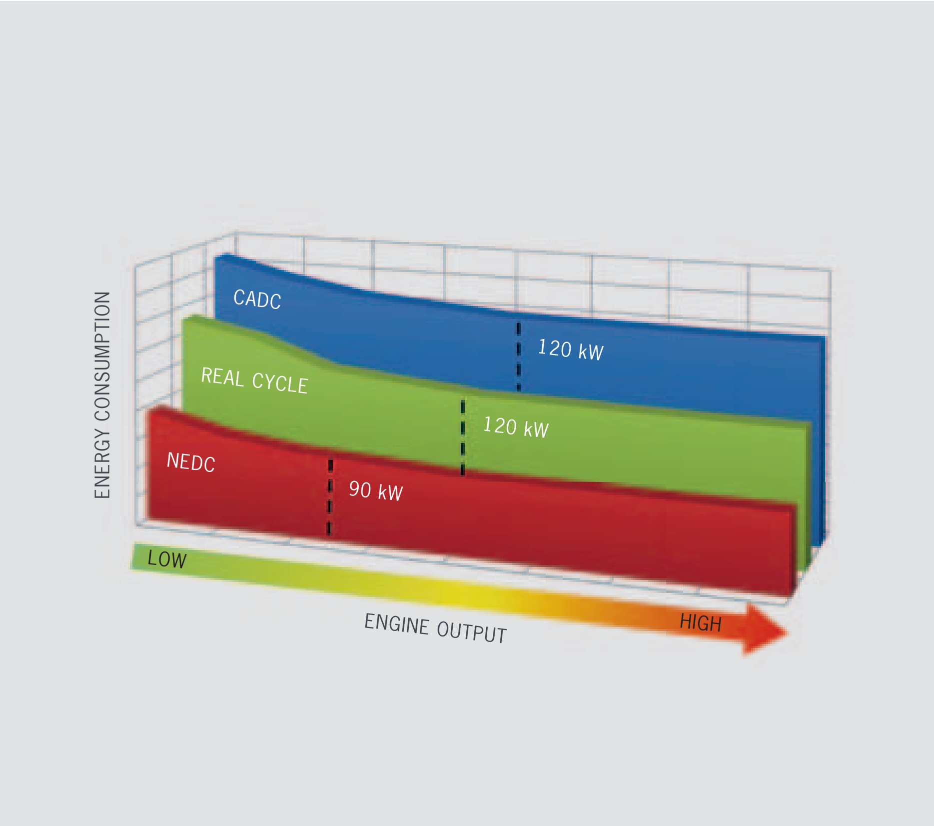


The CADC was created as part of the European research project ARTEMIS. The cycle is distinctive in that it is derived from real driving profiles.

Maximum speed	150.4 km/h
Average speed	59.2 km/h
Stopping time	9,7%
Length	51.7 km
Maximum acceleration	2.3 m/s²
Maximum deceleration	–3.6 m/s²

many constant speed drives, less driving power is required and relatively little energy consumed. Thus the motor is frequently operated in the low power range in the cycle. Electric motors with high efficiency and low power are advantageous here.

By comparison, a dynamic cycle such as the CADC has higher accelerations and decelerations of up to 3.6 m/s². In addition, the maximum speed is 150 km/h and there is hardly any constant speed driving to speak of. As a result, the cycle taps a larger power range of the electric motor. For a low cycle consumption, the efficiency must be high for a wide range of the performance map. Moreover, in a dynamic cycle, higher power is not just required briefly (recuperation braking) but over long phases. If the motor has insufficient power, not all of the energy can be recuperated during braking and the motor goes into thermal overload more quickly. The motor control then goes into derating mode. For the duration of a defined cooling phase, the available motor output is reduced. The greater the thermal mass of the motor and ›



Impact of motor size on energy consumption in the different driving cycles

the greater the power, the less often the vehicle will go into the derating range. This too speaks in favor of a minimum motor size in the design of a credible electric powertrain concept.

Impact of recuperative braking

Larger motors in combination with suitable transmission ratios provide additional benefits during recuperative braking. In a conventional vehicle, the kinetic energy is converted into heat through the friction brake and emitted into the environment without being used. Electric vehicles can recuperate a large portion of their kinetic energy. During braking, the electric motor switches into generator mode, converts the kinetic energy into electric energy, and stores it in the high-voltage battery. The amount of braking energy that can be recuperated depends primarily on the motor power, the transmission ratio, and the recuperation capacity of the brake management. Since the traction on the rear axle is limited early when braking through a corner, for example, it is advantageous to distribute the electric braking force between the front and rear axles to exploit the maximum potential of recuperative braking.

Definition of the transmission ratio

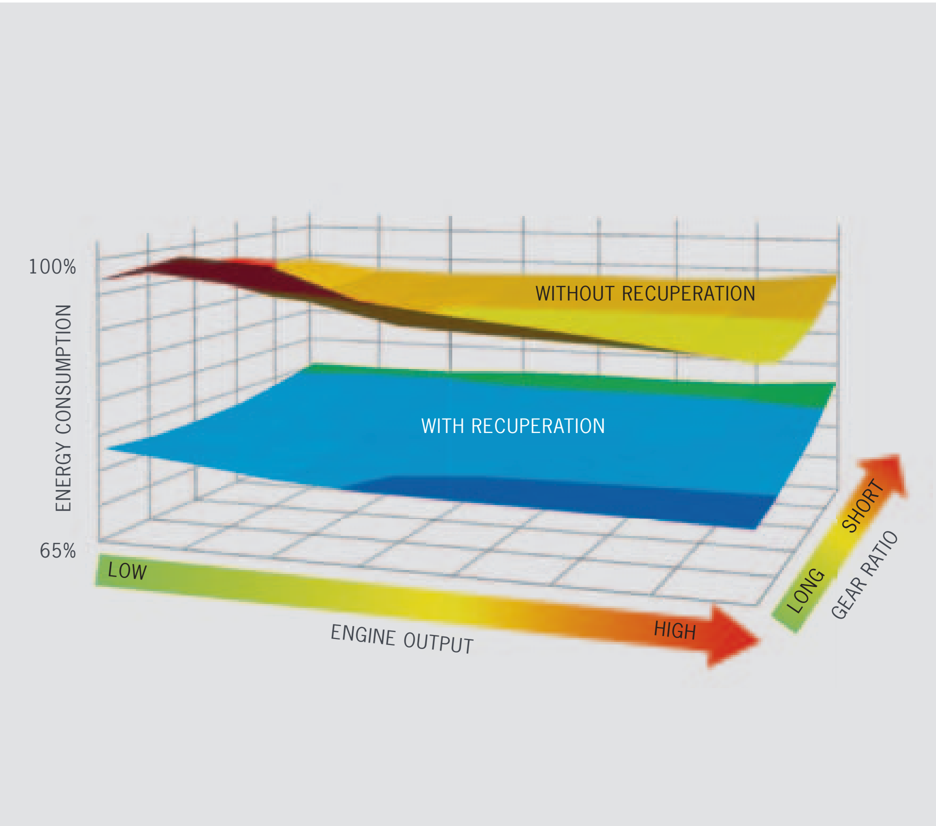
If a transmission with just one gear ratio is planned for a topology, this ratio is always a compromise between optimal power transmission, the lowest possible consumption, and top speed.

The transmission ratio defines the speed of the motor in relation to the wheel speed and how much motor torque is required for a defined acceleration of the vehicle. Since the efficiency of an electric motor is dependent on the torque and the motor speed, a given transmission ratio leads to a certain efficiency of the motor in a driving cycle. A vehicle with a long gear ratio will, assuming sufficient power, achieve worse acceleration values but also a higher top speed. With a short gear ratio, the situation is the converse.

Since the three objectives (acceleration, consumption, and top speed) may require different gear ratios, multiple-gear transmissions may present a solution. These make it possible to improve the driving performance and motor operating point distribution. But here, too, an overall system view is very important as more complex transmissions tend to be less efficient, reducing the benefit. Whether the use of multi-speed transmissions makes sense must be evaluated on a case-by-case basis in view of the project objectives.

Conclusion

The challenges with regard to electrification of the powertrain are manifold. New motor and battery concepts are being developed, and also their complex control systems and integration into vehicles have to be refined all the time. This in turn continually confronts engineers with new challenges to overcome with flexible thinking and ingenuity. For years, Porsche Engineering has been mastering these challenges successfully in a diverse array of projects. ■



Energy savings in the CADC through recuperation

ELECTRIFIED

Testing on the Electric Motor Test Bench

____ To transform powertrain concepts from the design and simulation phases into reality, comprehensive testing is indispensable. In particular, testing an electric motor and interpreting the results represent a major challenge. An electric powertrain offers many advantages, but also a few special characteristics that require keen attention from engineers. Test benches at Porsche Engineering enable complex testing and detailed evaluations that are important for the development process.

By Johannes Aehling, Stefan Gatzemann, and Dr. Jan-Peter Müller-Kose
Photos: Jörg Eberl

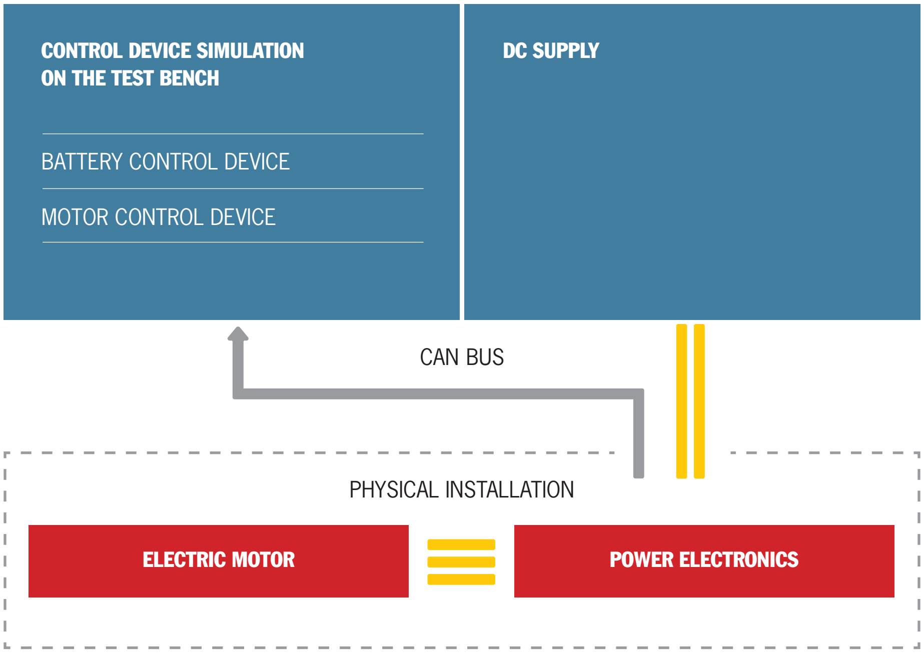
Once the design and simulation phases for an electric motor are complete, a model is built and put through its paces on the electric motor test bench. In the course of testing, theory is tested against reality, which requires special expertise on the part of the engineers. Above all this phase is concerned with ensuring that the motor fulfills the customer's requirements. Testing on the test bench is a part of every phase of the development of an electric motor, from the concept to series production. Before the machine can be measured, however, the application engineer must bring it to life.

Application

The application engineer enables the communication or interaction between the electric motor and the power electronics. These two components must first be coordinated with each other. A test bench offers two possible options for this: the electric motor can either be operated with a universal inverter or the inverter to be used later in the vehicle. If multiple motors are operated with the same universal inverter, comparing the test series reveals differences between the motor variants. Universal inverters are often significantly more powerful than the unit planned for the series. They can thus push the motor to its physical limits and enable a precise estimate of its performance threshold. By contrast, using power electronics from the later powertrain makes it possible to test the two components as they interact. Comparability then exists on the system level. This is where the ›

Testing on the test bench goes hand in hand with the development of an electric powertrain system of any type—from the concept to series production.

TEST BENCH SET-UP



Simulation of relevant CAN nodes from the vehicle on the test bench

performance limits of the later drive are tested.

Electric motors are not equipped with torque measurement technology in the vehicle. Thus the power electronics cannot directly regulate the torque. Generally speaking, the power electronics provide a current with which torque is generated. Through this correlation, a conversion from target torque into a target current and thus from torque control into current control is carried out. During the application, the electric motor is driven to various operating points. The parameters for the application of the characteristics and control maps are derived from the measurement values from the power electronics and the test bench. Of particular importance are the values from the torque sensor, which only exists on the test bench, so that a current/torque correlation can be established.

Beyond determining the machine parameters, additional development tasks are also a part of an application. The inverters, for instance, are generally outfitted with functions that protect the system against damage. This includes, for example, observing the current limits of the high-voltage (HV) battery and monitoring the temperature of the electric motor. For these functions to be applied, various specifications in the restbus simulation of the system environment must be changed in the meantime. These then provoke a reaction of the respective protective functions. Taking the example of current limits, the parameters would be set such that exceeding the battery current and thus damaging the battery are prevented.

Electric motors with permanent magnets are often used in the vehicle. Here it is important to bear in mind the temperature dependence of the magnets as the magnetic flux density of the magnets, changes with the temperature. The flux density is directly related to the generated torque, which is why torque would drop with a rising temperature. Development engineers refer to this as flux compensation. It compensates for the temperature dependence of the torque. For the compensation to be applied, an electric motor with special measuring technology (rotor telemetry) is required. Equipping such a machine with the appropriate technology is associated with dedicated machine design and carries additional financial costs. In this case planning security must be ensured through design freezes.

This applies in particular to the construction of the electric motor. All changes to the electromagnetic system—either to the materials or in terms of the connection of the cooling jacket after application of the temperature dependences—can adversely impact the torque precision, which in turn necessitates adjusting and updating the application across the various models.

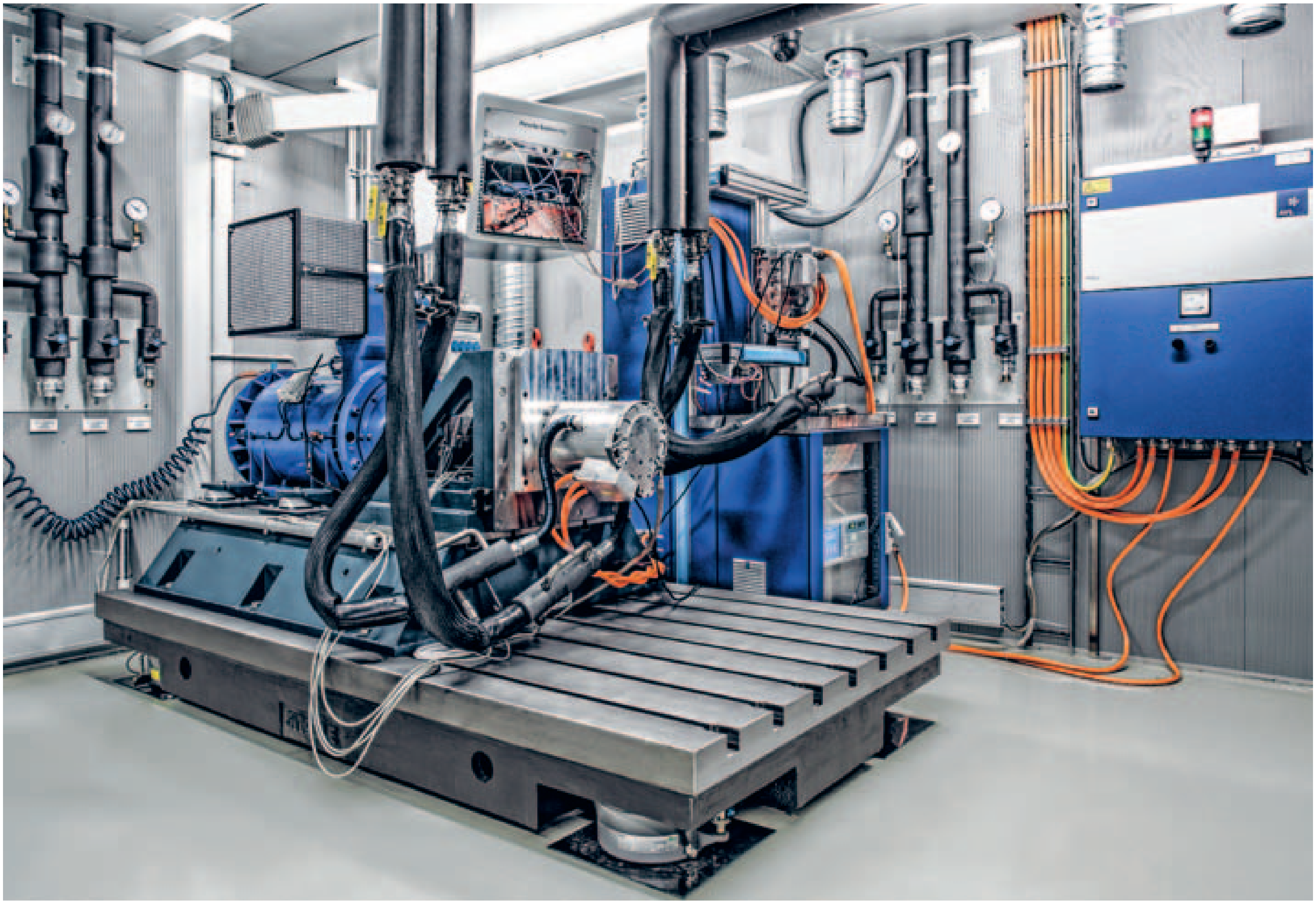
Testing

The testing process distinguishes between the following four requirement categories:

> Performance
> Durability
> Abuse
> Reference measurement

In performance testing the focus is on the electric motor's performance data. Durability testing tests the long-term robustness of the electric motor. Special test cycles compress the thermal and mechanical load spectra for the lifetime of the motor into a period of a few weeks. Abuse testing checks potential malfunctions and faulty reactions. The reference measurement is used to determine variation in the performance data. Multiple motors of the same type are measured in succession to document the range of variance.

To ensure that all requirements can be tested, Porsche Engineering relies on its own test catalog that has proven its mettle time and again. It includes more than 70 individual tests from series development that cover all as- ›



When using the test bench, the electric motor can be operated either with a universal inverter or with the inverter that will later be used in the vehicle.

TECHNICAL DATA

DC supply	
Rated power	250 kW
Max. high voltage	800 V
Max. DC current	600 A
Load machine	
Machine type	ASM
Rated power	250 kW
Max. torque	600 Nm
Max. engine speed	15,000 rpm
Coolant	
T_{min}	–40 °C
T_{max}	+140 °C
Measuring technology	
Power measuring device	WT1800
Torque measuring flange	HBM T12
Porsche measuring technology	SMT 5
Control unit access	ES593

pects of development. One of the important standard tests is checking the efficiency control maps. These values are then later used by calculation engineers, among others, to estimate the range of the vehicle.

In contrast to a combustion engine, an electric motor has a very large overload capacity, which can be several times the nominal power rating. To examine this time-limited overload range, a variety of maximum characteristics are determined. The definition of "time-limited" has usually already been defined in the design.

Beyond determining the indicators and control maps on the test bench, customer-relevant test cycles are also important. They represent the later user behavior in the vehicle and are differentiated according to market and vehicle class. The components reflect the mechanical and thermal properties in the overall system when operated in a customer-relevant cycle. Of interest here are stable and reproducible acceleration and driving comfort values that can hold their own against the requirements expected of vehicles with conventional drive technology.

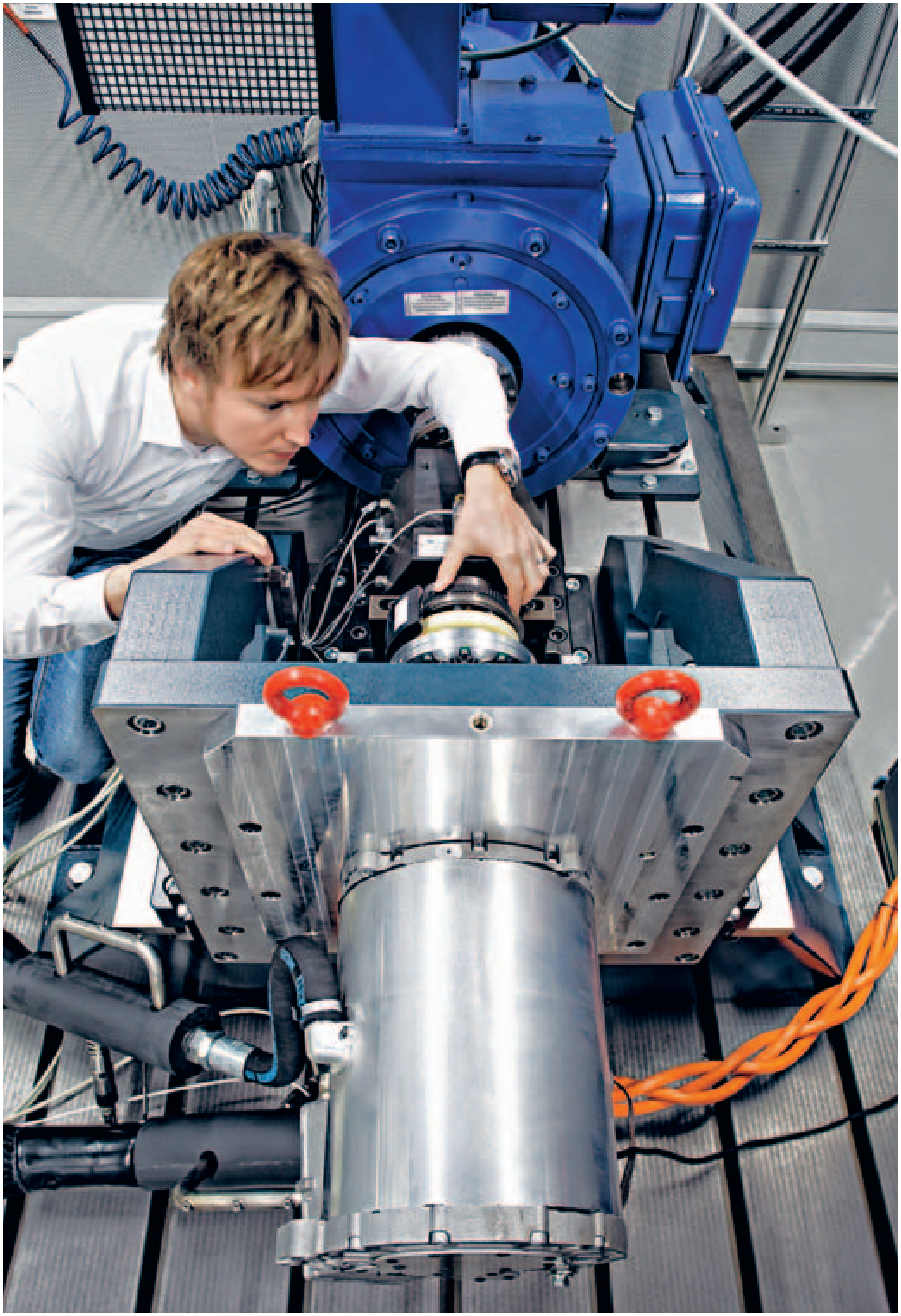
Beyond tests in the overall system or as individual components, the significance of a detailed view of subcomponents in the framework of testing is often underestimated. Porsche Engineering takes this into account in performance testing from the first concept onwards. Successfully integrating the drive in the vehicle requires attention to every last detail. One example would be the numerous environmental conditions in the automotive sector. For instance, developers are confronted with questions of material compatibility that normally do not occur in the standard environment of an electric motor. Early consideration of all factors makes it possible to recognize or avoid problems at an early stage.

In testing, the comparability and reproducibility of results are fundamental principles. The Porsche Engineering test bench has been validated against other internal and external test benches and the representation of the measurement results has been standardized. The new electric motor test bench is thus an ideal addition to the extensive Porsche testing landscape.

Evaluation and analysis

During the testing stage, preliminary results are already being continuously analyzed by the test engineer. In case of errors or anomalies, timely special measurements are often required to identify the actual result. The earlier a problem is analyzed and the cause identified, the less significant the impact on the project. Errors discovered late in the project are considerably more cost-intensive than those identified at an early stage. The continuous checking of the results can minimize the probability of damage to the test object.

Every individual component is continually regarded from a complete vehicle perspective, with experts from the various fields of vehicle development ready to offer their input on an interdisciplinary basis at short notice. Problems often touch on multiple areas of expertise, and an overall view of the situation only



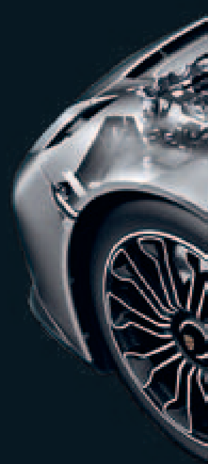
Porsche Engineering always views each individual component in the context of the complete vehicle.

emerges in consultations between experts from the different fields.

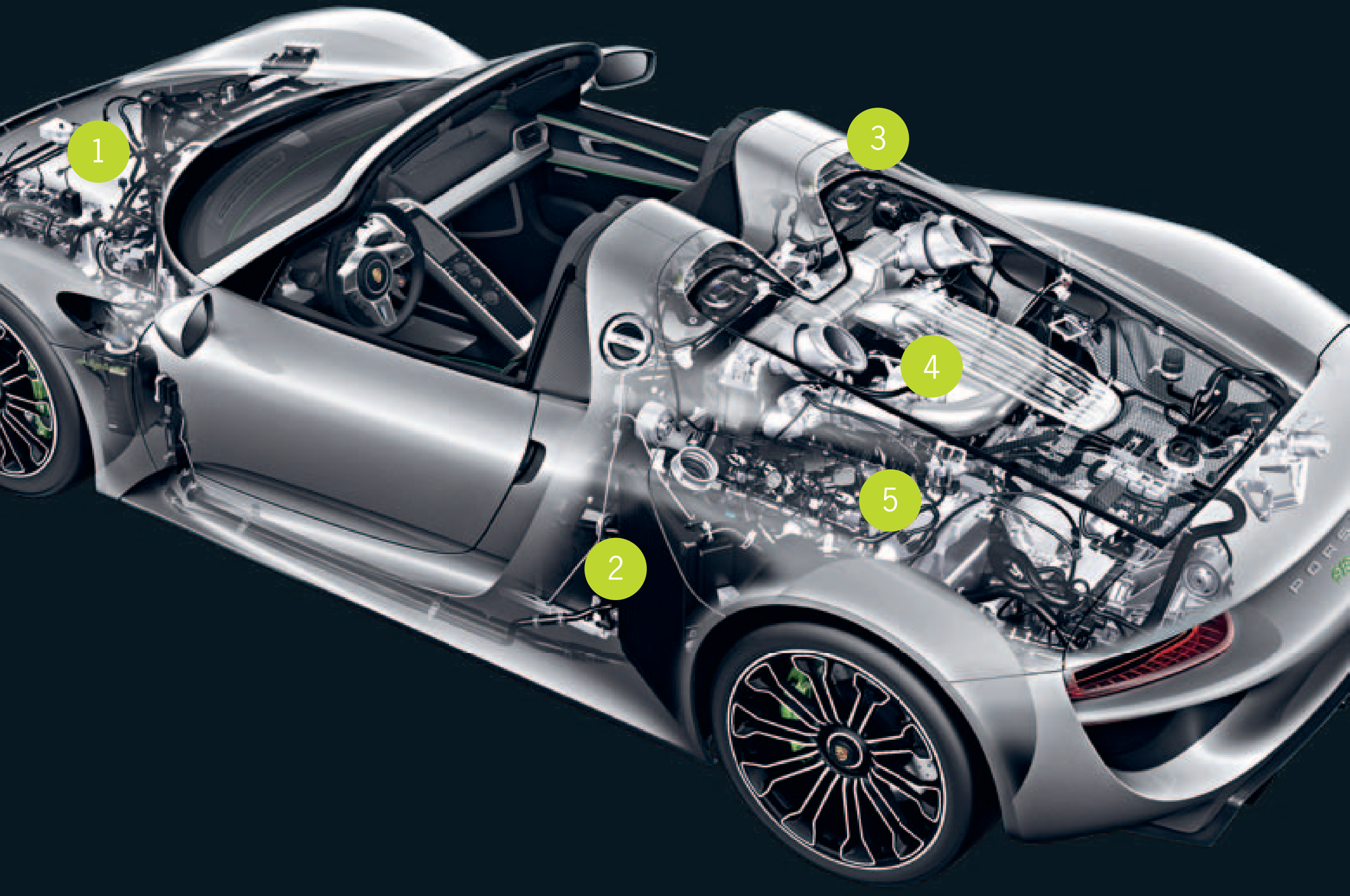
At the conclusion of testing, a report including a detailed interpretation of the results is created. The interpretation leads to a list of measures that the developers can use to refine their components and thus close the circle between design and testing. ■

PORSCHE 918 SPYDER

Mobility of the future? Not without the Porsche 918 Spyder. With the development of its new super sports car, Porsche is setting groundbreaking new standards. This car represents a decisive push towards new technologies and innovative vehicle concepts.



As a plug-in hybrid, the 918 Spyder uncompromisingly combines a high-performance combustion engine with advanced electric motors to achieve performances that are more than extraordinary: the best of both worlds give this super sports car the dynamism of an over 652 kW (887 hp) race car with consumption values—roughly 3 liters over 100 km (as per NEDC)—that are lower than those of most compact cars on the market. Beyond the innovative powertrain concept, Porsche's new technology benchmark also blazes new trails with spectacular solutions such as the carbon fiber-reinforced plastic (CFRP) body, fully variable aerodynamics, adaptive rear-axle steering and the "top pipes" exhaust system.



The Powertrain Concept

One thing or the other?
The best of both.

The 918 Spyder as a performance hybrid

The arrangement and function of the engines make the 918 Spyder a performance hybrid. What that means: it can be driven via the rear axle by the combustion engine as well as by the rear electric motor alone or together by both powertrains. Depending on the powertrain strategy, another electric motor kicks in on the front axle, powering the front wheels.

The V8 high-speed engine

The main powertrain source is the 4.6-liter eight-cylinder engine. With the power of over 447 kW (608 hp), the high-performance power unit rivals race car engines. And yet it is the lightest series-production V8 engine ever produced by Porsche. Its low weight of just 135 kilograms and its low position create the ideal conditions for extremely dynamic driving performance and the highest precision as it unpacks its power.

The electric motors

The two electric motors are mounted in front of the rear axle and behind the front axle. Together, they manifest extraordinary power relative to the weight and size. The total mechanical power is 210 kW (286 hp). The 918 Spyder achieves a purely electric top speed of up to 150 km/h and goes from 0 to 100 km/h in just 6.2 seconds—again, on electric power alone. To this is added the exceptional responsiveness of the electric powertrain. The maximum torque of 475 Nm is available from an absolute standstill.

High-performance traction battery

With its 230 kW of output, the liquid-cooled lithium-ion battery is currently the most powerful hybrid battery. With an overall weight of just 138 kilograms and an energy content of 6.8 kWh, extremely fast power output and the corresponding boost provided by the electric motors, it fulfills the energy demands that can be expected of a 21st-century super sports car. Specially designed for the 918 Spyder—and built for performance.

The high-performance hybrid brake system

The 918 Spyder can brake with both electric motors and thereby regain energy for the traction battery (recuperation). The high-performance hybrid brake system achieves the unparalleled combination of high recuperation performance with an authentic brake pedal feel. Unnoticed by the driver, the intelligent hydraulic system crossfades between electric braking and the hydraulic braking of the PCCB brake system (Porsche Ceramic Composite Brake) and ensures a consistent response of the brake pedal in every driving situation.

The 918 Spyder has arrived in the future. And it is leaving a new reality in its wake. Today. ■

1 ELECTRIC MOTOR ON FRONT AXLE
2 HIGH-PERFORMANCE LITHIUM-ION BATTERY
3 VEHICLE CHARGE CONNECTION
4 V8 HIGH-REV ENGINE
5 ELECTRIC MOTOR ON REAR AXLE

918 SPYDER Fuel consumption (combined):
3.1 – 3.0 l/100 km; CO_2 emissions (combined):
72 – 70 g/km; electrical energy consumption (combined):
12.7 kWh/100 km/h

6:57 min

Lap time on the Nordschleife, 918 Spyder with Weissach package

652 kW

(887 hp) System output

210 kW

(286 hp) Highest electric motor output in a series hybrid

2.6 s

0 to 100 km/h acceleration

3.1–3.0 liter

Fuel consumption per 100 km in the NEDC

Uncharted **Territory**

Porsche Engineering is Optimizing Crane Cabins for Terex Cranes

____ When it comes to development projects for external customers, Porsche Engineering likes to venture into unknown territory and put its automotive development experience to work for other industries. One successful collaboration of this type was the optimization of the crane cabin design for Terex Cranes, which was recently honored with a design prize.

By Jörg Thoma and Frederic Damköhler
Photos: Terex Corporation

The Terex® Challenger 3160.
The cooperation between Porsche Engineering and Terex Cranes to optimize crane cabins resulted in a new brand look for the crane models.


TEREX

Crane cabins and Porsche: at first glance, that may not sound like a very likely combination, but it turned into an exciting and successful cooperation. When you operate a crane for the first time, it's surprising how complex the operating sequences are. It quickly becomes clear that optimal working conditions are essential to maneuver the crane safely. With its commitment to continual improvement, the heavy equipment manufacturer Terex Cranes charged Porsche Engineering with developing a new vehicle cabin and crane cabin design—which ultimately visibly impacted the face of the Terex brand.

Terex® Quadstar 1075L

Design prize

The Terex Corporation, which develops solutions for work sites around the globe, is among the largest manufacturers of heavy equipment. The company has many years of experience and an extensive product lineup, including in the fields of construction machines and cranes. The new Terex "Superlift 3800" crawler crane is proof positive of the company's success. It was recently awarded the design prize of the state of Rhineland-Palatinate. Every year the Ministry of Economics, Environmental Protection, Energy, and State Planning honors outstandingly designed series products from industry and the trades. The Vice President of Marketing at Terex Cranes, François Truffier, explains: "At Terex Cranes, we strongly believe in the importance of our investments in product design, both from a functional and an aesthetic standpoint. The result is a crane that operators love to work with and bears the unmistakable look of Terex Cranes."

Form and function

One significant aspect of the prize-winning "Superlift 3800" design can be traced back to the collaboration with Porsche Engineering. Terex first contacted Porsche Engineering back in 2006 with the task of redesigning both the exterior and interior of the vehicle and crane cabins. The objective was to unite functionality and aesthetics, together with technical aspects, to create an appealing design.

The underlying idea was centered on the keywords ergonomics, function, and mobility. But in designing the exterior and interior of the cabin of a construction machine, Porsche Engineering was entering new territory. The engineers were confronted with the challenge of translating their expertise in the automotive field to the world of heavy equipment.

Customer-oriented solutions

Extensive market analyses and illuminating conversations with Terex customers yielded some initial clues as to what design criteria had to be fulfilled to satisfy the complex requirements of crane operators. Various cabins were examined with regard to their properties and characteristics and customer-oriented solutions were determined, which then served as the specifications for the development process.

By including Terex customers in the process, it became clear that comfort and ergonomics should not be regarded as luxuries but as critical elements for mobility. That made them a top priority in designing the operator's work space. Operating a crane demands great skill and absolute concentration on the complexity of the functions. Any physical discomfort, for example due to unwieldy operation or impaired views resulting from poor design, makes the crane operator's job more difficult. The task for Porsche Engineering was therefore to work on optimizing various components to make it easier for crane operators to carry out their demanding maneuvers.

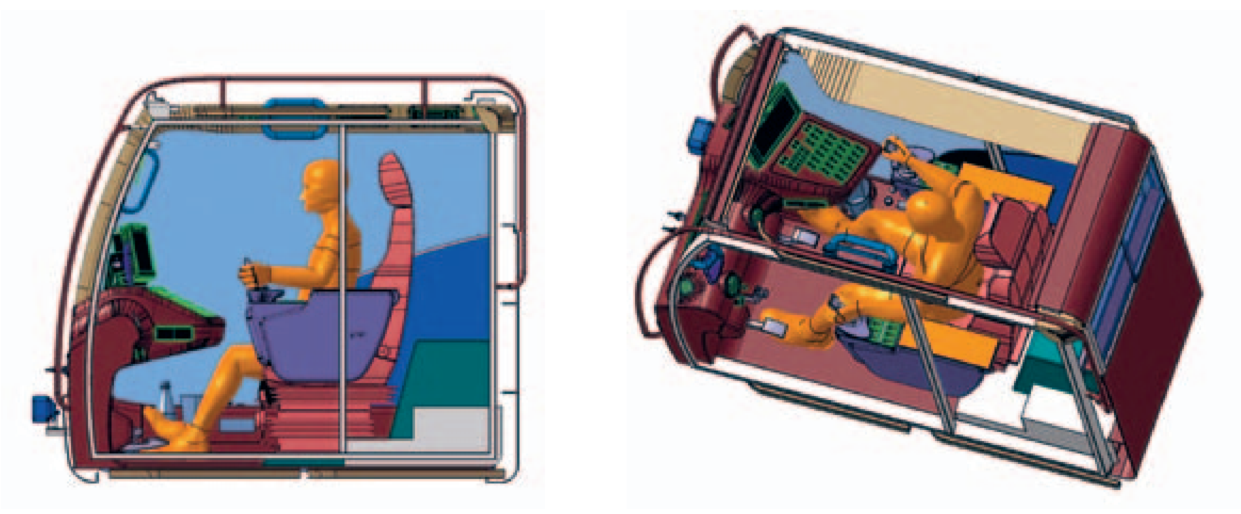
Efficiency and comfort in the cabin interior

The interior of a cabin must be precisely dimensioned to ensure that steering the crane and operating all control processes is possible from the workplace while also enabling space and access for servicing and repairs. One major challenge was to position the individual components in the interior so that they would be easy to reach and operate.

To optimize the arrangement of the components and improve user-friendliness, the individual operating elements were assessed in terms of a wide range of requirements and their ideal positions determined. The improved ergonomic characteristics of the joystick, for example, enable flawless and precise maneuvers. With the new crane control, crane operators can concentrate exclusively on their work. The intuitive system offers efficiency and comfort by enabling the user to configure the display individually by means of a touchscreen. With flexible adjustment options, the seat is both ergonomically correct and ideally suited to the complex requirements of crane operation. The seat can easily be adjusted to accommodate the size and weight of the individual crane operator. Additional storage spaces, adjustable air vents for heating and air conditioning, and an air-conditioned glove compartment that can also be used as a cooler ensure a comfortable environment in the cabin and aid the operator's performance.

Positioning and access

In the most varied working environments, the crane must first be brought to the work site and maneuvered into a safe working position to enable full use of its capabilities. Only when the crane is properly positioned can crane operators begin work. Ensuring safe access to the cabin also requires attention to specific requirements. Among other things, the position of the handles and the width of the steps were reconsidered to enable comfortable entry into the cabin. ›



First drafts for the ergonomically optimized crane cabins with rearranged controls.

Terex cranes—in this case the award-winning "Superlift 3800"—are used in widely differing environments all over the world.

“By creating a strong and uniform ‘Terex Crane’ brand, we’ve made great strides. Product design and the family look have contributed to that considerably. The defining brand identity is now clearly recognizable in all new products.”

François Truffier, Vice President Marketing

Optimized visibility

In the vehicle cabin as well as the crane cabin, unrestricted visibility is fundamental for flawless work. The size and shape of the windows must ensure maximum visibility. The driver cabin does without a B-pillar, which significantly improves the visibility of the exterior mirrors. Electrically adjustable and heatable exterior mirrors also ensure the requisite overview and remain operational in all conditions.

Thanks to a special park position of the windshield wiper in the crane cabin, the crane operator maintains a clear view of the load during the lift—even when the front window is open. A roof window wiper and tinted safety glass fend off both precipitation and strong sunlight.

The redesigned lighting system also improves safety. The lighting in the cabin as well as the use of various headlights enables the crane operator to adapt to a variety of light conditions and optimally illuminate the work area.

Initial concepts and validation of the new design

In 2007 the first concepts for the new design of the vehicle and crane cabins were presented at the bauma trade fair in Munich. At the world’s largest trade fair for construction machinery, building material machines, mining machines, construction vehicles, and construction equipment, visitors were able to take a virtual tour of the crane cabin and get a sense of the optimized operation of the crane. Illuminating talks with experienced Terex customers confirmed to the heavy equipment manufacturer and thus also Porsche Engineering that the development was on the right track.

The result is cabins whose design unites ergonomics and mobility, thus facilitating safe and concentrated work. With the optimization, a design was realized that impresses with its styling and technical capabilities, uniting form and function for a great result.

The new brand identity

The design of the cabin and the bold interior have made a lasting impression on Terex Cranes. Over time, the concept of the driver and crane cabins has been transferred to multiple crane models: the new face of the brand makes a Terex crane instantly recognizable. The front area of the cabins, which bears the emblem of the heavy equipment manufacturer, has serious and bold lines that underscore the strength and quality of Terex cranes. “By creating a strong and uniform ‘Terex crane’ brand, we’ve made great strides. Product design and the family look have contributed to that considerably. The defining brand identity is now clearly recognizable in all new products,” says François Truffier. ■

MACAN Fuel consumption (combined):
9.2–6.1 l/100 km; CO_2 emissions: 216–159 g/km

CAYENNE Fuel consumption (combined):
11.5–7.2 l/100 km; CO_2 emissions: 270–189 g/km

911 Fuel consumption (combined):
12.4–8.2 l/100 km; CO_2 emissions: 289–194 g/km

The New Porsche Macan

The First Sports Car in the Compact SUV Segment

____As the first Porsche model to break into the compact SUV segment, the Macan is setting new standards in the field of driving dynamics and enjoyment—on both paved streets and off-road terrain.

Its name comes from the Indonesian word for tiger. It combines the typical handling characteristics that Porsche has represented right from the outset: maximum acceleration and braking values, vast engine power, extreme agility and optimum steering precision, all combined with a high level of comfort and day-to-day usability.

Design: deeply rooted in Porsche's legacy of sports cars

The sports car heritage of the Macan is evident in many details of its design. The design embodies sportiness, dynamism and precision, together with elegance and lightweight construction. Round lines are combined with strategically positioned precision edges. The side view window graphics and the sloping roof line at the rear end, for example, are a clear nod to the 911. The rear lights on the Macan are another striking feature, boasting an extremely compact three-dimensional design and LED technology.

The focus on agility and breadth continues into the Porsche Macan's interior. Sophisticated lines, precise transitions and high-quality workmanship create a harmonious fusion of sportiness, quality and elegance.

Three different engine types

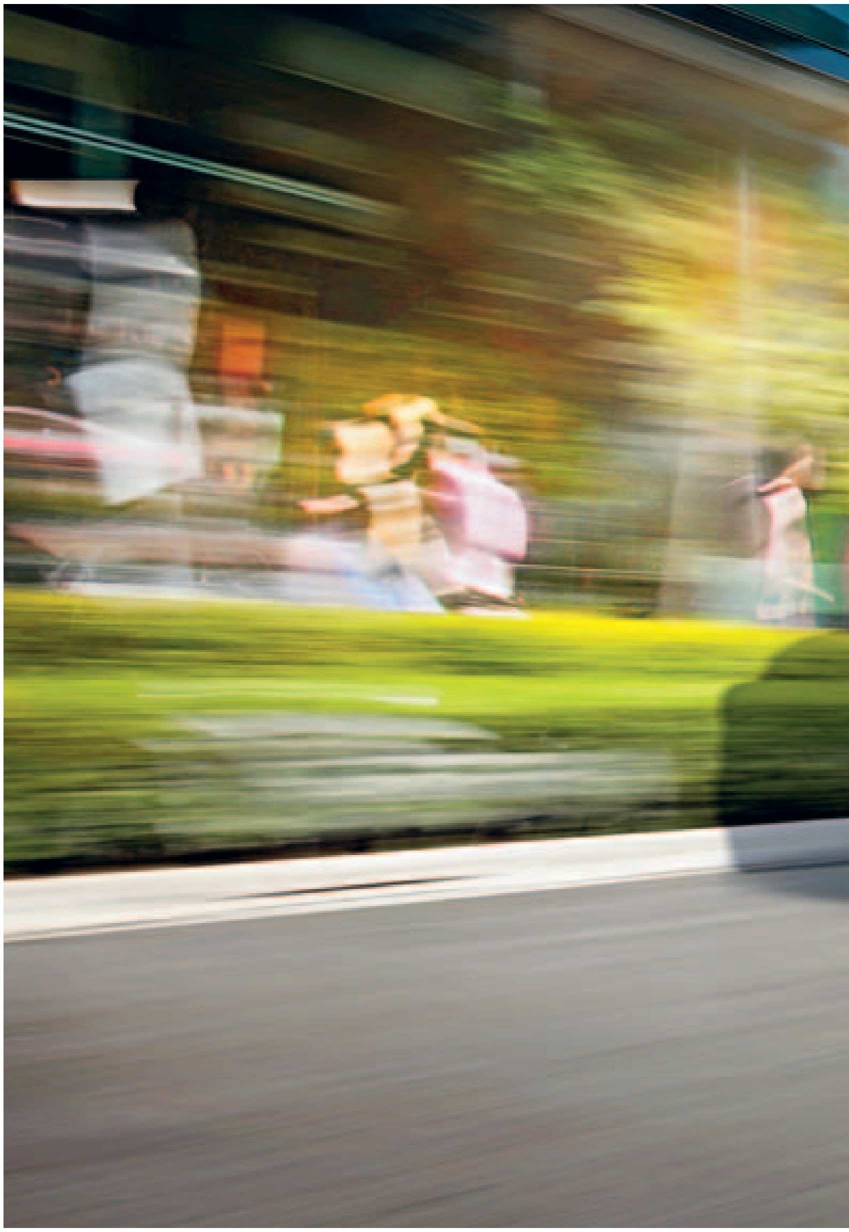
The new Porsche Macan is available with three different engines, but they all have one thing in common: They deliver performance, efficiency and emotions and make a typical Porsche out of every variant.

The Macan S is powered by the new three-liter V6 biturbo engine. With a bore of 96 millimeters and a short stroke of 69 millimeters, the engine loves to rev. It unpacks its optimal power of 250 kW (340 hp) at 5,500 to 6,500 rpm. For the sprint from 0 to 100 km/h, it needs just 5.4 seconds (5.2 seconds with the Sport Chrono package) and posts a top speed of 254 km/h.

With its three-liter V6 turbo diesel, the Macan S Diesel is a true endurance athlete, combining great performance with low fuel consumption. The enhanced 190 kW (258 hp) engine familiar from the Cayenne, which was adapted specially for the Macan through the engine application, works perfectly with the Porsche double-clutch transmission (PDK) and underscores the sporty character of the vehicle. The high torque of 580 newton meters at 1,750 to 2,500 rpm enables vigorous acceleration in every situation. It hits a top speed of 230 km/h and goes from 0 to 100 km/h in 6.3 seconds (6.1 seconds with the Sport Chrono package).

For the Macan Turbo, Porsche developed the new 3.6-liter V6 biturbo engine. The engine unpacks its maximum output of 294 kW (400 hp) at 6,000 rpm. The power of the Macan Turbo is unparalleled in the compact SUV segment. Two turbochargers with a boost pressure of up to 1.2 bar provide a powerful thrust to the 90-degree V6 engine. This power results in 0 to 100 km/h acceleration of just 4.8 seconds (4.6 seconds with the Sport Chrono package) and a top speed of 266 km/h. The new Porsche engine is based on the three-liter V6 biturbo with a longer stroke of 83 millimeters (previously 69) and puts the Porsche's decades of experience in sports car engine development to work in a compact SUV for the first time. ›

As the first sports car among compact SUVs, the Macan is eminently practical, but never dull. The Macan is great for the city, young, sporty and dynamic.



A new feature on the Macan is the hood with a raw air duct integrated on the underside for ventilating the engine. Two channels direct the incoming air from the front air intakes in the direction of the two turbochargers. These channels are precisely dimensioned to meet the air requirements of the drive motor. The decision to integrate the raw air duct was prompted by a number of factors: the space conditions in the engine compartment, additional savings on weight, the need for the hood to sit as low as possible and stringent pedestrian protection requirements.

At the same time, the engines have very low pollutant emissions. All three versions meet the Euro 6 emissions standard. Consumption figures in the NEDC range from 6.1 l/100 km (Macan S Diesel) to 9.2 l/100 km (Macan Turbo).

Technology for maximum efficiency

The Macan is defined not only by its performance, but also its efficiency. With its drive technology and efficiency technologies, the Macan stands in the finest tradition of sports cars, putting it at the top of its segment. In addition to the turbo-downsizing engines, the standard Porsche double-clutch transmission (PDK) and an overall intelligent material mix, numerous technologies contribute to low fuel consumption—for instance the electromechanical power steering, the automatic, enhanced start/stop function with engine switch-off when stopping and intelligent thermal management.

A sporty all-rounder for on- and off-road

The Macan utilizes selected chassis technologies derived from the 911. These elements form the basis for providing the handling characteristics typical of a sports car in a compact SUV.

Active all-wheel drive and Porsche Traction Management (PTM)

Active all-wheel drive is part of the Porsche Traction Management (PTM) system and comes as standard for all Macan models. Together with the other elements of the system—the electronically controlled, map-controlled multi-plate clutch, the Automatic Brake Differential (ABD) and Anti-Slip Regulation (ASR)—the all-wheel drive looks after traction and safety. The Macan's all-wheel drive is characterized by high dynamic response and supports the sports car character of the Macan through its design. Porsche opted for a flexible torque split through an additional flange-mounted transmission (hang-on all-wheel drive) as is also used in the all-wheel drive versions of the 911. The rear axle is always driven; the front axle receives its drive torque dependent on the locking ratio of the electronically controlled multi-plate clutch. ›

With its subtle contours and harmonious curves, the Macan's rear unites sportiness and elegance.

The Macan combines a high level of comfort with day-to-day usability—a sporty all-rounder for the road and off-road terrain.

Off-road mode

The Macan offers outstanding road performance, whether on city streets or off the beaten path. A ramp angle of 17.1 degrees (with air suspension in High Level I: 19 degrees), ground clearance of 198 millimeters (230 millimeters) and an approach angle of 24.8 degrees (26.6 degrees) as well as a departure angle of 23.6 degrees (25.3 degrees) also present a consistent message.

Powerful brakes offering a top-class performance level

In line with the usual exacting standard set by the Porsche brand, the Macan is leading the way with the most powerful braking system available in its market segment. It has six-piston fixed-caliper front brakes with aluminum monobloc brake calipers. On the rear axle, each of the Macan models offers combined floating caliper brakes with an integrated electric parking brake.

Mixed tires: functional and visual benefits

The use of tires on the Macan is typical of a sports car: in combination with the all-wheel drive system that was specifically designed for tail-heavy vehicles, the wider tires on the rear axle both increase traction and enhance driving stability. The front tires facilitate sporty yet precise steering maneuvers, which in turn contributes to the overall agility of the vehicle. Moreover, all Porsche Macan models come with Tire Pressure Monitoring (TPM) as standard. The TPM system increases driving safety and comfort by warning the driver when the tire pressure is too low or if it detects any rapid drops in pressure.

Three chassis versions for the Macan

There are three different chassis versions for the Macan. The standard steel-spring design of both the Macan S and

The Macan combines all the qualities of a sports car with the benefits of an SUV—a true Porsche.

Macan S Diesel already meets stringent requirements in terms of performance, driving pleasure, off-roading capabilities and comfort. The consistent lightweight construction philosophy embodied by the aluminum axles and chassis components contributes to driving dynamics and comfort.

The second version of the Macan chassis is a combination of the steel-spring design and the Porsche Active Suspension Management (PASM) system, which comes as standard in the Macan Turbo top model. PASM can be selected as an option for the Macan S and the Macan S Diesel. The electronically controlled adjustable shock absorber system actively and continuously regulates the damper force on the front and rear axles. Combining the steel spring design and PASM allows the vehicle to fulfill high standards for long-distance comfort, performance and agility even more successfully.

The third version of the Porsche Macan chassis, and exclusive in this vehicle segment, is the optional air suspension including leveling system, height adjustment and PASM. It provides the greatest possible spread between driving dynamics and comfort, and satisfies even the most stringent requirements in terms of comfort, sportiness and performance.

All of the chassis components, the running-gear setup and the brakes on the Macan allow it to take on an exclusive position as the sports car in its class.

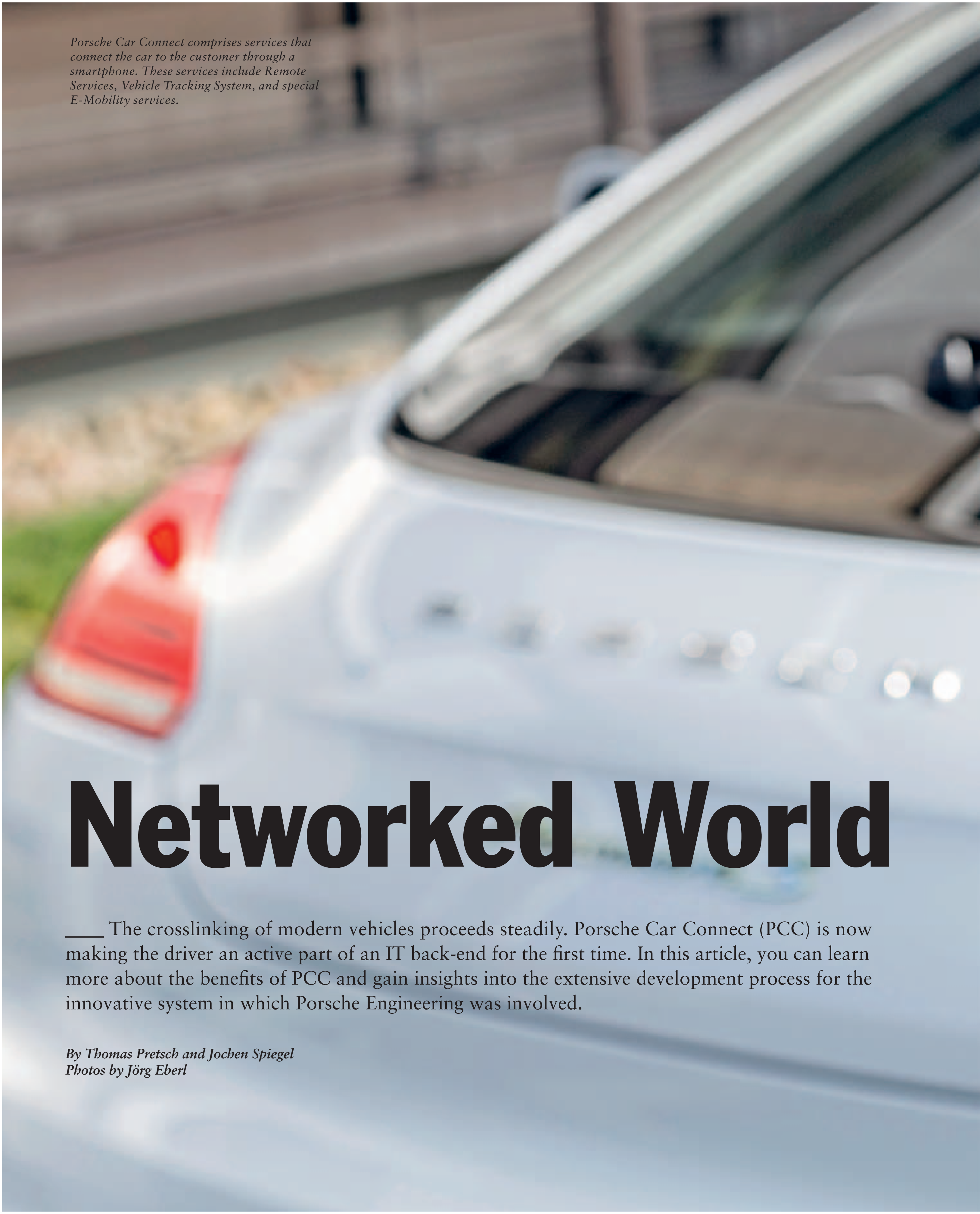
A genuine Porsche

Overall, the features of the Macan meet the exact requirements of a roadworthy SUV—it's perfect on the roads while providing the special reserve capabilities of all-wheel drive and off-road performance. No other vehicle in this segment is as precise and stable as the Macan even at higher speeds.

That makes the Macan a genuine Porsche and the sports car among compact SUVs. ■

MACAN TESTING IN NARDÒ

As part of the development of the new Porsche Macan, various testing exercises were carried out on the test track at the Nardò Technical Center in Apulia in southern Italy. Beyond the high-speed testing on the 12.6-kilometer circular track, the Macan was also subjected to braking tests, oil consumption measurements and race starts. Special focus was given to testing the new Macan models at the limits. With its variety of courses, the Nardò Technical Center provides the ideal infrastructure for carrying out demanding load tests, which yield important insights regarding the long-term behavior of a vehicle that are crucial to the development process.



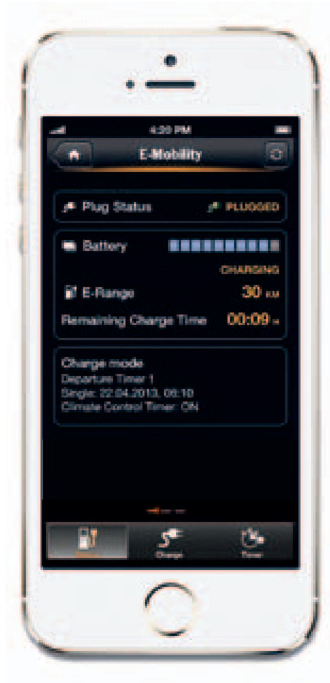
Porsche Car Connect comprises services that connect the car to the customer through a smartphone. These services include Remote Services, Vehicle Tracking System, and special E-Mobility services.

Networked World

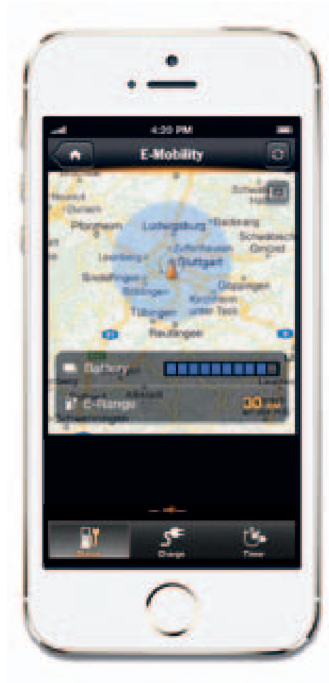
____ The crosslinking of modern vehicles proceeds steadily. Porsche Car Connect (PCC) is now making the driver an active part of an IT back-end for the first time. In this article, you can learn more about the benefits of PCC and gain insights into the extensive development process for the innovative system in which Porsche Engineering was involved.

By Thomas Pretsch and Jochen Spiegel
Photos by Jörg Eberl


4:20 PM
E-Mobility
Plug Status
PLUGGED
Battery
CHARGING
30 KM
E-Range
00:09 H
Remaining Charge Time
Charge mode
Departure Timer 1
Single: 22.04.2013, 06:10
Climate Control Timer: ON
Charge
Timer



E-Mobility status display



Electric range with current charge level

By means of the Porsche Car Connect system, the driver can use a smartphone app to access a variety of vehicle functions without being in the direct vicinity of the vehicle. This form, or rather expansion, of connectivity presents new challenges for the entire development chain—from specification of the functions and application in the vehicle to manual, semi-automatic, or fully automatic tests, and raises a lot of questions along the way: How do you unite the driver and the vehicle data in a convenient way when the customer knows neither the chassis number nor the registration number when the vehicle is ordered? How can the system be put into operation quickly and efficiently? Should the customer be able to connect multiple phones to the vehicle, or perhaps control multiple vehicles with a smartphone? To find the right answers and solutions to these questions, we had to design, test, and ultimately institute new processes.

What exactly is Porsche Car Connect (PCC)?

Porsche Car Connect integrates two additional components into the networked reality of modern vehicles: the smartphone and a secure server. The latter ensures the correct authentication and thus secures communication between the two components—vehicle and smartphone. The functional scope of PCC is divided into three major blocks: e-mobility, remote, and security services. The functions of the "E-Mobility" package, for example, enable easy setting of departure times, i.e. the time at which the vehicle should be fully charged and ready to depart. If the customer has also purchased the "auxiliary air conditioning" option, the vehicle can be set to have a certain cabin temperature at departure time. The advantage is obvious: if, for example, the cabin is heated while the car is connected to the power grid, it doesn't have to use energy from the high-voltage battery.

The "Remote Services" area includes information about the current mileage, remaining range, tire pressure, and the status of the doors and windows. The vehicle can be located and its position displayed on a map, allowing easy calculation of a route to the car. While the ignition is switched off, the blinkers and horn can also be used to make the car easier to find. It is also possible to define areas using a map outside of which a notification is sent to the customer's smartphone.

Under the "Security" menu item, you'll find functions like the Porsche Vehicle Tracking System (PTVS), which has been available as an option for all Porsche models since 2005. Among other things, this package includes an automatic emergency call in case of an accident that triggers the airbags, as well as extended breakdown assistance. If the customer calls for help via the "Porsche Assistance" smartphone app, additional information about the vehicle's location and vehicle statuses can also be transmitted, allowing quick and targeted help in case of a breakdown.

Privacy and data protection are guaranteed

With the multitude of means to locate the vehicle, it should be noted that the driver—not least for privacy reasons—always maintains control of his or her data, including data regarding location. A corresponding menu item in the instrument cluster enables the driver to temporarily remove the connection between one or more smartphones to the vehicle. Excluded from this are of course the safety-related functions such as locating the vehicle when the automatic emergency call is triggered or in case of vehicle theft.

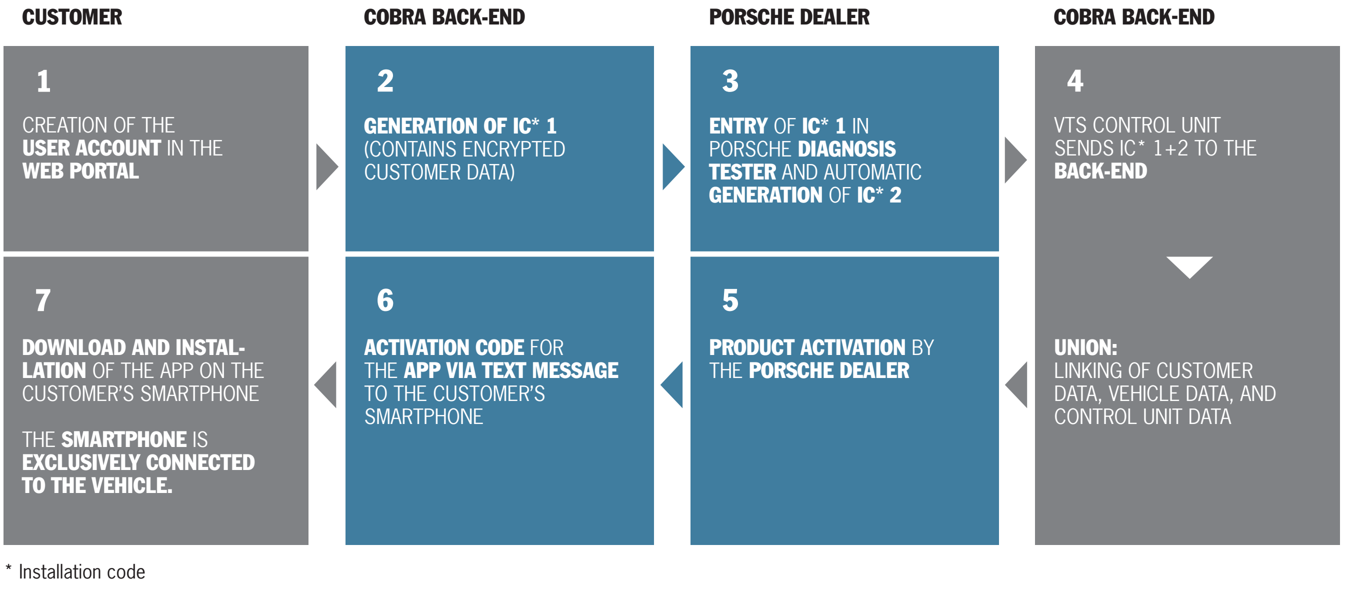
Comparison of driver and vehicle data

When configuring the vehicle, the customer knows neither the chassis number nor the registration number, as already mentioned. So there had to be some way of bringing the driver's data and that of the vehicle together at a given point in time.

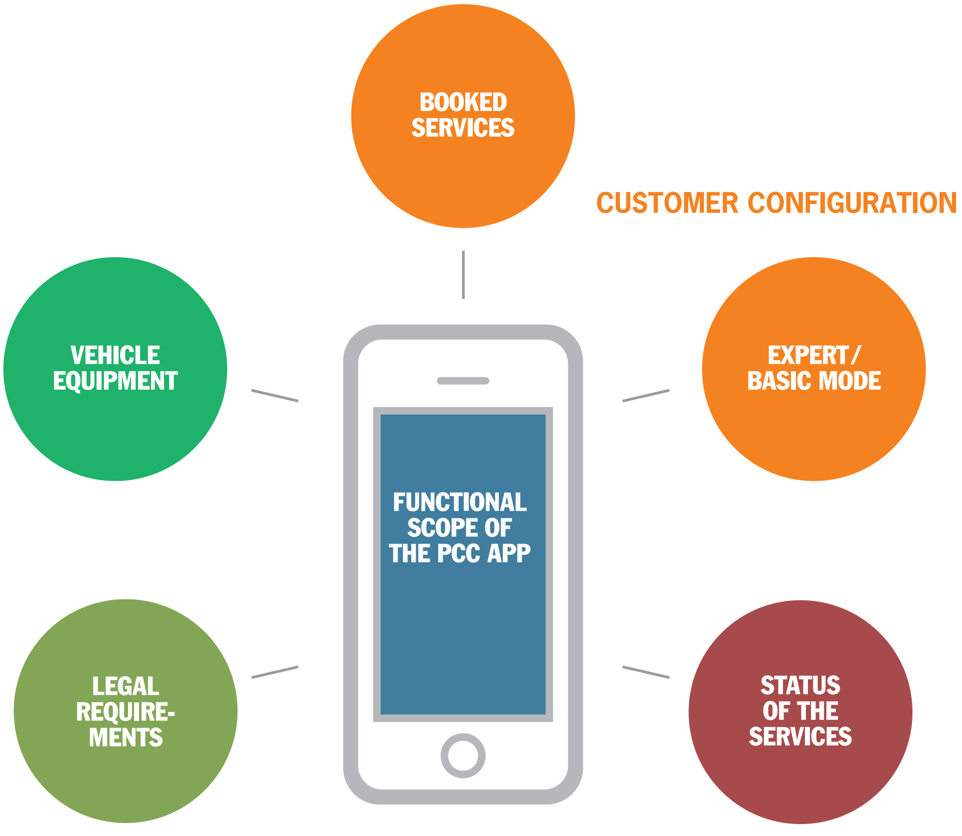
To do so, a process was developed that made it possible to link the data in a simple, fast, and secure manner. First the customer creates a PCC account through the Porsche website (www.porsche.com/connect) by entering his or her e-mail address and cell phone number. He or she then receives an e-mail and text message with a confirmation code that must be entered in the next step for verification purposes. Once the user's personal information, including name and address, has been entered, the installation code (IC) is sent to the user, who then gives it to the dealer to use in putting the system into operation.

Once the dealer has received the vehicle, he or she can put the system into operation using the Porsche integrated Diagnostic Tester (PiDT) and the installation code. The process was designed to be highly automated to prevent incorrect configuration of the system due to human error. While the system is being activated, for example, information about the equipment, color, and chassis number is output automatically. Here is where the first communication with the secure server takes place: the customer's installation code entered by the dealer and the automatically output vehicle data are sent to the server, where the user data and vehicle data are now linked. This forms the basis for the configuration of the system in the vehicle and the subsequent function tests. To ensure compliance with country-specific insurance requirements, the triggering of the horn, blinkers, and engine immobilizer ›

Customer portal for Porsche Car Connect



Registration and start-up process



Several dimensions impact the function of the smartphone app.

is automatically checked by the PiDT. After a successful check, the system is automatically activated by the server, and the customer receives a welcome text message with a link to the PCC app and the activation code required for it. After installing the app and entering the activation code, the customer can access the vehicle. Afterwards, other vehicles and smartphones can be added and linked via the portal as needed. It's possible, for instance, to control multiple vehicles via an app and switch between the vehicles. In the same way, multiple cell phones can be linked to one vehicle.

The changing appearance of the app

During the system start-up, some data regarding the vehicle configuration is output and sent to the server. When the app is opened for the first time, this configuration is checked and the appearance of the app is automatically adjusted, in particular as concerns the vehicle-specific menu items and optional packages such as the E-Mobility, Remote Services, and Security submenus.

Innovative testing as part of the development process

As we have just seen, there are a number of possible variations with respect to the appearance of the smartphone app as well as the underlying functions. And then there was the expansion of connectivity beyond the vehicle itself to the customer's smartphone. This required new approaches in testing to enable end-to-end checking of the communication chain. Thus the term "connectivity" has multiple meanings in the PCC context.

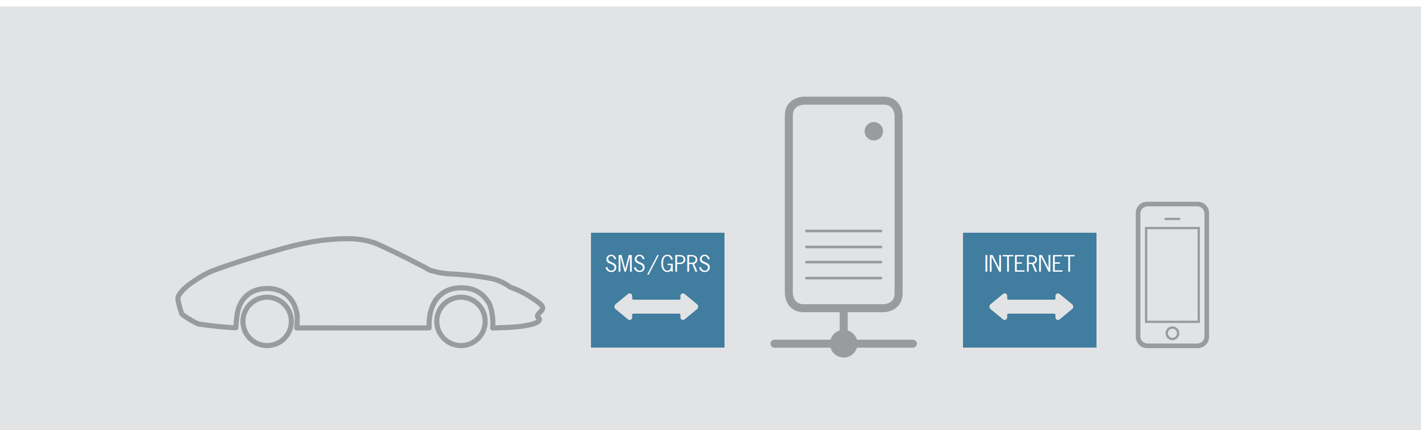
One aspect is the networking of the VTS control unit within the vehicle and the associated dependencies with other control units. One example here would be setting the departure timer, in which—in addition to the correct routing—the instrument cluster and charging electronics are critical in painting a picture of the overall function.

The greatest challenge, however, lies in the "smartphone—backend—control unit" communication path, which required a completely new form of testing for the automotive industry. As the figure below shows, not only the individual components had to be validated, but also their interfaces and thus the complete end-to-end chain.

If we now add the aspect that each individual component has different release cycles, models, and smartphone generations, as well as several dimensions of customer configuration (see page to the left: lower graphic), the complexity of the task quickly becomes clear.

To handle all of these challenges, new approaches had to be developed in the "test environment" area. Vehicles were developed into special unit carriers to represent a particularly realistic environment. This involved integrating Porsche Car Connect into existing series-like vehicle structures, in which adjustments to the signal routing were made and simulations were carried out. One example was the use of the interface control unit to simulate the charge electronics. The interface control unit made it possible to integrate e-mobility capabilities in a conventional vehicle. This enabled functions such as setting the departure timer or outputting the climate control status so that these things could ultimately be validated on the customer front-end: the smartphone app.

Another important point is the enhancement of the data loggers in the context of cellular phone communication/air interface. To track the data exchange between the vehicle and ›

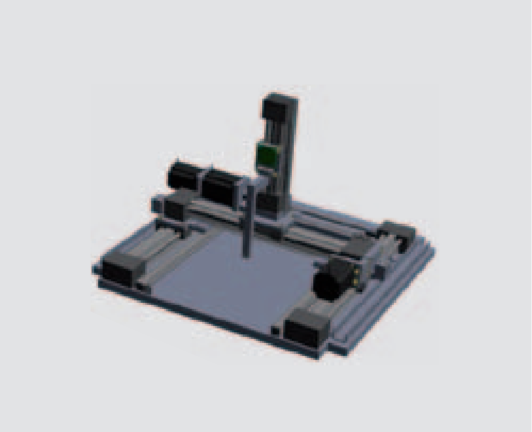


End-to-end communication chain

server and understand temporary limitations in the availability of the control unit in the GSM network, special loggers were added directly to the control unit. These can record the internal control unit communication and analyze it as needed.

To handle all of the test cases and their permutations, automated testing on hardware-in-the-loop systems (HiL systems) was employed. In this context, an existing HiL system was enhanced to enable automated testing of the requirements of the entire end-to-end chain.

Beyond the control of power supply units—for instance, for voltage drop and on-board voltage drop scenarios—the antennas attached to the VTS control unit (including the GPS and GSM antenna) can be automatically connected and disconnected. Another important role in this regard was played by the modular robot integrated in the HiL (figure at the bottom left), which can operate any smartphone. One typical application case is the "childproof lock" that suspends communication to the vehicle when it has been awakened remotely more than 100 times via smartphone app. We also had to bear in mind that Porsche Car Connect is already offered for many different model lines. For this reason, a modular plug-in concept was established in the HiL system that made it possible



Operating robot for any smartphone

In the automotive industry, a "hardware-in-the-loop system" is a simulation set-up combining real hardware components (e.g. control units) with software-based simulations, which thus enables highly realistic testing.

to depict any model line and take the respective factors into account in the test environment. The automated tests conducted on this specially adapted HiL are supported by other trials specifically related to the respective vehicle carried out on department-based HiLs. Here the connectivity of the control units is the focus, which enables an overarching view of the complete vehicle.

The bridge between automation and customer behavior

To ensure complete coverage of the functions of Porsche Car Connect, in particular from a customer viewpoint, endurance tests, field testing and internal testing by the team are indispensable.

In view of the fact that the communication module plays a crucial role within the VTS control unit, cross-national testing is imperative and requires special expertise in communications and mobile technology to take account of the various conditions in different environments. The developer's concentrated view of the products is an additional part of the examination of other open functional topics.

Endurance testing can be regarded as the bridge between the developer and the customer. In these tests, the product is used multiple times daily and defined inspection catalogs are used. This leads to important insights into behavior in cases of greater-than-normal usage. The respective driver systematically tests the smartphone app using the test catalog and documents any issues that arise.

Field testing, by contrast, reflects typical behavior and tests realistic behavior patterns.

Many other comfort functions are possible

The expansion of the networked components to the customer creates the scope for a number of potential new functions for interaction between the driver and the car. Porsche Car Connect

A great number of tests must be carried out to ensure proper functioning of the PCC from a customer viewpoint.

thus offers the customer more ways of interacting with the car and greatly increases the convenience of such interactions.

For the development engineers, these new functions and the expansion of connectivity beyond the vehicle itself present a variety of new challenges in the areas of specification, application, and testing that will continue to grow in the years to come. Topics such as remote diagnostics, car-to-car, and car-to-infrastructure are still in the early stages and offer a wealth of potential for further developments. Porsche Engineering will play a role in shaping this connected new world. It should be very exciting. ■

PANAMERA S E-HYBRID Fuel consumption (combined): 3.1 l/100 km; CO_2 emissions: 71 g/km; energy consumption: 16.2 kWh/100 km; efficiency class: DE/CH A+/A

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PUBLISHER
Porsche Engineering Group GmbH
Porschestrasse 911
71287 Weissach
Germany
Tel. +49 711 911 0
Fax +49 711 911 8 89 99
Internet: www.porsche-engineering.com

EDITOR-IN-CHIEF
Frederic Damköhler
EDITING | COORDINATION
Nadine Guhl
ADVERTISEMENT
Frederic Damköhler
DESIGN
VISCHER&BERNET, Stuttgart
TRANSLATION
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