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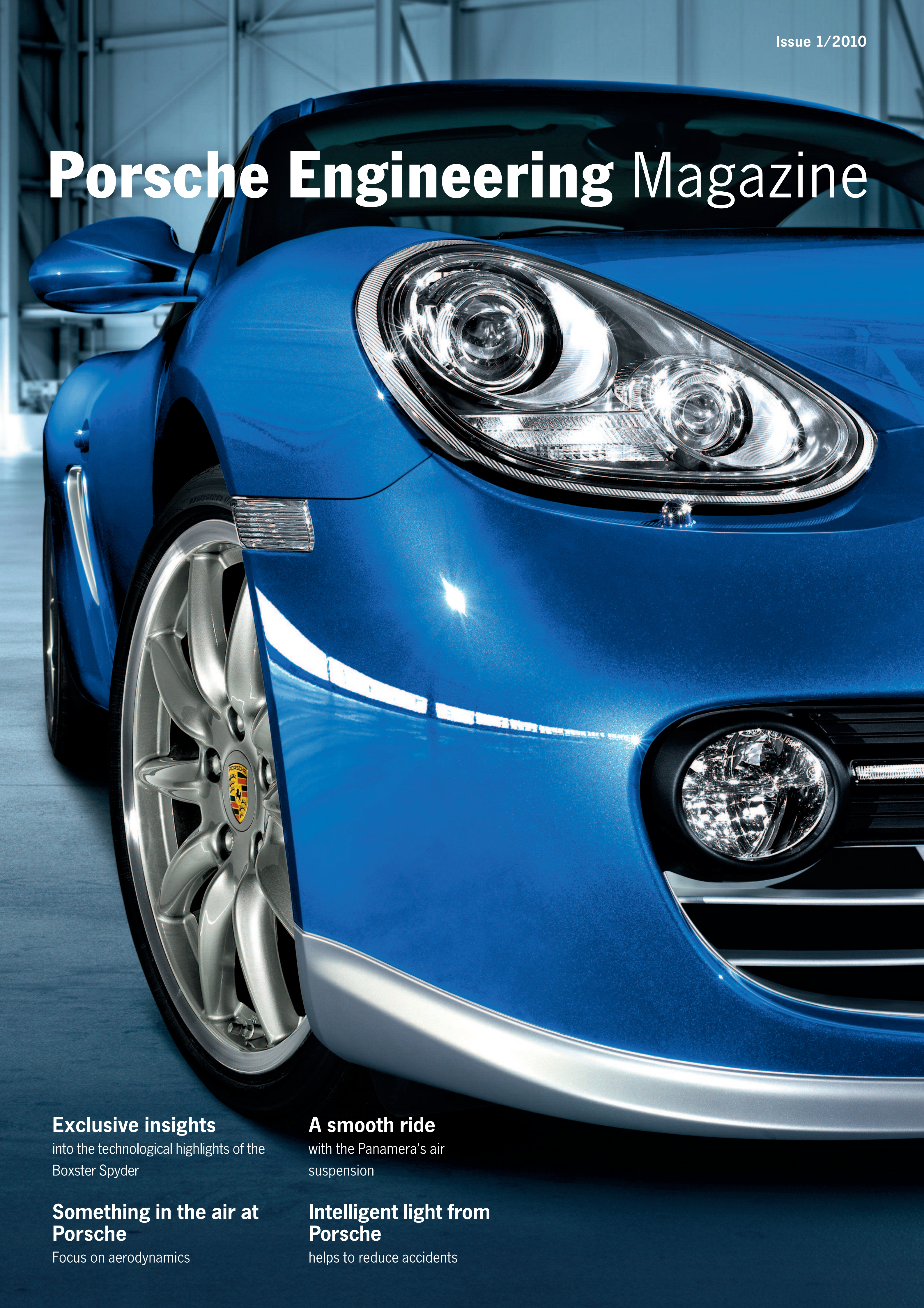
Porsche Engineering Magazine



Exclusive insights
into the technological highlights of the Boxster Spyder

A smooth ride
with the Panamera's air suspension

Something in the air at Porsche
Focus on aerodynamics

Intelligent light from Porsche
helps to reduce accidents

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Dear Readers,

Innovation and passion mean action and not just on our test track but in the minds of our employees as well. We are creative, and with our innovative ideas we help our customers to succeed.

In our projects, our engineers design a little piece of the future everyday. Accompany us on a short journey through the world of development and experience at first hand our day-to-day fascination with our work and our understanding of performance.

Take a look, for example, at the way we develop vehicle control systems that enable reproducible road tests and therefore not only yield reliable results but above all save time and money in development. Safety is also an important issue when shaping the future. One bright spot in this issue is our intelligent light systems. Learn more about how Porsche Engineering has contributed to a reduction in traffic accidents as a result of these ingenious systems. From lighting to our anti-theft system we show you how and why Porsche customers need no longer fear having their vehicles stolen. The Vehicle Tracking System from Porsche is the key to this peace of mind.

We always safeguard the confidentiality of our external customer projects. In order to give you an insight into our vehicle development process, in this issue, we present a Porsche highlight under the heading derivative development: the new Boxster Spyder, which has set a new benchmark with its lightweight construction. The Panamera's air suspension system is our next step, not only is it light as a feather but more importantly it ensures a smooth ride.

Enjoy these and other highlights from the Porsche development department.

TIP: You can also read our magazine online at www.porsche-engineering.com/customermagazine.

Enjoy this issue!

Yours
Malte Radmann and Dirk Lappe
Managing Directors of
Porsche Engineering

About Porsche Engineering

At Porsche Engineering, engineers are working on your behalf to come up with new and unusual ideas for vehicles and industrial products. We develop a wide variety of solutions for automotive manufacturers and suppliers, ranging from designing individual components and complex modules to planning and implementing complete vehicle development projects, including production start-up management. What makes our services special is that they are based on the expertise of a premium car manufacturer. Whether you need an automotive developer for your project or would prefer a specialist systems developer, we can offer both, because Porsche Engineering works at the interface between these two areas. All the expertise of Porsche Engineering converges in Weissach, but it is available all over the world, including at your company's offices or production facilities. Wherever we work, we bring a part of Porsche Engineering with us. To find out more about us, please request our image brochure by email:
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News

New Management at Porsche Engineering

On October 1, 2009, Malte Radmann was appointed chairman of the executive board of Porsche Engineering Group GmbH and Porsche Engineering Services GmbH. In both companies he succeeded Dr. Peter Schäfer, who moved at that time to Dr. Ing. h. c. F. Porsche AG, where he has taken the reins as Head of the Main Chassis Development Department.

Malte Radmann was previously a member of the executive board of both subsidiaries and the commercial director, a role in which he will continue.

The executive board will also welcome Dirk Lappe, who has been responsible for the Electrics/Electronics group at Porsche Engineering since 2002 and now holds the position of technical director.

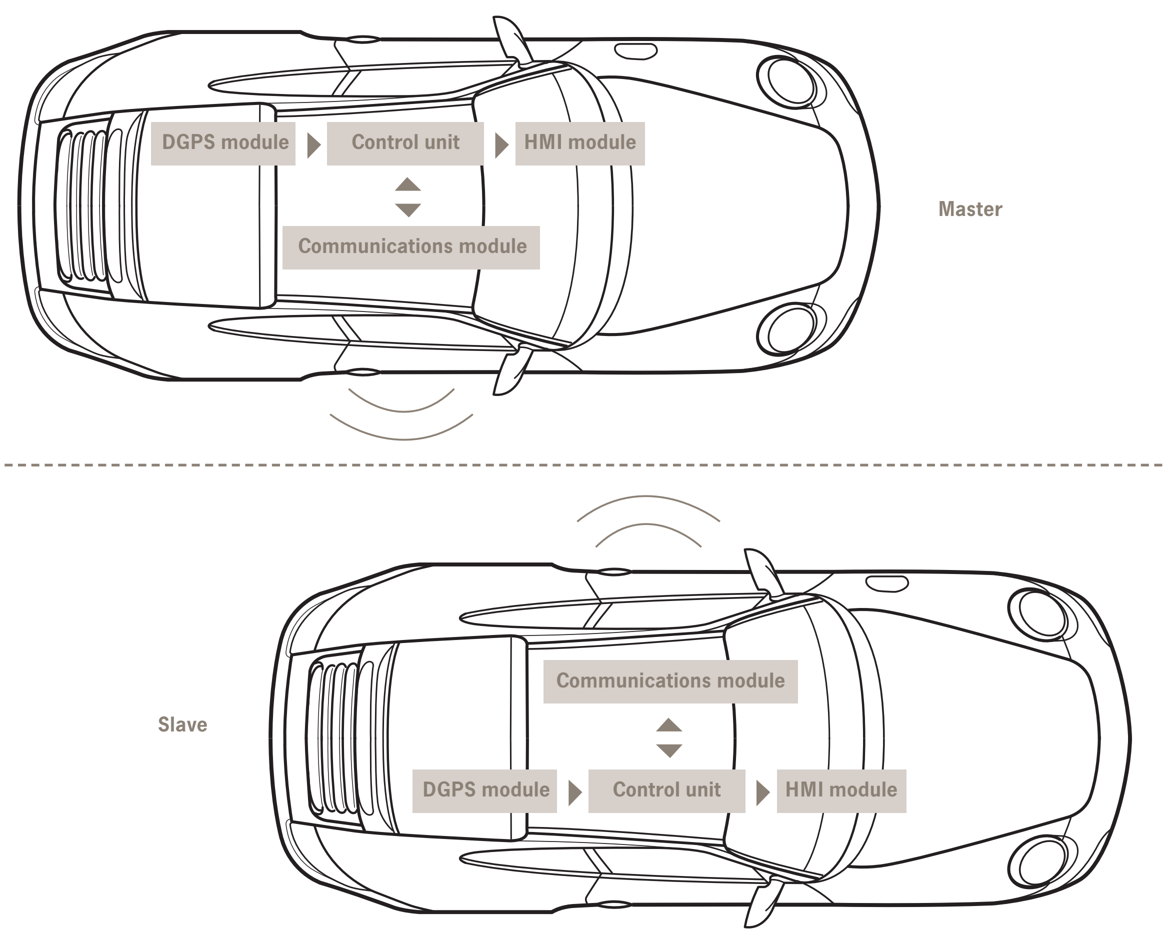
Porsche Engineering Magazine – now online too

Our Porsche Engineering magazine is now available online: www.porsche-engineering.com/customermagazine

Vehicle control system to create reproducible road tests

Real road tests are an essential part of the development of modern vehicles. To date the challenge posed by test runs in the field has been the reproducibility of the trials. Porsche Engineering has made a great leap forward with this issue.

Components of the vehicle control system



When developing functions and testing various systems in the automotive sector, for example the driver assistance systems, it is important to be able to reproduce a defined test scenario. In order to support the test driver in this context, Porsche Engineering has developed a special vehicle control system (VCS). The basic version of the vehicle control system comprises several components in a modular structure. The central module and heart of this system is the control unit, to which the other components such as the Differential Global Positioning System (DGPS) and the communication and Human Machine Interface (HMI) modules are connected.

The modular structure with defined interfaces offers numerous advantages. For example, the modules can be adjusted either customer-specifically or project-specifically. In addition, the basic system can be easily extended with further components, such as the connection to a vehicle bus.

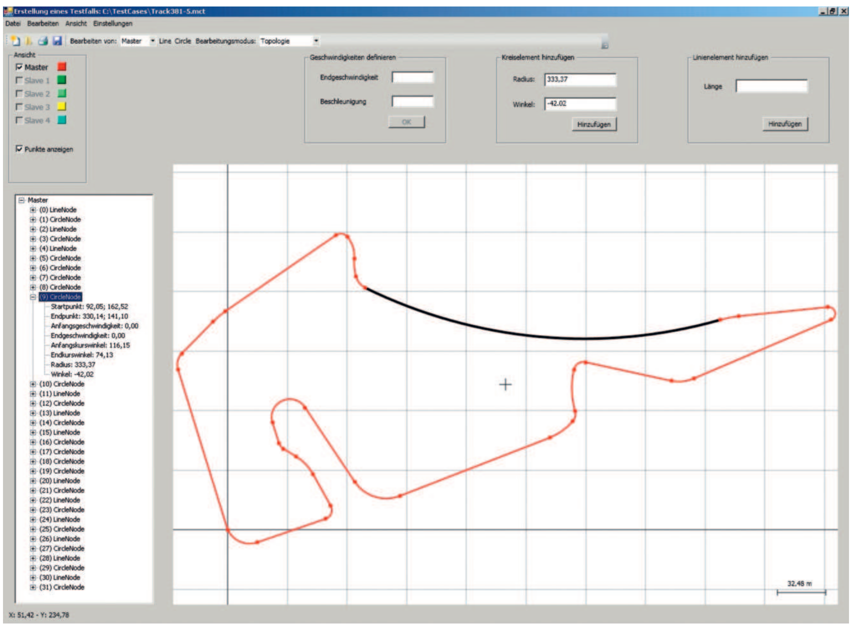
DGPS module

The vehicle control system works on the basis of position location which compares the current position with a reference position. In order to locate an object's position, services such as those of the Global Positioning System (GPS) can be used. However, given that such services feature deviations in excess of ten meters, they are too inexact for applications in a vehicle control system. The vehicle control system requires an accuracy of less than 50 centimeters. In order to achieve these high accuracies, a differential GPS (DGPS) receiver is used. These receivers achieve a greater accuracy in that they correct or better interpret the standard GPS signal. There are a multitude of different correction and evaluation systems, which differ in terms of their accuracy, price, availability and in their properties.

A mobile DGPS receiver that is accurate to within one meter and boasts high availability was chosen for this vehicle control system.

Communications module

If several vehicles are involved in a test case, wireless communication between the vehicles is required in the form of an ad hoc network. This is used to synchronize the progress of the test case. In addition, optional data such as GPS coordinates can also be exchanged between the vehicles. The slave vehicle, for example, transmits its actual data to the master, which then combines this information with its own actual data in order to calculate the relative distance between the two vehicles.



Manual creation of a route

Control unit

The control unit is the heart of the vehicle control system, to which all other components are connected. Given the multiple tasks and interfaces, the control unit is also the most complex component. Its main task is to serve as a central process controller.

The tasks can be broken down into the following:

- Test case recording by travelling the route or manually marking landmarks in a map
- Test case editing by changing the course or landmarks in a map
- Reproduction of the test case by issuing instructions to the driver via the HMI
- Evaluation of the test case

Human Machine Interface (HMI)

The vehicle control system makes it possible to reproduce saved test scenarios under defined conditions and thereby run through them such that they can be compared. Particular attention is placed here on the HMI being comprehensible, appropriate for the task and effective. With the assistance of the HMI, the test driver should be incorporated in the driving process through visual, haptic and acoustic feedback via the control device, as the controller in a real road trial. Here the driver performs primarily stabilization level driving tasks. As the longitudinal and transverse deviations must be kept to a minimum while driving the target route – in order to guarantee the comparability requirement – real-time and unambiguous feedback to the driver is required. The table on the right provides an overview of the feedback strategies.

Feedback strategies in the vehicle control system

	Single mode	Dual mode
Stabilization level	**visual** (Stage 1: Information) E.g. Lane departure within tolerance path	**visual & haptic** (Stage 2: Warning with call for action) E.g. Lane departure outside tolerance path
Maneuver level	**visual** (Stage 1: Information for advance notice) E.g. Symbols for event display	**visual & acoustic** (Stage 2: Call for action) E.g. Voice output to describe future events

An 8-inch display with touch function is used to provide visual feedback so that the test driver can start every drive independently via the interface. The display enables the integration of a vehicle-independent vehicle control system with minimal installation time. In order to guarantee contact with the road, a camera mounted on the windscreen displays a picture of the route ahead and the required feedback is crossfaded in.

The haptic module comprises two gloves with integrated vibration elements and a control device which is connected to the central control unit by USB. The vibration gloves offer further feedback on the lateral guidance (see table above).

The distance and speed behavior of a vehicle are part of the vehicle longitudinal control. For the vehicle control system we developed, the adherence to prescribed speeds plays a decisive role. The general requirement is that anticipative dynamic driving handling (acceleration/deceleration/cornering) be displayed. As this is a simple control activity with little complexity, single mode feedback is sufficient for this driving task. A "follow-me" bar is placed across the road, showing the speed to be adhered to via a distance control.

The vehicle lateral guidance in the vehicle control system is designed such that when the vehicle leaves the driving lane (or the stored "vehicle path" from the GPS coordinates), a two-stage feedback strategy counteracts this. To enhance the meaningfulness of the haptic feedback, it is combined with a visual display which shows the direction of the steering correction to be made.

This control strategy with tolerance corridor and steering vibration on the hysteresis edge also corresponds to the basic idea of the interaction metaphor presented here. The driver can move freely within the objective limits and only when he reaches these will he receive tangible feedback.

No correction required

Longitudinal and transverse correction required

Intelligent light helps to reduce accidents

Road safety for all road users is the very top priority for Porsche Engineering. A new intelligent light system provides the required technical progress.

In the future, “marking light” will assist the driver while driving at night.

Current figures from the Federal Statistical Office in Germany (DESTATIS) show that the number of road deaths and road injuries in 2008 has fallen once again. While the continuing development of technical innovations in vehicles, such as for example improved side impact protection, has contributed significantly to this good news, it is not the only factor. Increasingly, passive safety systems have been supplemented by active ones in all vehicle classes and this is set to further support the positive trend in vehicle accident statistics in the years to come. On the other hand, the absolute figures of 4,600 dead and 407,000 injured road users has long been sufficient reason for all responsible institutions and communities (incl. legislative, scientific and industrial) to search for further improvements in a bid to achieve accident-free driving.

Worth a closer look

Databases such as GIDAS (German In-Depth Accident Study) show exactly where potential still exists to effectively reduce the above figures. It is precisely while driving at twilight and in darkness, when drivers find it most difficult to identify objects in traffic, that the probability of being involved in an accident with other road users rises significantly. The cause of this increased accident risk is the relatively low level of ambient brightness together with the fact that drivers are sporadically dazzled by oncoming vehicles, which requires the human eye to adapt quickly. Making things even more difficult is the fact that the depth of field and the ability to see is reduced significantly at night.

On the test stand

Porsche Engineering is therefore cooperating closely with the Karlsruhe Institute of Technology (KIT) on research into how vehicle drivers can be best assisted in their task when driving at night. In this regard, various light-based driver assistance systems are put through their paces on the test stand. Particular attention is paid to a very promising and innovative light function, which is called “marking light”. In the near future, this system aims to avoid collisions with persons (or indeed cyclists and animals) through targeted illumination, a light-based marking system.

In the spotlight

In order to be able to examine light-based assistance functions, a prototype structure was realized in which a horizontally and vertically swiveling Bi-Xenon module and an LED-based “automotive spotlight” were integrated. Communication with the Bi-Xenon modules is based on the CAN (Controller Area Network) bus; the actuators and sensors of the automotive spotlight are served by a real-time-capable prototyping unit. All thermal sensors have an FIR (Far-Infrared, Ï = 8–12µm) camera, which offers a resolution of 320 x 240 pixel at a frame rate of 25 Hz. A multi-core processor system with sufficiently dimensioned resources is available as the central computer for image processing and for downstream strategic evaluations.

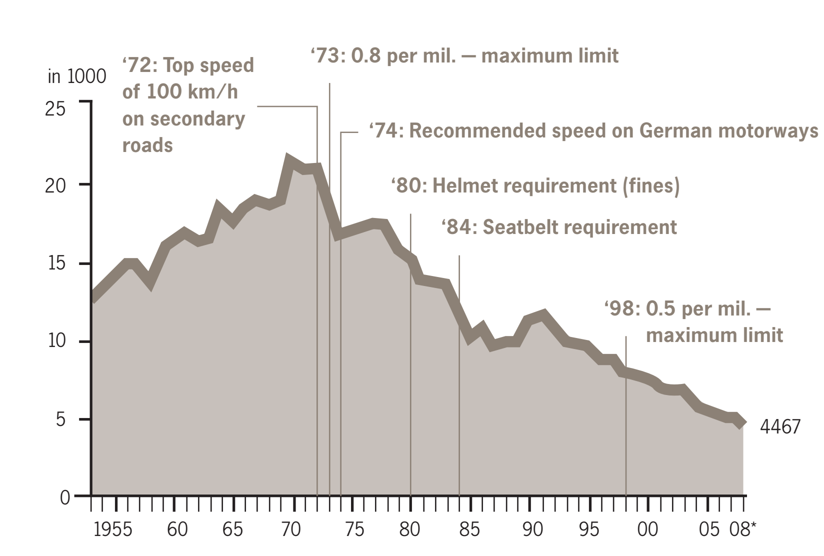
At the speed of light

The complex internal flow of information between all participants involved (peripherals and computing processes) is mapped via a central real-time database. This database not only synchronizes all sensor and actuator conditions per time unit, it also saves these for more convenient evaluation, for example at a workstation.

Detection of pedestrians

The thermal imaging camera, which is used as a sensor system, also provides the driver with information on potentially dangerous objects in his environment through a technical analysis of the image sequences. The detection and localization of, for example, pedestrians, cyclists and wildlife in front of the vehicle plays a central role here. The detection and classification of the named objects in image sequences is highly complex because the appearance or pose of the objects to be detected can vary hugely. For this reason, the process is being subjected to particularly intense scrutiny in the technical disciplines of image processing and pattern recognition. Effective, developed image segmentation and advance classification on the basis of thermal image sequences provides for a dual-adaptive limit value filter. This algorithm brings together two different limit values, which are measured pixel by pixel on the basis of the available image information. The following advance classification binarizes the existing grayscale image utilizing a highly sophisticated methodology. Results of the dual-adaptive limit value filter are shown here; these will be further segmented in the next step of the process. In order to keep the computing

Numbers of persons killed in road traffic accidents 1953-2008



* provisional result

time for the final classification to an absolute minimum, the previously mentioned advance classification reduces the number of image sections using heuristic assumptions. To this end the object size, position within the image coordinates, the width to height ratio and the relationship with the bounding box are all evaluated in order to exclude as many sources of incorrect classification as possible in advance.

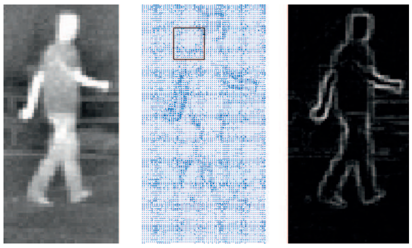
Preparation for classification

One promising approach, as preparation for the final classification, is based on extracting features (symmetry, form-invariant characteristics etc) from image sections, which are assumed to contain objects to be classified, e.g. pedestrians, cyclists, wildlife. The classification is performed here by means of an adaptive instance, which compares technical indicators of an image section with previously learned knowledge. Those indicators for an efficient classification which have great potential are those derived from the "histogram of oriented gradients (HOG)". Here the shape and form of objects are described in an image segment using the associated distribution and alignment of locally calculated intensity gradients. In the approach selected, the HOG descriptors are determined in three stages and then passed on to the final classifier:

- Calculating the gradients via the intensity in the detection window,
- Determining the histogram via the orientation of the gradients,
- Standardizing the histogram in relation to a higher-level unit area.

Classification of pedestrians

A "Support Vector Machine (SVM)" is used as the classifier; it learns how to make classification decisions on the basis of a number of training examples with known classes. With this knowledge, it is possible to classify objects successfully and efficiently in the following image sections from everyday driving situations.



Determination of the intensity gradients of a pedestrian as preparation for the classification

Positive outlook

The prospects for the described system are positive, as initial simulation results have confirmed the expected high detection and classification rate in different driving situations. In the next step, test subject studies are planned in order to obtain a representative statement as whether and to what extent such innovative light-based driver assistance systems can best support drivers in their tasks. The resultant scientifically sound findings will serve in the medium-term to ensure that the active assistance in our vehicles is improved further and afford our customers added value in terms of their safety and comfort.

Active assistance in vehicles enhances safety and comfort.

Heavenly efficiency: there shall be no grinding of teeth

As assemblies become increasingly complex, the requirements placed on gearing systems in engines and transmissions rise also. Moreover, as engines become quieter, the acoustic behavior of the gear wheels is pushed further into the spotlight.

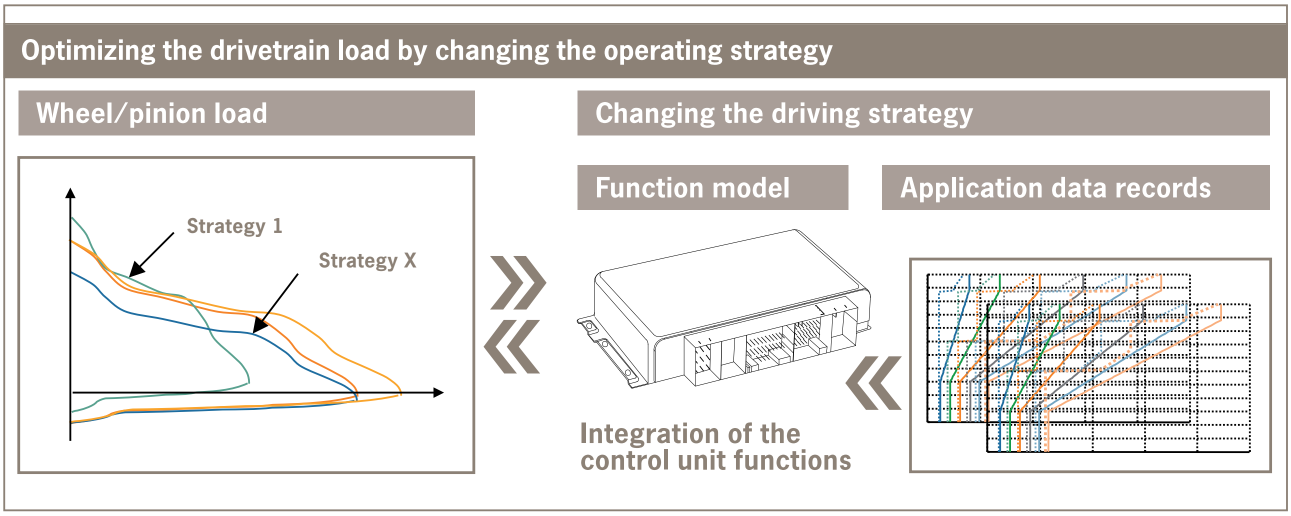
However it is not just the complex requirements on the gearing and its acoustics that are increasing constantly. There is a simultaneous requirement to optimize the power-to-weight ratio of the components – two goals which are often in direct opposition. Therefore, precise knowledge of the loads to be expected is gaining importance, while rising cost pressures are making the implementation of effective measures more and more difficult.

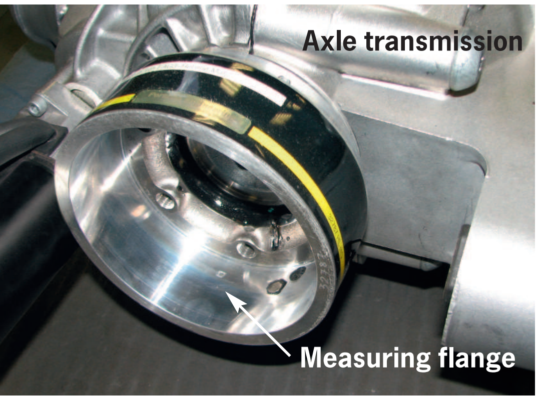
Porsche Engineering is meeting this challenge head-on with an effective strategy. First the gearing is designed and optimized in terms of its load capacity using simulated load spectra, based on measured data, which enable a requirement-led design. There is a special focus on the load capacity which is achieved without special modifications. This lays the foundations for acoustically optimizable gearing.

Turning the right wheel

Customers of Porsche Engineering benefit from the new development methodology which enables efficient drivetrain design while also giving due consideration to customer specifications.

To define realistic load spectra, operating loads are recorded, not in expensive measuring hubs or on measuring side shafts, but rather on the flange of the transmission output shaft (see figure on page 12). The influence of the torsional rigidity between the drive and output shafts can thereby be circumvented and creeping or permanent faults caused by plastic shaft deformations during measurement are avoided. The measuring flanges endure peak torques that are ten times higher than a measuring side shaft without an accompanying increase in the measurement error while providing the same measurement accuracy. The complete encapsulation of the measuring technology enables significantly longer endurance test deployments compared to conventional systems. The patented flange application procedure makes it possible to run misuse loads on the same test setup as the usual endurance tests, which significantly reduces development costs. Only with the assistance of these exact signal qualities can a simulation environment to predict drivetrain loads be reliably verified in endurance tests. The heart of this calculation tool is a 3D route model for all standard Porsche durability routes. For this, race, test and defined mixed routes with uphill and





Measuring the operating/misuse loads

downhill sections were measured in detail and stored in a database as a function of their latitude and longitude (see figure on the right). Using this methodology, the Porsche engineer is assured that the climbing resistance acting on the vehicle can be entered into the simulation environment with a high level of accuracy.

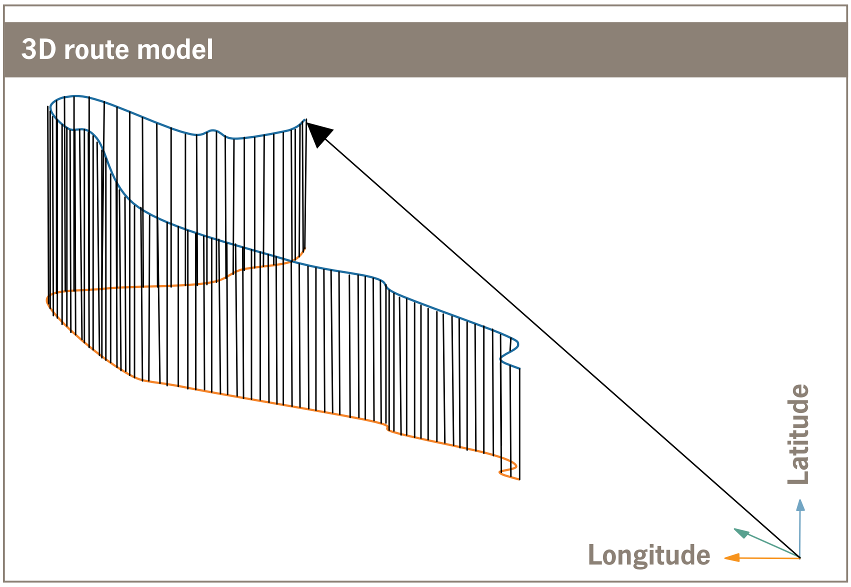
Realistic braking simulation using a synthetic driver model

To ensure that the load forecast can be made under realistic conditions, Porsche Engineering developed a new type of synthetic driver model with human characteristics. This model is capable of reproducing the accelerator and brake pedal positions almost exactly. The virtual driver works with a decision-making level and an action level, which process and implement the information in front of the vehicle. The combination of both levels prevents unrealistic acceleration and delaying tactics, particularly while driving in a curve.

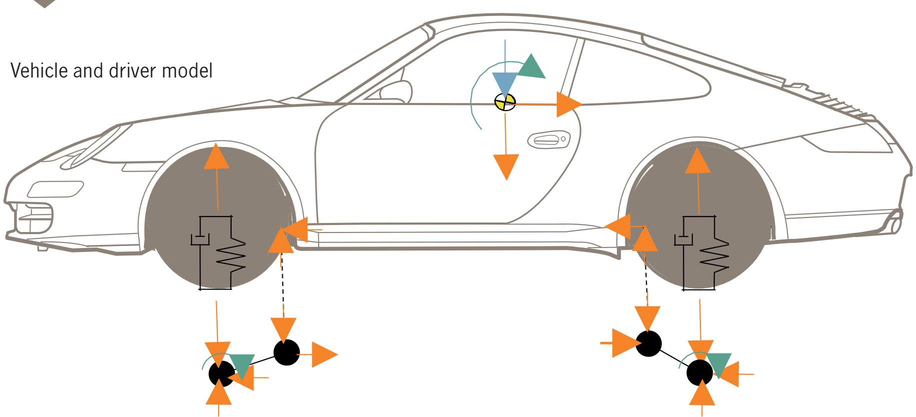
The mechanical model of the vehicle, which is tailored to the application, also encompasses the real control unit functions as Software-in-the-Loop (SiL), so that the latest data statuses of the software development can be tested for their effect without the need to have prototypes available. It is possible to make a statement, quickly and cost-effectively, as to how the individual components of the drivetrain are loaded by the current software statuses and how an overload of the current design can be counteracted by targeted interventions in the functions of the control unit. This procedure thus enables the systematic examination of the complex interactions between optimal efficiency and drivetrain load within the framework of variant calculations over several thousand kilometers.

Gear design

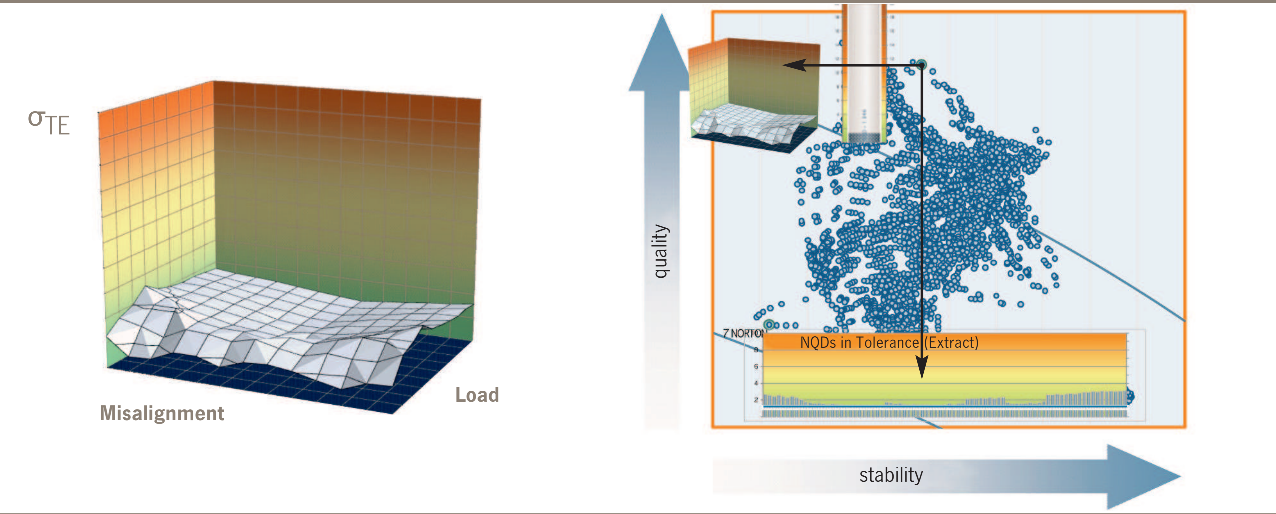
After the new load spectra are defined, an iteration loop starts to determine the optimal gear geometry, taking into consideration the requirements regarding service life and noise generation behavior (NVH). Thanks to their long years of experience, Porsche Engineering succeeded in resolving the conflict between load capacity and noise optimization. The final gear design meets the service life expectation and at the same time delivers a solid basis for subsequent optimization of the gear noise, which can be influenced by making corrections to the tooth flanks.



Vehicle and driver model



Representation of a tolerance cloud to evaluate stability and quality



In addition, the noise behavior of the gears is dependent on the torque to be transferred (M_d) and the environmental influences acting on tooth engagement. Shaft bending and inclination, bearing clearances and housing rigidity values all impact on tooth engagement and shift the contact pattern on the flanks depending on the load. These influences can lead to gaps in the tooth engagement and are factored in during optimization by altering misalignment ($f_{H\beta}$). The "range of deviation of the transmission error" (σ_{TE}), which derives from the tooth-rigidity-determined transmission error, serves as a measure of the tendency to generate gearing noise.

Noise generation

The 3-dimensional representation above shows an ideal noise excitation diagram with low reactions to changes in load, ambient influences and small values for σ_{TE}.

To optimize the noise generation behavior, various corrections are made to the tooth flanks and their influence on the noise generation determined. This leads to millions of variants, which are evaluated in production in terms of their acoustic suitability and the tolerance-determined acoustic fluctuations. To make this wealth of information more comprehensible, the noise excitation diagram is reduced to just one value, the Noise Quality Dimension (NQD) which describes the acoustic quality.

Next, the variance in the tolerance field is determined; this is equivalent to the stability. The smaller the variance, the more stable the manufacturing process is. The art here lies in finding the ideal compromise between quality and stability (see figure above). Both the quality and the stability parameters are entered in a complex algorithm which calculates the final evaluation criterion: the "Noise Resistance to Tolerances" (NORTON). Like the ATZ ranking, this moves on a scale from 0 to 10 and can be achieved through various combinations of quality and stability.

The practice of tolerance

The methodology presented produces a gearing system that is in line with service life requirements and optimized in terms of the noise generated. In addition, it is possible to create instructions for manufacturing as to which flank corrections have a particularly large impact on the acoustic stability of the gearing system – and this can be done during development before a single prototype is ever built. Conversely, it is also possible to determine the tolerances required for a robust design and to open up individual tolerances in a targeted fashion. This can lower manufacturing costs without sacrificing acoustic quality. The result is a design which is optimized in terms of noise generation and service life and which also factors in the rising cost pressures within production.

The Porsche Vehicle Tracking System – Tracking Car Thieves

With the Porsche Vehicle Tracking System, the Porsche engineers have succeeded not only in enabling the remote location of a vehicle but also in utilizing further helpful applications. Through networking with other control units, for example, it is possible to remotely trigger alarms on the vehicle or even the engine immobilizer.

The Porsche Vehicle Tracking System is used in many parts of Europe and can do much more than just locate vehicles.

The primary objective of the Vehicle Tracking System development project was to satisfy the conditions set down by insurance bodies in Europe. These demand a location system for vehicles, for example as of a certain value which varies depending on the country. However, over the course of the development project, Porsche added certain features to the Vehicle Tracking System above and beyond the original development task. This is surely why the system has become so successful in the interim and has already been implemented in 27 European countries as well as Russia and South Africa.

Well connected

The Vehicle Tracking System was developed, tested and released by Porsche engineers in Weissach – after more than one million test kilometers and in excess of 2,000 successfully completed service tests. To this end, no detail, from packaging through networking and function tests and up to closed-circuit current measurements, was overlooked in ensuring that a fault-free system was brought to series production.

The engineers are particularly proud of the integrated LIN authentication: for example, the vehicle engine can only be started once the Body Control Module (BCM) has uniquely identified the corresponding Vehicle Tracking System. This makes it possible to protect the system from a manipulation or bypass attempt. If someone tries to steal or interfere with the vehicle, an alarm is triggered, for example, if the battery is disconnected (sabotage alarm), the antenna is disconnected, the vehicle moves over a radius of 400 meters without the ignition being switched on (motion alarm).

> “Porsche added certain features above and beyond the original development task.”

And the engineers came up with much more besides: depending on the country, the most varied differentiations of the Vehicle Tracking System have been created. For example, in certain countries, the police can activate the vehicle’s alarm system “remotely” through a central service center if requested. Also the car can be prevented from starting using the engine lock function.

Some underwriting associations also require a “driver card” as additional customer authentication. The customers’ security request that the car can only be released for driving after a key combination is input via a remote control was met with the development of the “remote keypad”. If the key code is incorrect, too late or not input at all, a corresponding message is sent to a service center.

Catch me if you can

The Porsche Vehicle Tracking System works with the latest GPS technology. An integrated telephone module transmits all messages and commands between the Vehicle Tracking System and the Service Center. A GPS antenna, a GSM antenna and the Vehicle Tracking System control unit are installed in the vehicle. The server-supported location of the vehicle does not run constantly, but only when it is actually needed, i.e. in serious cases. A silent alarm is triggered automatically when the vehicle is stolen or a manipulation has been detected or following notification by the vehicle owner.

“Retrieval”

If the car is stolen or there is any attempted manipulation, the Vehicle Tracking System in the vehicle sends an alarm to the Security Operation Center (SOC). The SOC contacts the customer to verify the theft and automatically reports the vehicle position to the police.

As the SOC of the customer’s home country is always notified even if the theft takes place in another country, the customer can always speak to SOC staff in his native language. By networking the SOCs together, cases of theft can be processed using the “roaming” function. In this case, the SOC abroad assumes responsibility for communications with local police. These then take up the case and retrieve the vehicle.

In order to avoid dangerous situations, which may occur for example while in pursuit of a vehicle, the SOC can prevent the vehicle from being started again. This means that once the thief switches off the vehicle, it cannot be restarted.

The Vehicle Tracking System also makes it impossible to hide the vehicle in a crowd – for example in a large car park: the police can request that the hazard warning lights and the alarm sirens be activated remotely.

Something in the air at Porsche

Aerodynamic vehicles are hardly a new idea. Lower air resistance makes vehicles faster and more economical and Porsche has decades of experience to prove this.

The wind tunnel in Weissach is renowned for its excellent air flow quality.

Statutory regulations combined with the worldwide explosion in demand for energy have increased the demand for low-consumption, efficient vehicles with low CO_2 emissions. The field of aerodynamics has a huge contribution to make towards lowering consumption.

At low speeds, for example in city driving, the vehicle mass has a critical impact on fuel consumption. The air resistance, which increases in line with the square of the vehicle speed, already exceeds the rolling resistance as of approx. 80 km/h (50 mph) and represents, particularly when driving cross-country and on motorways, the lion's share of the entire external road resistance.

As a result it is important to ensure that the product of the drag coefficient and the frontal area (c_d x A) is low. However, this is not the only task of vehicle aerodynamics.

To ensure the quality of an automobile, Porsche engineers are constantly working on new solutions to improve features, such as the straightahead tracking, lane-changing behavior, the crosswind stability and cooling of engines.

The efficient cooling of gearboxes, brakes and individual components along with comfort issues such as wind noise, the heating and ventilation of the interior or the soiling behavior, to mention but a few of the many contributory factors, depend on the air flow around and even through the vehicle. For generations, we have been working towards creating, quite literally, the least possible resistance.

"Even back then the air resistance of a Porsche was almost half that of its competitor vehicles."

History's no drag

The constant battle for consumption advantages and the key role that it plays in development are not new. The engineers at Porsche have been grappling with solutions to counteract windforce since as early as 1948. When developing the Porsche 356 in Gmünd for example, the quality of the air-flow around the vehicle was still being assessed as the car drove past by documenting the behavior of wool fibers attached to the body. Even back then the air resistance of a Porsche was almost half that of its competitor vehicles.

Wool fibers are no longer used these days in Weissach. Instead, a broad range of simulation methods, including wind tunnels and computer-assisted calculation methods, have been developed. For example Porsche commissioned its own wind tunnel in the Research and Development Centre in Weissach in 1986 and then started to make its knowledge in the field of aerodynamics accessible to more than just its automotive customers.

The system is renowned to this day for its excellent air-flow quality. It can also measure aerodynamic forces and moments at the same time as the pressures acting on the vehicle. The boundary layer thickness of the air flow can be influenced as required by full-surface extraction of the air in the measuring section floor.

Vehicles are not the only products for which aerodynamics are key, however. Many exciting and challenging customer projects have had to prove their aerodynamic credentials here.

From trains to cycle teams, umbrella manufacturers to tent makers, Porsche Engineering has assisted on a vast range of projects. Further below, we have detailed a small selection of our in-house aerodynamic stars.

Going with the flow

The demand for constant improvements in performance and the required compliance with increasingly stringent statutory conditions necessitates constant improvements in aerodynamics. History is only one of the reasons underlying our commitment to advancing the pioneering development of aerodynamics into the future. Our desire for excellence is another.

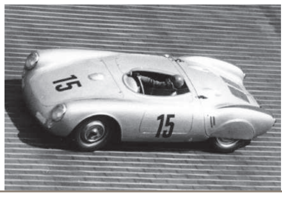
"For generations, we have been working towards creating, quite literally, the least possible resistance."

Porsche has a long tradition of aerodynamic development

1948

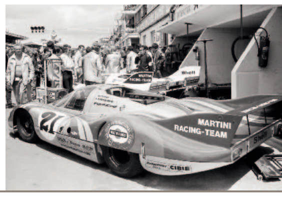
In order to assess the quality of the air flow around the vehicle, wool fibers were attached to the body of the 356. The 356/2 “Gmünd” achieved a drag coefficient of 0.29 and had a frontal area of 1.62 m². This resulted in an astoundingly good c_d x A value of 0.470 m².

1955



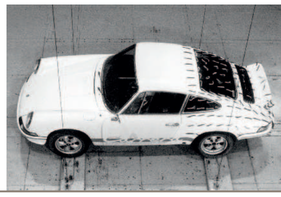
For the Avus high-speed track in Berlin, the 550 Spyder was given a cover for the side seat, the wheels and a small windshield.

1971



As early as 1969, the Porsche 917 came in short tail and long tail forms. In 1971, the 917 long tail achieved a top speed of 386 km/h on the Mulsanne Straight in Le Mans. At the time, that was the fastest speed a Porsche racing car had ever recorded during a race.

1972



The Carrera RS 2.7 was the first 911 to boast a front and rear spoiler. The rear spoiler reduced the large lift on the rear axle. A front spoiler was then also required to achieve the desired aerodynamic balance between the front and rear axles.

1986

Thanks to the aerodynamically redesigned body with flat, lined underbody and effective wings, the 959 achieved a top speed of 317 km/h with a neutral aerodynamic lift force on the rear axle.

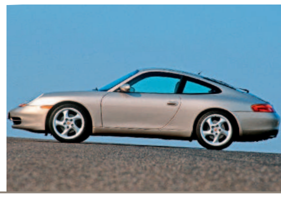
1987

The Porsche 928 S4 had a low front spoiler, a wide rear wing and underbody paneling that covered the entire front section of the body as well as electrically controlled cooling air flaps. The c_d value of 0.34 was the best achieved by this series.

1988

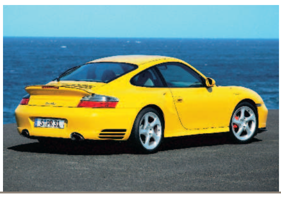
The new 911 series 964 was launched in this year. Its particular development feature was a radical aerodynamic improvement of more than 10% compared to the predecessor model. The low c_d value of 0.32 and the small frontal area of 1.79 m² yielded a c_d x A value of 0.573 m².

1997



The 911 Carrera (996) with its c_d = 0.30 demonstrated a significant improvement in the drag coefficient of the 911 series. The first-ever water-cooled version of the 911 had highly aerodynamic cooling air ducting with radiators arranged in front of the front wheels.

2000



The Porsche 911 Turbo (996) set a new standard with a c_d value of 0.3 l, which made possible a speed of 305 km/h. This was also the first standard production car to feature an extendable wing element, which was much more effective aerodynamically than the previous rear spoiler.

2004

The c_d values of the Porsche 911 Carrera (997) were, depending on the version, between 0.28 and 0.29. Despite larger frontal areas and higher cooling air requirements, the drag index of c_d x A was at 0.56 m², less than the predecessor vehicle. The best in the Porsche 911 series.

2006

The Porsche 911 Turbo (997) had a c_d=0.31 and a negative lift coefficient of c_l=-0.01. The wing element was made larger and thanks to its aerodynamic design manages on a smaller extension height. New to the series: rear axle brake ventilation.

2009

One highlight of the Porsche Panamera series is the active 4-way rear spoiler on the Porsche Panamera Turbo, which thanks to optimal management of the attack angle and area geometry delivers maximum aerodynamics and performance. Porsche Panamera S c_d value: 0.29.

Hats off! Boxster Spyder – The development of a Derivative

The projects that Porsche Engineering work on and for whom are often strictly classified. That we develop Porsche derivatives however cannot be. Hats off to the new Boxster Spyder!

Uncompromising openness

The objective: extreme handling and high cornering acceleration – all these while keeping the vehicle light, strong, efficient and providing an open-air feel. The result is worthy of a second look! The various departments at Porsche Engineering have more than proven their overall vehicle competencies in developing the Boxster Spyder, particularly in the area of modularisation. This coupled with the streamlined development processes has yielded unrivalled results.

When less is more

At 1,275 kilograms, the Boxster Spyder is the lightest model in the Porsche range. Nevertheless, it produces 320 hp – 10 hp more than the Boxster S. When equipped with the Porsche Doppelkupplung (PDK) and the Sport Chrono package, it goes from 0 to 100 km/h (62.5 mph) in 4.8 seconds. It has a top speed of 267 km/h (167 mph) – with its top down. The vehicle rides 20 millimeters lower, which, together with the weight reduction measures, means that the center of gravity is lowered by 25 millimeters. The sporty chassis of the Boxster Spyder is characterized by its stiff and short springs, large anti-roll bars on the front and rear axles, and

Process steps in developing the top

Defining the blank

- Securing loose top parts to the attachments on the vehicle
- Stipulation of seams and contours
- Preparation of pattern in manual work
- Coordination of all blank templates with respect to seam segments and lines

Acid test

- Check for accuracy of fit, functionality and look
- Convertible top fulfills all technical an visual requirements
- Check of top contour using contour templates

Labeling and digitizing the completed blank templates

- Pattern for the cutter
- Determining the optimal material utilization and consumption

The development of the convertible top starts with the definition of the blank. During the first trim loop, loose material parts of the top are attached to the fixtures on the vehicle by means of adhesive tape and clips, in order to then determine seams and contours. The material parts are removed one after the other and manually transferred onto patterns. Next the blank templates are coordinated with one another in terms of the seam segments and seam lines and supplemented with seam allowances, notches and markings.

specially tuned tension and pressure stages of its four shock absorbers.

A lid for the rear

The rear lid, an important identifying feature of the vehicle, posed a particular challenge for the Porsche Engineering development team. Its large size, measuring 1.5 square meters, required a wealth of inventiveness, particularly in terms of the paintwork processes and final vehicle assembly. Adopting simultaneous engineering philosophy, finite element models for casting, static and dynamic strength simulations were performed as early as the styling phase using the initial CAD surfaces. These simulation tools were used to assess the potential use of different lightweight constructions and also to assess the first detailed engineering design for the adjoining components. Based on the simulation results, the engineers and designers decided on the required design modifications.

With this condensed design cycle, it was possible to release the design quickly followed by the tooling design release just one month later. The first component tests and module trials commenced just twelve months after the start of the project.

Open to all

In terms of the “headgear” one thing became clear very quickly: an open vehicle concept – as the name implies – requires that there be no roof at all. Least of all an electric one. If push comes to shove, perhaps a manual one. For this sporty vehicle, an ‘emergency top’ for purists was developed. This two-part structure makes it possible to use the top purely as a sunshield, creating a completely new driving experience. Porsche Engineering developed, tested and released this emergency top through to series production.

Rear with Carrera GT-look scoops

Liberated

All the development goals were achieved. The result is a very light and easy to use soft top that offers the driver protection from the wind and rain. There is no missing out on any fun with the hood on either; it is possible to reach a top speed of 200 km/h (125 mph) with the emergency top fitted.

The most striking technical feature of the top is the unique design style, that makes it possible to fold the top optimally and stow it in the luggage compartment without reducing the luggage compartment space. In fact, the manual top is very easy to use because there are just a few connection points on the vehicle and it can be fitted and stowed very quickly. The top is fixed across the roof frame to the cowl frame by means of a tension cable behind the roll-over bar and over the fins on the rear lid. The soft top contour is additionally shaped by a bow on the roll-over bar which produces an elegant line. The type of materials, e.g. carbon fiber and aluminum, were also chosen for their lightweight properties.

The essentials at a glance

The requirements placed on the top were consistently pursued and implemented during development of the convertible top covering. Unnecessary and expensive extras, such as roof liners, were omitted and the number of components minimized. Once the design was completed, the next step was to handover the project to the production suppliers. They were supplied the electronic template set, a master sample, the parts list and detailed sewing and assembly instructions. With this information, the suppliers were able to start the industrialization process which includes procuring the various parts and equipment required for series production, creating the patterns, drafting and fitting instructions and setting up the production line. The aim is to always achieve optimal coordination between developers and suppliers.

The Boxster Spyder is a very sporty variant of the Boxster series. Further enhancements in driving pleasure, driving dynamics and performance were therefore at the very top of the performance specification for the Porsche Engineering´s chassis developer. To achieve this goal, however, driving comfort, a feature that is very important for the driver was indeed not ignored. Extensive fine-tuning on the suspension and damping yielded a very successful compromise between driving comfort and driving dynamics. Compared to the basic model, the developer was right on track with a number of key chassis changes that were made to the Boxster Spyder. The central feature is a sports chassis that has been lowered by 20 millimeters and features conventional damping. Added to this was a mechanical rear differential lock installed as standard which is offered only as an option for the basic Boxster model. As part of the lightweight construction, 8.5J x 19" and 10J x 19" unique and weight-optimized wheels were developed. Summer tires with dimensions of 235/40 R19 and 265/35 R19 are fitted as standard.

Comparison of wheel assembly weights of the Boxster Spyder and Boxster S

	19-inch Boxster Spyder wheel to 18-inch Boxster S wheel	19-inch Boxster Spyder wheel to 19-inch Boxster S Carrera sports wheel
Front axle	-3%	-9%
Rear axle	-2%	-12%

Light, efficient and open

Easy going

The wheels are cast aluminum wheels manufactured using the flow-forming method. Porsche Engineering was responsible for the complete development of all components. Furthermore, the supplier's finite element calculations were counterchecked and assessed, their development process coordinated and monitored, as were all external and internal tests used for sampling and release. The result of this optimization is a reduction in wheel weight and therefore a reduction in unsprung mass.

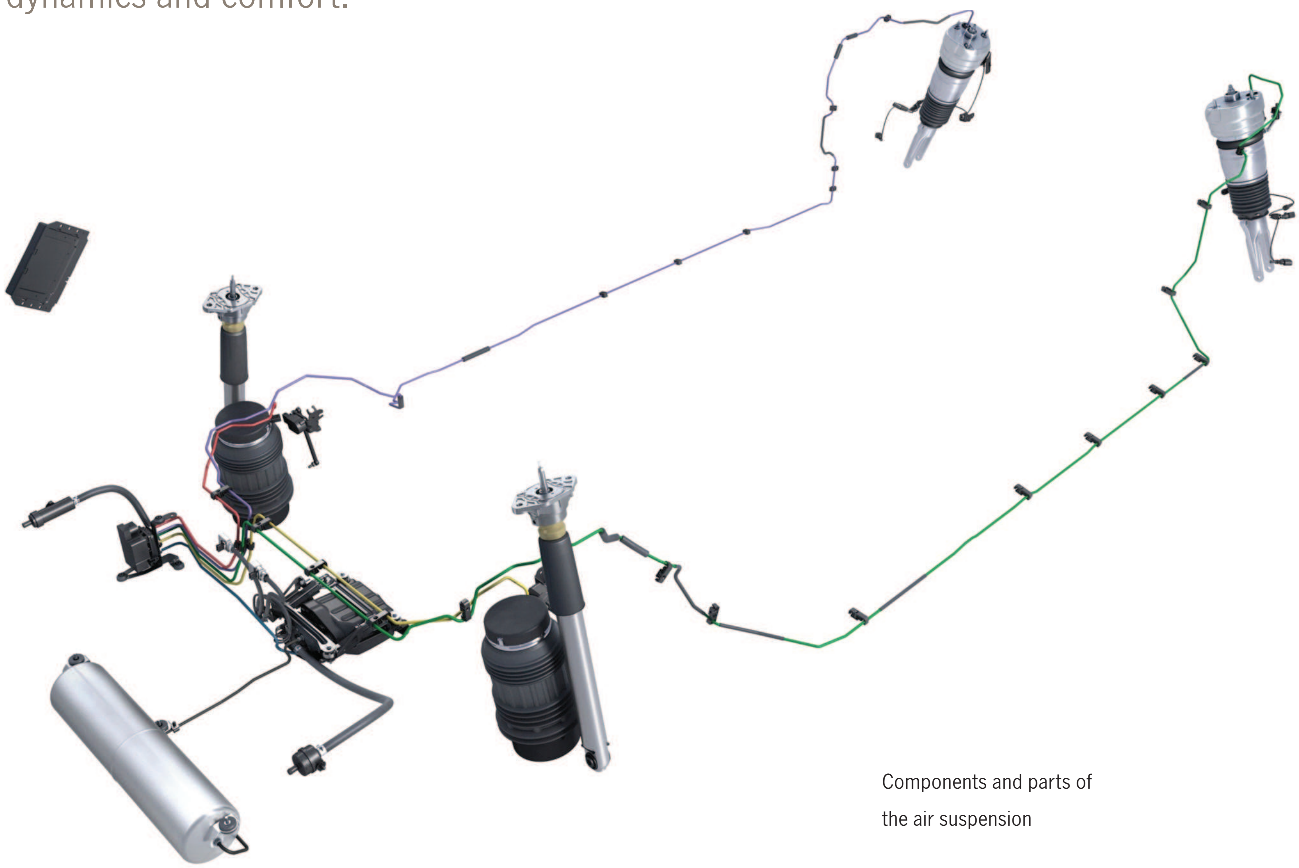
The driving dynamics-oriented design of the Boxster Spyder benefits from the already excellent dynamic driving characteristics of the Boxster model. Lowering the vehicle trim provided further potential through a lower center of gravity. The main springs were redesigned to cater for the chassis being lowered by 20 millimeters, the change in vehicle mass and the driving-dynamic requirements. In the design position, the stiffness levels resulted in an increased structural resonant frequency from the front to the rear axle. This reduces the pitching sensitivity when driving over bumps and enables a higher lateral acceleration.

The core of the driving dynamic design is the design of the shock absorber. Special attention was paid to ensure a highly dynamic roll stability, minimal dynamic change of wheel load for optimal traction on the driven axle and a fast response from both axles for spontaneous steering behavior. These requirements were achieved by balancing the ratio of rebound and compression damping. The stabilizers were specifically designed to generate high rolling-resistant and neutral rolling rate distribution. This chassis tuning resulted in very agile, precise handling and neutral setup that achieved maximum lateral acceleration coupled with the driving comfort that is expected from vehicles of this class.

The aluminum cast wheels are manufactured using flow-forming technology.

A smooth ride – the Porsche Panamera air suspension

With the active air-sprung chassis on the new Porsche Panamera, the Porsche engineers have succeeded in creating the best possible balance between driving dynamics and comfort.



Components and parts of the air suspension

For the first time, the new Porsche Panamera offers the driver the opportunity to select whether he wants to drive a comfortable, sporty car or a distinctly dynamically-tuned one. The engineers succeeded in producing a car that is as comfortable as it is sporty, with power far beyond that previously known, through the introduction of one single system. To create the driving characteristics that are synonymous with Porsche, important guidelines were created for the chassis and suspension systems of the new Porsche Panamera: maximum driving dynamics, outstanding traction and excellent control. Driving pleasure and the agility of the vehicle were likewise right at the top of the requirements list.

Harmony of components

The new air suspension which was built from scratch with a lightweight design comprises four air springs with additional air volume valve on demand to change the spring rate. It also features an air supply system with supercharger, accumulator and solenoid valve block. Rounding off the components are four height sensors, a pressure sensor, a temperature sensor, three body acceleration sensors as well as a control unit for the air suspension and Porsche Active Suspension Management System (PASM).

Better closed than open

The air supply system is a pioneering innovation, which provides compressed air to the air suspension. It is characterized by its closed operating principle. In closed systems, the energy level in the vehicle is maintained, which has certain

Compressor for the closed air suspension

attendant advantages. In an open system, air from the environment is filled into an accumulator. It is from this that the air springs are filled when the vehicle is raised or loaded. When reducing the load or lowering the vehicle, air is released out into the environment. In a closed system, the air quantity required for the control operations is taken from an accumulator into the air springs and then returned.

The very low pressure differences prevailing in the closed system enhance its efficiency significantly. Moreover the closed system reduces energy consumption by around one third and reduces the compressor runtime by about a quarter, while still providing superior control speed, which is not the case with open function systems.

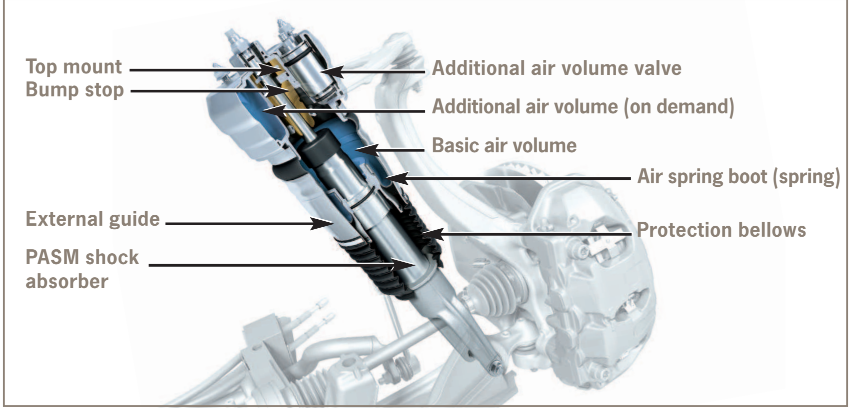
The closed air supply and the compressor developed especially for its application in the Panamera represents the first time it has ever been used by a premium European automotive manufacturer in a luxury class car.

State-of-the-art control

The switchable spring rates primarily involve a newly developed valve which is integrated in the air springs and a control strategy which was developed and coordinated specifically for the requirements of the Porsche Panamera.

The Porsche engineers developed a complex control strategy to switch the spring rates, as the switching process is influenced not only by the driver's selection but also by the driving and vehicle conditions at that time. In addition to the horizontal-dynamic processes, the vertical-dynamic movements are also factored into the calculations in order to determine the ideal switching time, the optimum of which is always the current required level. In addition, body- and wheel-dominant signal shares must be detected, which can result in spring rate adjustments depending on the behavior of different strategies. Furthermore, numerous special situations, for example the air volume heating up while driving, must be taken into consideration by the switching strategy. The aim of this control is that the vehicle always displays the same familiar and foreseeable driving behavior for the driver, even in Sport Plus mode.

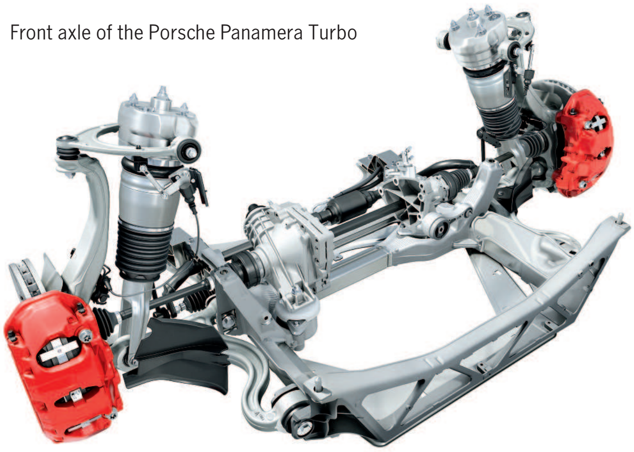
Air-spring strut on the front axle



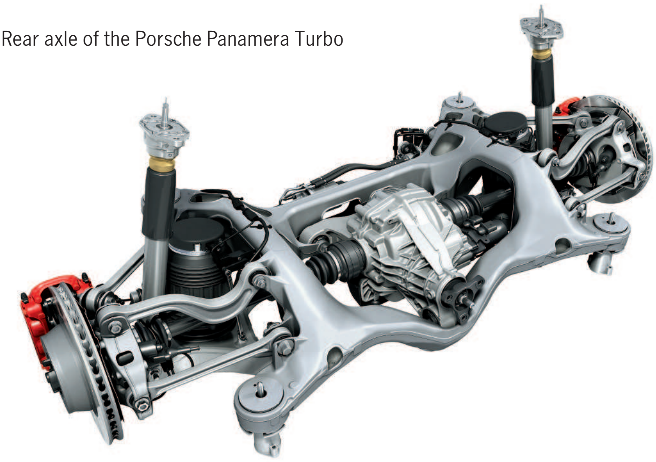
A heavy lightweight

With the air springs, the engineers at Porsche succeeded in combining the high kingpin inclination of the spring rates with a compact design. A major factor here was the development of an

Front axle of the Porsche Panamera Turbo



Rear axle of the Porsche Panamera Turbo



additional volume valve, which is both smaller and lighter than the current state of the art. The lightweight design is supported by the arrangement of the air springs, which minimizes the required air volume.

In addition to the large kingpin inclination and the low component weight, it was of huge importance for the air springs that a very comfortable suspension behavior be achieved. This is critical for the perception of comfort in this vehicle class. This challenge was met in that very thin-walled air spring boots with appropriately selected rubber mixes were used in combination with a thin-walled aluminum external guide. The front axle is a double-wishbone axle, on which the air springs including switching valve and additional volume form a compact unit together with the damper. In the multi-link rear axle, the damper and the air spring unit are arranged separately.

Despite very limited space, it proved possible to develop a free-standing air spring (air spring that is not coaxially arranged on the air damper) with integrated additional volume and switching valve. Another feature of the rear axle air spring is that this is the first time that a free-standing air spring with external guide has been used to enhance comfort. Through the consistent use of plastics, the weight of the air spring module was reduced significantly.

No detail is too small

The engineers at Porsche in cooperation with the development and system suppliers also developed a compressor specifically for use in a closed air suspension. Electric motor, compressor, dryer and switch valves have all been integrated into one module. This offers a weight advantage of around one kilogram when compared to open air suspensions. The air supply system is watertight and completely maintenance-free. To supplement for leaks and to compensate for high temperature fluctuations, air is topped up from the environment. To avert freezing, a complex regulation strategy was developed which makes it possible to dry the air.

Total control

Faced with the large system scope and the multitude of power outputs in the Porsche Panamera air suspension, Porsche developed a new hardware platform for the control unit. The same control unit is also used as a variant for the PASM system without air suspension.

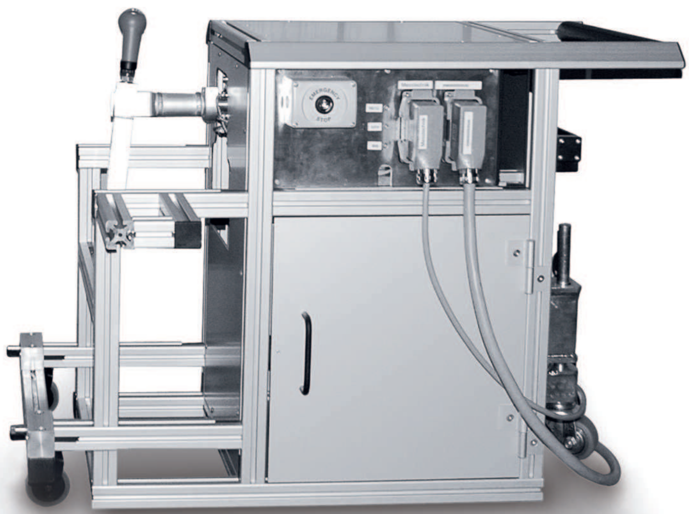
Strategic control

The individual software modules are structured modularly and designed such that they can be used again in subsequent projects. Before creating an ECU software program, the software developer can at an early stage use a PC to simulate the functionality of his module or component, with the help of MIL (Model-in-the-Loop) or SIL (Software-in-the-Loop), or, using appropriate hardware (for example an autobox), can test them directly on the vehicle without being dependent on the creation of a complete ECU software package. This led to a significantly reduced development time and guaranteed huge flexibility in the development process and during software updates.

Feel the shifting force

To ensure optimal shifting comfort and a shift response that is typical of the brand — these are the requirements that Porsche Engineering have always and ever held dear.

The second generation shifting force simulator developed by Porsche Engineering now offers a broader application spectrum



Since 2005 Porsche Engineering has used the first generation of its own, internally developed simulator both for its in-house and customer developments. The simulator makes the shifting force of any gear tangible right from the very early concept phase, making it possible to save on valuable development time and costs.

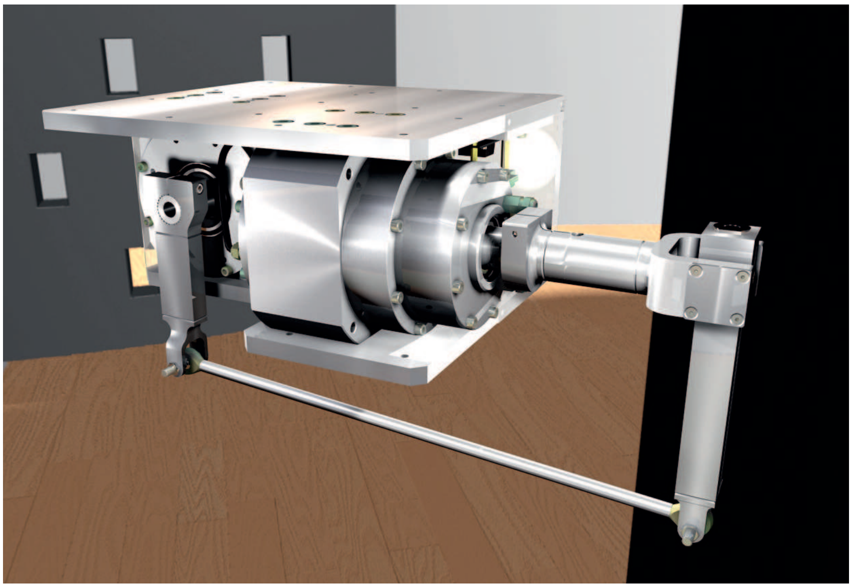
Up until a few years ago, the definition of new vehicle shifting patterns in the early development stages relied almost exclusively on the experience of a handful of engineers, while pure simulations were only used in isolated cases. Since the completion of the first shifting force simulator at Porsche, it has been possible to marry the experience gained in testing with the variable options offered by simulation. Even before the availability of the first real prototypes, the shifting characteristics can be perceived, evaluated subjectively and initial optimizations can be defined.

The simulator is combined with a one to one scaled driver seat, with which the relevant driver environment can be reproduced vehicle-specifically. The test person thus takes up his actual position as if being in the vehicle. The realistic seat position means that the simulator also takes ergonomic influences on the shifting process into consideration.

Real-time simulation software maps the gear shifting. In addition to shifting-specific parameters, the influences of the vehicle on the transmission are also taken into consideration here, for example through the transmission mounting or the side shafts. The shifting forces are calculated in real-time and made tangible on the gearshift lever by means of special electric motors. The impact of the smallest changes to the computer-assisted parameters is immediately perceptible on the gearshift lever. If what is felt is not what is desired, the shifting forces, paths and geometries can be redefined and optimized in real time at the click of a mouse.

The system developed by Porsche Engineering assists automotive engineers already in the concept phase to define the desired power transmission characteristics. Thus the shifting comfort can be evaluated objectively and reproducibly at an early stage in the project. Furthermore, it is possible in every development phase and under the same framework conditions to check whether the desired shifting characteristics can still be maintained without having to use a prototype transmission.

Based on the the experience gained from a multitude of customer development projects and in-house Porsche applications, this year sees the completion of the second generation of the Porsche shifting force simulator, which has been completed an dalready been sucessfully used in sports car development. Thanks to the significantly greater computing power of the new simulator, combined with a newly developed procedure to optimize computing time, it is now possible to run the same models in the classic shifting simulation (offline/ PC) and on the shifting force simulator (real-time hardware). Consequently, high-precision blocking synchronizer models can be used, which were previously only possible in the offline simulation. The effort involved in creating real-time models is also significantly reduced by the act of standardizing the models.



Second generation actuators

However, it was not only the computing power of the real-time unit that was improved. While the actuators of the first generation were designed for comfort shifting, the second generation of the simulator is also capable of generating forces that would only occur with very sporty shifting.

To this end, special rotatory electric motors were used, which were exclusively developed for Porsche Engineering. In the shifting direction, two of these motors are run in parallel in order to be able to supply maximum forces while maintaining a consistently high level of dynamism. In the selection direction, one motor outputs the calculated forces.

All in all, the completely new second generation of the shifting force simulator offers a significantly expanded range of applications. In addition to the adjustment of the engagement force in the shifting direction and the evaluation of shifting impulses, malfunctions can also be represented with greater accuracy, regardless of whether they involve doubled pressure points or gear clash at low temperatures or are due to vibrations in the drivetrain. In addition to the shifting direction, combined investigations with the selection direction are also possible, for example a study of the influence of various gear selection characteristics and gate contours on the transverse shifting ability. Safety-lock forces can also be felt and adjusted at the touch of a button.

The shifting force simulator offers an advantage in that it is not just finished components that are “brought to life”. In the simulation process it is possible to evaluate ideas and designs, for which only preliminary specification is available at the time. With the simulation system, it is possible to quickly identify promising designs and then focus on the detail design engineering and on the implementation of the technology.