Issue 2/2009

Porsche Engineering Magazine

The Panamera
Start/stop saves fuel

Staying on track
Wheel development at Porsche

Resistance is futile
Highlights of the 911 GT3

One day at sea
Acoustics in a cruise liner

Contents

Editorial 3

About Porsche Engineering 4

Virtual reality 5
Digital automotive development

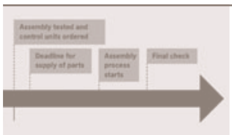
One day at sea 8
Cabin development for a cruise liner

Resistance is futile 10
Engineering highlights of the Porsche 911 GT3

Staying on track 14
Reinventing the wheel every day at Porsche

Numerical simulation methods 16
The Automotive Simulation Center in Stuttgart

The Panamera 18
Start/stop saves fuel



Test strategies for vehicle systems 22
To test or not to test – that is beyond question!

Engine development 24
From inner conviction – the RS Spyder

Dear Readers,

At Porsche Engineering we are well known for thinking outside the box. This is because we focus on creating the products of the future: on land, in the air or at sea. In all areas of technology, we must take what is good and improve on it.

The sea is a good introduction to the magazine, because in this issue we would like to tell you about an exciting project at sea where our engineers heard the wind roaring in their ears. They were working on improving the acoustics in the cabins of the largest cruise liner ever built in Germany and once again were able to demonstrate their strength in depth.

Do you prefer your transport to be a little sportier? Then we have just the thing for you. The magazine also includes a detailed look at the development of the Porsche RS Spyder engine and an overview of the engineering highlights of the Porsche 911 GT3. Or you can journey with us to a completely new dimension and discover the Panamera, the latest member of our family.

You might think that with all these wonderful Porsche models around it would be difficult for us to keep our feet (and our wheels) firmly on the ground, but that's not the case. Our wheel developers have been working on this for decades. Discover for yourself why we have always "remained on track".

With an eye to the future, we are also coming to grips with the latest challenges, such as creating the ideal network of electronic components with the use of sophisticated test strategies. We will also reveal to you how we will be making our product development process even more efficient in future, with the help of numerical simulation methods.

As you can see, we are designing the future for you, by developing new technologies and questioning tried-and-tested approaches. 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.

We hope you enjoy the latest issue of the magazine.

Dr. Peter Schäfer and Malte Radmann
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. If you would like to find out more about the different areas of our business, please visit our website at: *www.porsche-engineering.com*

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VR tools used in computer-aided engineering (CAE)

The digital automotive development process, optimized by Porsche, focuses both on function and design. The result is the best possible combination of the benefits of computer-aided engineering and virtual reality tools.

The quality of virtual prototypes is constantly being improved. At Porsche, virtual prototypes are at such a high level of development that they can be used as the basis for important process decisions. This saves both time and money and dispenses with the need for additional materials for the production of real models. As a result, the use of resources and the environmental impact are also reduced, because technical components no longer have to be disposed of, for example. In contrast to the prototypes used in real-life crash tests, virtual prototypes also have a longer life.

The use of digital functional processes allows the potential for functional improvements to be identified and exploited at an earlier stage. For product stylists it is particularly valuable to be able to put models into different scenarios and environments. In the case of traditional processes, this would involve significant transport and organization costs and the necessity for secrecy. Alongside all the general benefits of using digital processes in product development, over the course of time a number of applications have proved particularly valuable in the different departments. While stylists use special software to develop models, design engineers choose different applications with a different type of graphical representation and level of detail.

Driving dynamics in real time – a direct comparison between the handling of two Porsche models

Styling versus design engineering

Virtual prototypes are used in both the styling and design engineering process. However, in design engineering the data is presented in an abstract form which generally only allows experts to interpret the results of the functional analysis quickly and accurately. In contrast, the photorealistic representation of styling data can be easily understood even by those who are not experts on the subject. If a decision-making process is about to start which will involve the evaluation of both functional and stylistic factors, it is often easier for the specialists from the design departments to present their position clearly and therefore successfully.

However, the use of different systems in different specialist areas has the disadvantage that the individual departments only extract the data which is relevant to their work. As a result, possible synergies based on the combination of functional and stylistic data cannot be fully exploited. For example, designers could test the vehicles they have designed by simulating them driving past. The driving dynamics data which would make this possible are held by the engineering departments, but in the past could not be accessed by the design tools.

The virtual car in motion. Properties such as wheel forces which are not directly visible are indicated by arrows

Networking digital processes

Porsche AG has identified a solution which will overcome the problem of the different objectives of styling and design engineering and their systems landscapes. The introduction of a computer environment which will simultaneously analyze data from different digital processes creates unique added value for engineers and stylists alike. The visualization software RTT DeltaGen allows the Porsche developers to bring together data for the functional analysis and the evaluation of the design so that they can be represented in a way which is easily understood by everyone involved. This makes communication between the different departments considerably easier. Another positive impact of the new software application is the fact that it visualizes products realistically, so that complex, functional data become comprehensible even to external people with no expertise in the area. For example, it is possible to highlight the particularly positive characteristics of new models by means of a virtual aerodynamics analysis using visualizations.

New technology for new generations

The ability to present the latest technologies makes a major contribution to the brand image, in particular in the

Realistic visualization of flow simulation data: Physical processes such as air flow distribution are made visible on the design model

automotive industry, for example in the case of current environmental issues and hybrid technology.

The use of the RTT DeltaGen real-time visualization software at Porsche allows vehicle dynamics to be evaluated even more efficiently. The software has a very simple interface which enables the components in the design model to be rapidly coordinated with the vehicle dynamics model. In addition, the application can generate high-quality images in real time. Camera settings on the vehicle can be changed during the virtual journey and the driving simulations can be viewed in real time, so that all the aspects of the interaction between the handling characteristics and the design can be carefully analyzed. This gives the stylists a particularly good idea of how the moving vehicle will look in real life. The option of presenting driving dynamics data using the design model can also be made use of by the engineers, because the better and more realistic quality of the image also enables them to display their results effectively.

The visualization software is also used to bring styling and aerodynamics into line with one another. Porsche uses RTT RealFluid, the CFD (computational fluid dynamics) module of RTT DeltaGen, to evaluate the air flow behavior in the design. RTT RealFluid enables simulation results, such as the formation of eddies around the vehicle, to be presented in real time in combination with the corresponding virtual design model. The relevant aerodynamic properties are shown in the form of virtual flow lines, intersections or isosurfaces directly on the surface of the car. Different variants of the vehicle, for example with or without a rear spoiler, can be evaluated at the same time from both an esthetic and a functional perspective.

Adding driving dynamics data or aerodynamic information to realistic visualizations of 3D prototypes makes the evaluation of the automotive design much easier. Test scenarios of this kind bring a new dimension to design evaluation, make complex data clearly visible and increase the quality and the reliability of decision-making.

Looking to the future

The introduction of a standardized presentation and analysis tool at Porsche is one step towards a standardized digital product development process. By taking a modern approach, development issues can be resolved more quickly. Interdepartmental communication and an interdepartmental understanding of the issues involved allow the number of iteration loops to be reduced even further and time and money to be saved throughout the entire vehicle development process. Simulation results can now be used immediately in visualizations. It may also be a significant benefit that CAE and VR tools use different processors (CPUs and GPUs) which are both available as standard in PCs, resulting in no reductions in performance on either side.

Visualization on a real-time prototype

Calm during the storm

Porsche Engineering optimizes the passengers' cabins in the Celebrity Equinox – the largest cruise liner ever built in Germany.

Meyer Werft in Papenburg has been building high-quality ships for more than 200 years. It has achieved a leading market position by specializing in developing and building cruise liners. As in many other areas, in the case of shipbuilding "Made in Germany" stands for special products with very high quality standards. Meyer Werft has committed to meeting these standards and to providing the highest possible levels of quality. The main priorities in the design and construction of a cruise liner are to fulfill the increasing demands for quality, to satisfy the customer's requirements and to complete the project on schedule.

One of the passengers' main requirements on board ship is peace and quiet. Meyer Werft aims to meet this requirement and to identify areas for improvement in order to offer customers the best possible noise insulation within the cabins and on the ship as a whole.

One day at sea

Porsche Engineering was tasked by Meyer Werft with analyzing the potential for improvement in the cabins. The project team joined the imposing Celebrity Equinox on a trial voyage in the North Sea. The power produced by the ship was enough to impress even the Porsche engineers. The liner is powered by engines with an output of more than 50,000 bhp (the same as one hundred Porsche 911 GT2). The wind roared in the engineers' ears and it became clear to them that the situation when the ship is at sea is totally different to that in a sheltered port. Heavy seas put the quality and performance of the wall and ceiling joints and seals to the test.

The experts from Porsche Engineering used the latest measuring devices to track down the sources of noise on the ship. These included an ultrasonic meter, a near field probe and high performance microphones, an acoustic camera, loudspeakers, an endoscope, an accelerometer and a radio-controlled camera system for inaccessible false floors. In the areas of the ship which are particularly noise-critical, the engineers from Porsche Engineering tracked down the problematical noise and located its source using the measuring devices they had put in position.

The first stage involved measuring the current noise levels in the cabins. In order to evaluate the noise transmission between two neighboring cabins, the sound reduction index of the cabins was assessed. In accordance with the ISO 140-4 standard, a standardized signal was generated using a spherical loudspeaker in the cabin and the sound level was measured using microphones in the cabin itself and in the neighboring cabin.

The microphone signals were represented in the form of third octave spectrums. These indicate the effectiveness of the sound insulation and show which frequencies are particularly well damped and in which areas there is room for improvement. In order to evaluate the effect of the insulation in each cabin, the microphones were positioned in and around the cabin. The difference between two microphone measurements is the weighted sound reduction index “R_w”, a term used in architectural acoustics. This is the measurement of the noise reduction between two neighboring rooms and between one room and the outside, for example in the passageway.

Using their experience of developing sports cars and working on product development in many customer projects, the experts from Porsche Engineering were able to identify useful parallels and potential areas for improvement.

All the proposed improvements highlighted by the specialists from different departments within Porsche, including acoustics, materials technology and lightweight structures, were gradually added together. Reproducible results play a particularly important role in the evaluation of the individual improvement measures. These results were produced in the next stage of the process using measurements in a laboratory environment where there is no noise interference of the kind which occurs in a shipbuilding hall in a dry dock or at sea. There was absolutely no possibility of bringing the Equinox to the development center in Weissach for noise tests, as she is 317 meters long and 37 meters wide and has a draft of 8.30 meters, together with 1450 cabins. Instead individual cabins were brought to Porsche Engineering on special trucks so that they could be tested in a low-interference environment. In special workshops the cabins were welded to a specially erected floor or deck as they would be on board ship and were taken into use. Noise was generated by powerful loudspeaker systems and the ship’s movements were simulated using hydraulic presses. The cabins were gradually measured and improved, every technical detail was refined and a new concept was developed which would allow the shipyard to produce lighter and more cost-effective cabins in future. New wall and ceiling panels were developed by Porsche Engineering and the structures of the entire cabin were optimized using finite element analyses. The structures were simulated and designed to accommodate the loads to which they are subjected. The result was significant weight savings and a cabin which has a much greater torsional strength and also offers a better sound reduction index.

The Meyerweft in Papenburg

The development project was highly successful and the Porsche engineers can be confident that all the passengers on board the Equinox will be able to enjoy peaceful and relaxing vacations.

Porsche 911 GT3

You can develop a sports car on the basis of experience. Or from the depths of your heart. We are proud to present the new Porsche 911 GT3.

Porsche engineers are strongly opposed to any form of compromise and this principle has been applied to the new Porsche 911 GT3. It produces more power than its predecessor, but its fuel consumption is comparable. The previous models set very high standards in this respect. The result of the development process is now ready to take to the roads: a perfect synthesis of track car and everyday transport.

Resistance is futile

Significant changes have been made to the aerodynamics of the new 911 GT3. The new front end is characterized by eye-catching, broad outer cooling air intakes which give the new 911 GT3 a powerful appearance and provide the necessary cooling air to the engine. The slightly prominent center cooling air intake reaches as far as the spoiler lip and forms a wedge shape to increase its aerodynamic efficiency. The center air intake is also highlighted by the joint between the apron and the spoiler lip. Its broad profile, which covers the full width of the vehicle, contributes to the downforce on the front axle. The additional air outlet in front of the luggage compartment lid has been completely redesigned. It has two striking trim strips and is fully integrated into the front end. The large opening is an indication of the high level of efficiency of the system for managing outgoing air from the center radiator and the additional downforce on the front axle. The 911 GT3 can overcome any resistance.

A perfect whole

The grilles in all the cooling air intakes represent another unmistakable highlight of the new 911 GT3. Their delicate yet robust mesh protects the radiators from damage and dirt and allows for a large throughput of air. The fixed rear wing is a traditional component of all 911 GT3 models. The new shape of the rear wing, which now stretches beyond the wing supports, is taken from the 911 GT3 RS and the 911 GT3 Cup and 911 GT3 RSR racing cars. This gives the 911 GT3 a more racing-style wing design with increased efficiency which improves aerodynamic performance and further increases the downforce on the rear axle. The wing side plates are fully integrated into the wing profile. Other new design features can be found on the rear lid. These include two additional ram air hoods and a narrow black spoiler lip (gurney flap) on the rear edge of the lower wing profile. The scooped ram air hoods act as efficient air intakes to the engine and improve the supply of cooling air to the engine compartment. The additional, highly effective spoiler lip creates an air flow with a pronounced trailer edge which contributes to the downforce on the rear axle.

Brakes, lift system and chassis

The standard braking system has been completely overhauled. The diameter of the front brake discs has been increased from 350 mm to 380 mm (the rear brake discs remain the same at 350 mm) and, for the first time, the 911 GT3 has composite brake discs. The front and rear discs are made of cast iron and the calipers are made of lightweight aluminum. These components are joined using several steel pins in a radial pattern. The use of aluminum allowed the unsprung weight on the front axle to be reduced by around 2.2 kilos. In the case of the optional ceramic composite brake (PCCB), the weight reduction is 4.8 kilos. Additional brake air ducts for the rear braking system are another new feature. They are located at the sides of the underbody in front of the rear axle and direct the cooling air onto the rear brakes. The result is an increase in braking performance under heavy loads.

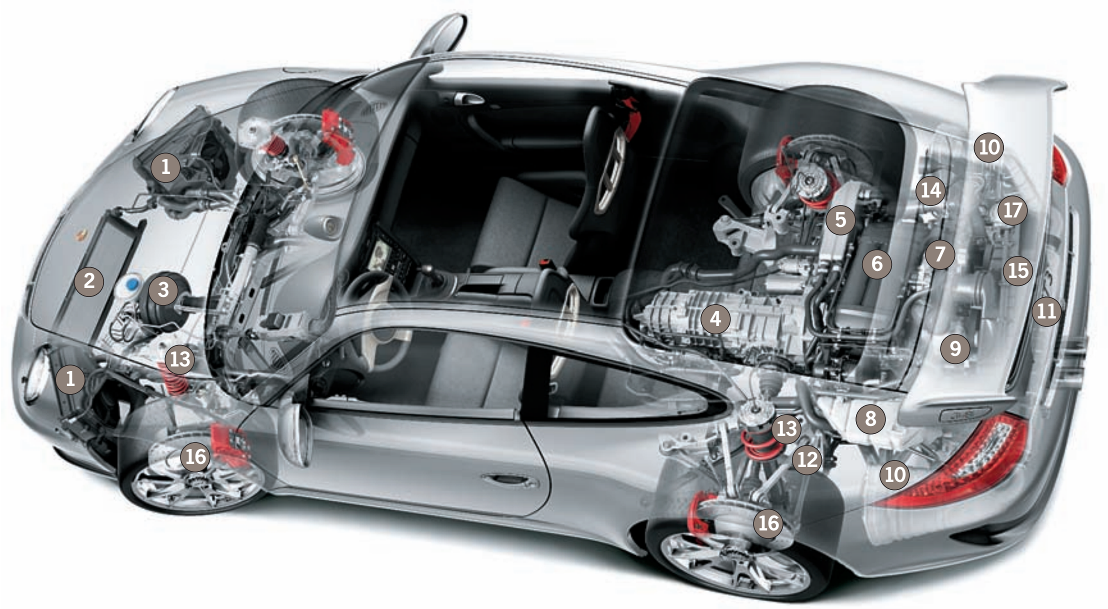
One completely new optional extra is the front axle ride-height lift system, which makes the 911 GT3 even more usable in normal traffic. An electro-pneumatic system can be used to lift the body at the front axle via the PASM shock absorbers. The system is activated by a switch in the centre console and, at speeds up to around 50 kilometers per hour, it raises the body at the front by around 30 mm. The front axle ride-height lift system allows the 911 GT3 to drive over ramps, entrances and speed bumps in cities and residential areas with much less risk of grounding.

Another highlight of the new 911 GT3 is the central locking device for the wheels. The single high-quality anodized central wheel stud which comes directly

Technical data

Body	Two-seater coupé; fully galvanized, lightweight, all-steel monocoque body shell; full size and side airbags for driver and passenger.
Drag	Drag coefficient cW = 0.32 Frontal area: A = 2.013 m^2
Engine	Water-cooled, six-cylinder boxer engine; aluminum engine block and cylinder heads; forged titanium connecting rods; four overhead cams; four valves per cylinder; variable inlet and exhaust valve timing (continuous VarioCam); hydraulic valve clearance adjustment; four-stage variable intake manifold; dry sump lubrication; twin exhaust with two metal catalytic converters and two lambda sensors.
Bore	102.7 mm
Stroke	76.4 mm
Displacement	3.797 cm^2
Compression	12.0:1
Engine performance	320 kW (435 bhp) at 7600/rpm
Max. torque	430 Nm at 6250 rpm
Power output per liter	84.3 kW/liter (114.6 bhp/liter)
Maximum revs	8500 rpm
Power transmission	Six-speed manual transmission; drive via dual drive shafts to the rear wheels.
Performance	Top speed: 312 km/h Acceleration: 0–100 km/h in 4.1 seconds 0–200 km/h in 12.3 seconds

Cut-away image of the 911 GT3

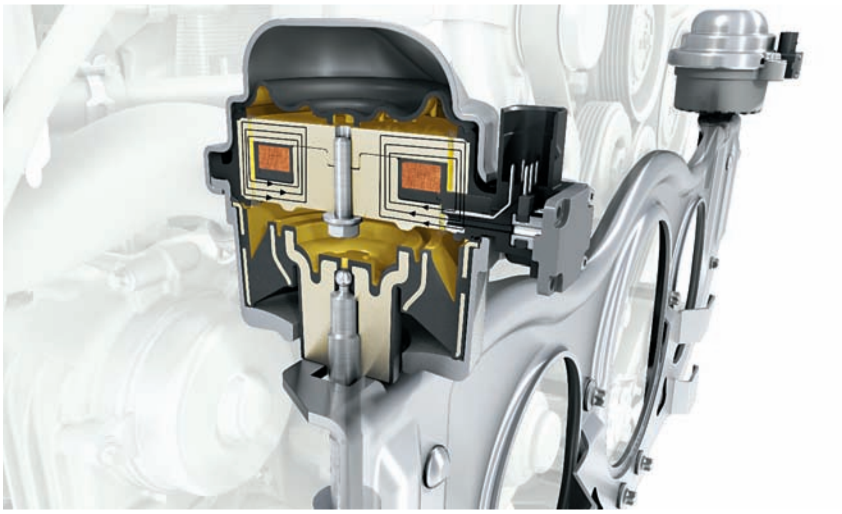


1: Radiator module; 2: Central radiator; 3: Tandem brake booster; 4: Six-speed manual gearbox; 5: Separate engine oil reservoir (dry-sump lubrication); 6: Variable intake manifold; 7: Throttle valve (electronically actuated); 8: Coolant expansion tank; 9: Generator; 10: Front muffler; 11: Main muffler on sports exhaust system; 12: Multi-link rear suspension; 13: PASM damper; 14: Oil filler pipe; 15: Air filter; 16: Composite brake discs; 17: Engine mount

from the world of motorsport has a very distinctive appearance and also allows the tires to be changed more quickly. This is a major benefit for customers who want to use their new 911 GT3 on the racetrack. In addition, the new system, which is fully enclosed, is ideal for everyday use because it is protected more effectively from dirt than an open 5-hole fitting.

The second decimal place – It's how we measure our achievements.

The engine of the new 911 GT3 is based on the 6-cylinder boxer engine of its predecessor. The displacement has been increased from 3.6 liters to 3.8 liters. With a power output per liter of 84.3 kW or 114.6 bhp, it is one of the most powerful sports cars with a naturally aspirated engine. It has a vertically split alloy crankcase. The high-strength crankshaft with 8 main bearings and the "sandwich" design of the short engine come originally from the 911 GT1. In this case "sandwich" design means that the barrels, cylinder head and camshaft housing in each row of cylinders are individual components and are bolted to the crankcase. The increase in displacement from 3600 cc to 3797 cc was achieved by enlarging the bore from 100 to 102.7 mm and enlarging the pistons accordingly. The diameter of the piston pins was increased from 21 to 22 mm in order to ensure that they were sufficiently strong. Despite this increase and the larger diameter pistons, detailed adjustments to the design allowed the weight of the pistons and pins to be kept the same as the previous model. Lightweight titanium connecting rods are part of the high engine speed design of the 911 GT3. The material used ensures that the connecting rods have sufficient strength at high engine speeds (8500 rpm) and allow for the necessary reserves of speed required by racing engines (more than 9500 rpm). The titanium connecting rods are around 150 grams or 26 percent lighter than equivalent steel components. The lubrication system consists of a traditional dry sump with external oil reservoir. The oil pump is driven by the crankshaft via intermediate and connecting shafts. The pump consists of three segments, one of which is responsible for the high pressure oil supply to the engine. It pumps the engine oil out of the separate oil reservoir via an oil/water heat exchanger to the oil filter where it is fed into the engine oil circuit. The other two pump segments pump the oil out of the crankcase and back into the separate oil reservoir. The four oil pumps which extract the oil from the cylinder heads have been moved. They are now in a central position in a separate module together with the water pump at the back of the engine. Other changes include new oil lines between the cylinder heads and the oil extraction pumps. In total the new 911 GT3 has seven oil pumps. The cylinder heads are made from a highly heat resistant lightweight alloy and have additional cooling for the exhaust valve seats.

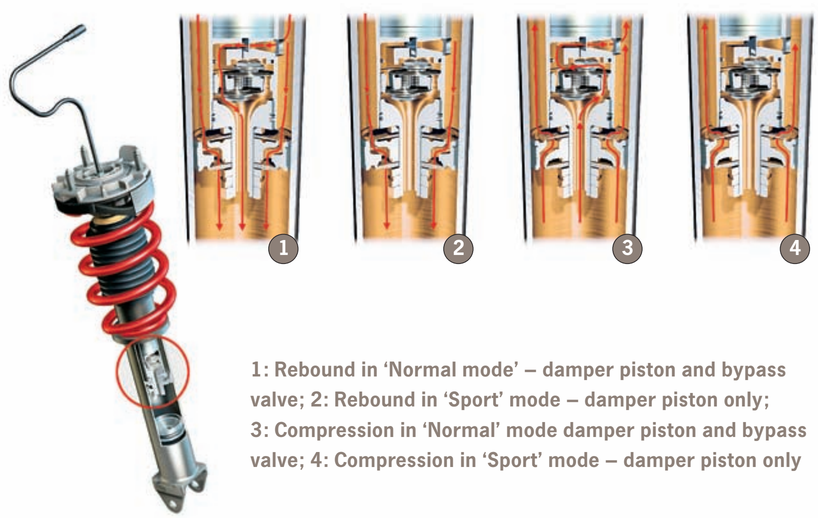


The new PADM (Porsche Active Drivetrain Mount) dynamic engine mount

Dynamic engine mounts

For the first time dynamic engine mounts have been fitted to the new 911 GT3 in order to improve the driving performance. These dynamic engine mounts automatically keep noticeable oscillation and vibration of the entire drivetrain, in particular the engine, to a minimum by means of an electronically controlled mount system. This is the result of a change in the hardness of the mount caused by a magnetizable (magnetorheological) liquid and an electrically generated magnetic field. The inertia of the engine, for example when steering into a corner or driving through a chicane, exerts a delayed force on the body and therefore on the chassis. Hard engine mounts significantly reduce this effect and result in more stable and accurate handling. In racing cars the engine is bolted to the body to keep this effect to a minimum. However, the disadvantages of this solution are more noticeable engine vibration and a car which is less suitable for everyday use. Softer mounts filter the engine vibrations. The dynamic engine mounts also reduce the vertical oscillation of the engine during acceleration under full load. The result is smoother delivery of a larger amount of power to the rear axle with increased traction and better acceleration.

The PASM actively controls the damping forces



1: Rebound in 'Normal mode' – damper piston and bypass valve; 2: Rebound in 'Sport' mode – damper piston only; 3: Compression in 'Normal' mode damper piston and bypass valve; 4: Compression in 'Sport' mode – damper piston only

Reinventing the wheel every day at Porsche

No other self-contained component which requires relatively little development work makes such a powerful and impressive impact on the appearance and image of a vehicle as the wheels.

As well as looking good, wheels have a number of other functions. They form the direct link between the surface on which the vehicle is travelling and the power produced by the drivetrain. In addition to influencing the overall appearance of the vehicle, the wheels also have an impact on its structural durability, comfort, dynamic performance and other safety features. For this reason, the engineers in Weissach are working every day on making wheels even lighter, more robust and more attractive. You could say that they are reinventing the wheel on a daily basis.

Complex development process

At Porsche the process of creating a wheel consists of three complex areas. The first of these is the definition and design phase, during which the engineers and designers specify their requirements for the wheel. Next comes the implementation phase when the strength of the wheel is determined and calculated and the drawings are created. The manufacturing process only begins after subsequent agreement with the suppliers. Porsche developers choose one of three production processes for the manufacture of the wheels: low-pressure casting, flow forming and forging. Low-pressure casting is used primarily for smaller wheels. In the so-called chill casting process, the liquid aluminum is fed at high pressure into a mold and remains there until it solidifies. Every cast wheel is X-rayed to ensure that the microstructure is of the required quality. The result of the process is the cast wheel, which is already clearly recognizable and which is then turned on the lathe, drilled and deburred. Flow forming is a metal forming process in which the wheel rim base is rolled out over a mandrel by one or more rollers. The diameter of the wheel and the thickness of the material can be changed at the same time. By rolling the wheel rim base, the Weissach engineers can reduce the wall thickness of the rim by up to a millimeter without compromising its stability. During the forging process, the wheel is created under pressure from a solid block of aluminum in several stages. The forging mold determines the result of the process. As forging involves high pressures and several phases of production, it is one of the most costly and time-consuming methods of producing wheels. The Porsche developers make use of this process when manufacturing the Exclusive wheels for the Porsche 911 turbo. Regardless of which process is used, all of the wheels have one thing in common. They are all subjected to strict testing procedures by the Weissach engineers before they can be fitted to a Porsche. Each type of wheel must comply with predefined material, surface and strength specifications. The criteria include tensile strength, strain, hardness and microstructure, together with corrosion and coating adhesion. During rotary bending, impact and radial runout tests and other tests on the Porsche biaxial wheel test stand (ZWARP), the wheels must show that they meet all the relevant requirements. Only when the wheels have successfully passed all these tests are they approved for use on a Porsche.

Staying on track

There is a long tradition of wheel development at Porsche. In 1962, when Porsche began developing the 911 range, the engineers were looking for a very special wheel for the new model. They needed an alloy wheel with excellent properties and a completely new look. As a result of their work on development projects for the German army, the Porsche engineers already had experience of alloy wheels. The track rollers of the tank running gear they had developed were made of forged aluminum. Therefore they decided to use the experience from this project. The 911 was the first car to have forged alloy wheels – the Fuchs wheels which are still popular today. But that was not the end of wheel development at Porsche, it was only the beginning. Many more high points were to come, as a glance at the history of Porsche wheels shows. Because of their light weight and high levels of stability, only alloy wheels are now used at Porsche, made mainly of aluminum.

1899

Lohner Porsche

The two front wheels of the Lohner Porsche contain two electric motors.

1942

Porsche tractor type 112/4

The driving wheels on the tractor are enclosed.

1966

“Fuchs rims” of the 911 coupé

Forged aluminum wheels with aluminum Fuchs rims make it easy to identify the sporty 911 S.

1967

910 magnesium wheels

Die-cast magnesium wheels with a central locking device and alloy nut.

1979

Porsche 924 Turbo

Vehicles are fitted as standard with alloy wheels with five wheel studs.

1983

Carrera die-cast wheels

The 911 Carrera had 15-inch die-cast alloy wheels with a “telephone dial” design.

1985

Porsche 959

The cast magnesium wheel had hollow spokes containing sensors which indicated to the driver if the tire pressure dropped.

1988

Porsche 928 S 4

For the first time a production vehicle was fitted with a tire pressure monitoring system.

1991

Porsche Carrera RS

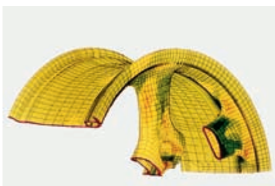
Cast magnesium 17-inch wheels were used for the first time.

1993

Porsche 911 Turbo S 3.3

Initially the Turbo S had 18-inch alloy wheels in three parts with bolted rims in the Cup design.

1995



Hollow spokes – 911 Turbo

Hollow spokes were used for the first time on aluminum wheels.

2003

Carrera GT

Forged magnesium wheel with a central locking device as standard.

Product development using numeric simulation

The Automotive Simulation Center Stuttgart (ASCS) provides the industry with the ideal conditions for developing and optimizing products using the latest numerical simulation methods.

Thirty years ago the process of developing vehicles was almost exclusively a manual one. Designers produced the first sketches on the drawing board and increasingly detailed models were tested repeatedly for stability, handling and many other criteria. Globalization and the accompanying competitive pressures have resulted in product development cycles being drastically shortened over the years. Car manufacturers are faced with the challenge of reducing costs, improving product quality and cutting product development times. In order to achieve these objectives, the automotive industry relies increasingly on virtual development methods. The goal is not to replace the current development process with a completely new and revolutionary digital process, but to choose the best possible method for each task.

The Automotive Simulation Center in Stuttgart (ASCS), established by the University of Stuttgart, Dr. Ing. h. c. F. Porsche AG and eleven other automotive companies and suppliers, brings together the necessary competence in this area. The research centers and the high-performance computing center (HLRS) at the University of Stuttgart provide the ideal conditions for research into applied numerical simulation. There are relatively few comparable high-performance computing centers in Germany. The computing center is managed by the company hww Betriebsgesellschaft mbH which was founded in 1995. By combining competence in IT, engineering and mathematics, the center aims to reinforce and develop further its leading position in the field of applied numerical simulation in the automotive industry. This project was initiated by

Areas of competence of the Automotive Simulation Center Stuttgart

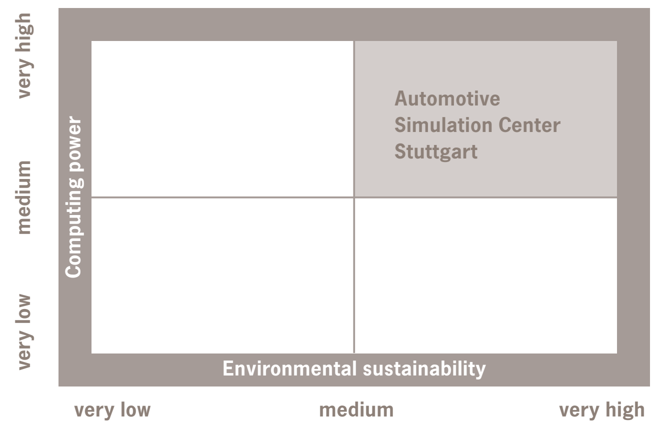
Automotive	Modeling and simulation	Mathematics	Information and communication
■ Energy efficiency	■ Rapid modeling	■ Basic principles	■ Vehicle electronics
■ Minimizing CO_2 emissions	■ Validation and certification	■ Computer algebra	■ Telematics
■ Cutting particulate levels	■ High performance computing	■ Numerical analysis	■ Traffic flow optimization
■ Noise reduction	■ Virtual world (virtual reality)	■ Optimization	■ Driver assistance systems
■ Overall vehicle concept			
■ Lightweight structures			
■ Safety (active, passive)			

Christoph Gümbel who is head of the department for development and innovation for virtual vehicles at Porsche. He is particularly pleased that it has been possible to involve a large number of the relevant companies in the project in just a short time. The ASCS represents a platform for developing innovative simulation methods. These are needed in order to meet the challenge of developing future generations of vehicles. Each simulation process is based on a mathematical model in which a huge number of equations have to be solved numerically at the same time, in order, for example, to optimize combustion processes. A high level of computing power is only useful if it can be accessed easily from each engineer's workplace. This is made possible by high-speed networks provided by CNS (Communikationsnetze Südwest) and by high-performance workstations and a corresponding computer landscape which are available to the Porsche engineers.

The ASCS is involved in simulation in a wide range of automotive-related areas, including the reduction of fuel consumption, pollution and noise and the development of electric and hybrid vehicles. The development of fuel-efficient vehicles and the further reduction of CO_2 emissions represent a major challenge for Porsche engineers. In addition, numerical simulations can be used to test at an early stage of development whether the chosen design meets all the aerodynamic requirements or whether all the necessary components will fit in the engine compartment. Real prototypes are now used much less often for this type of purpose.

Time-consuming computing processes are needed for these simulations. However, the performance of the computers and the numerical software place restrictions on what can be achieved. This is why the ASCS is focusing increasingly on cooperation with the scientific world, as Professor Erich Schelkle, managing director of the ASCS, explains: "For example, the University of Stuttgart can provide expertise in a number of different areas. In addition to the HLRS, which has the latest cluster systems with several thousand CPUs and very high levels of performance, the new Cluster of Excellence 'Simulation Technology' (SRC SimTech) has now also been included."

Positioning of the Automotive Simulation Center Stuttgart



The Porsche Panamera sets new standards

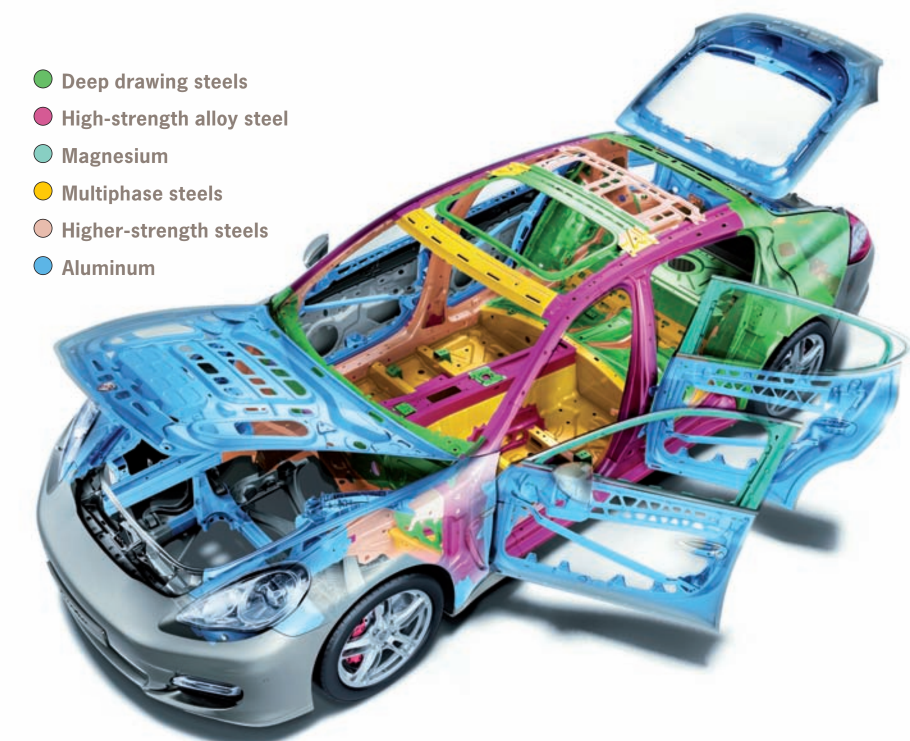
During the development of the Panamera the engineers at Porsche had to draw on their entire range of skills. In this article you can gain an insight into the development process for the Panamera and find out more about the engineering highlights of the fourth dimension at Porsche. In one thousand hours of highly detailed work the engineers analyzed solutions and developed alternatives only to reject them again, until they were fully satisfied with the results.

With a light touch

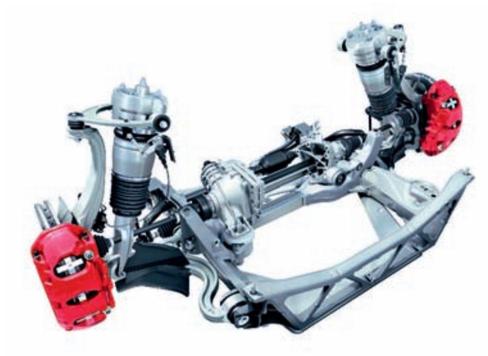
The body of the Panamera is the perfect combination of a lightweight sports-car-style design, high levels of ride comfort, a spacious interior and efficient aerodynamics. A large underbody panel, which for the first time covers the rear muffler, and other sophisticated aerodynamic details give the Panamera a very low drag coefficient (cw) of 0.29. The underbody weighs 40 percent less than conventional systems and helps to reduce the lift on the vehicle significantly. On the Panamera Turbo an adaptive rear wing, which is perfectly integrated into the bodywork, helps to provide the necessary downforce at high speeds. The wing has adjustable sides which help to optimize the vehicle's aerodynamics and performance by adjusting the angles and surface geometry to suit the vehicle's situation.

The adjustable rear spoiler on the Turbo

An intelligent mix of materials has been used in the Panamera. The components responsible for the safety and stability of the Panamera are made of high-strength alloy steel (16 percent of the material mix), while for add-on parts, such as the engine hood and components at the rear of the vehicle, lightweight metals, including magnesium and aluminum (22 percent), are used. The lightweight doors, for example, have a supporting structure made of laser-machined die-cast aluminum, an aluminum outer skin and a window frame made of thin die-cast magnesium. Other materials include deep-drawing steels (20 percent), higher strength steels (25 percent) and multiphase steels (11 percent). In addition, stainless steel and plastic are used. The intelligent choice of lightweight materials keeps the weight of the Panamera S, for example, to as little as 1770 kilograms.



Lightweight design with an intelligent mix of materials



Axle with adaptive air suspension

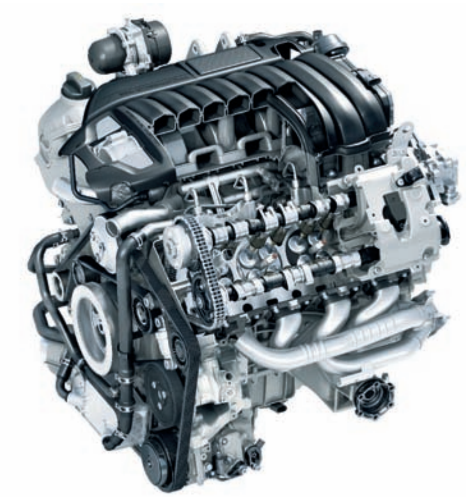
The weight-saving principle was also applied to the interior of the Panamera. The rear seats of the Gran Turismo set new standards of comfort and adjustability in the premium class. The molded individual seats, which have special headrests and an aluminum frame, offer the highest levels of comfort, even in the rear. The seats are also available on request with versatile electrical adjustment and climate control options. Another striking feature of the Panamera is its highly functional and variable luggage compartment. The split, folding rear seat backs with additional luggage compartment overflow area allow for a luggage compartment with a volume of up to 1263 liters and a floor on one level. One other new feature is the sun sensor in the windshield. The intensity of the sunlight and the angle of the rays are measured over an area of four square meters and the information sent to the climate control system.

The fastest concert hall in the world

It is not only the Burmester high-end surround sound system, used for the first time in a production model, which ensures a premium audio experience in the Panamera. By carefully coordinating the sound from the exhaust system, the air intake, the engine and the aero-acoustics, the developers have succeeded in transforming the sound produced by the Panamera into a characteristic and harmonious overall pattern. For example, the aero-acoustics were analyzed using a clay model at a very early stage of development and were then optimized by applying a range of different selective measures. The results are impressive: wind noise is kept to a minimum in the interior of the vehicle in line with what is expected of a premium class model. However, the typical Porsche sound, which conveys a sense of power and dynamics, can still be heard under acceleration. The wide spectrum of sounds produced by the Panamera ranges from discreet and unobtrusive noise while the vehicle is cruising to a sound which evokes a strong emotional response when the Panamera is driven in a more sporty style. The selective use of both new and tried-and-tested technologies has allowed the engineers at Weissach to develop intelligent solutions in order to fulfill apparently contradictory objectives during the development of the Panamera.

Aiming for performance and efficiency

The Panamera is supplied only with engines using fuel-efficient direct injection



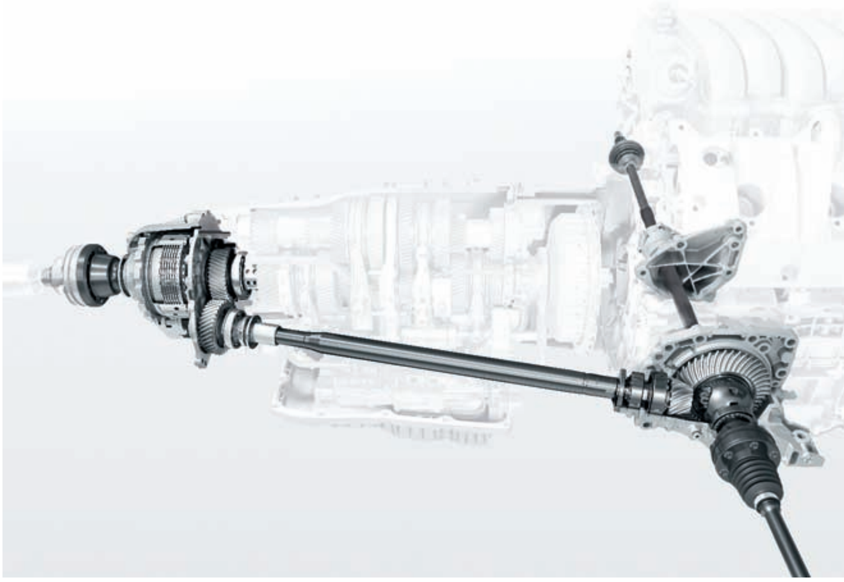
The Panamera Turbo engine

systems. The resulting reduction in friction in the engines is accompanied by new features such as the map-controlled coolant heat management system and a reduction in the weight of moving parts and auxiliary components in order to improve their efficiency. The Porsche Doppelkupplung (PDK) in the Panamera is the first double-clutch gearbox offered by Porsche in the premium segment. It improves efficiency, provides exceptionally sporty performance and gives a very comfortable ride. The PDK is significantly more efficient than a conventional automatic gearbox and the addition of the tall seventh gear which functions as an overdrive saves even more fuel. As a result of the optimum gear ratios and unparalleled, ultra-fast gearshifting without any interruption to engine power, it also offers exceptional performance. In addition, the PDK is 15 kilograms lighter than conventional automatic gearboxes.

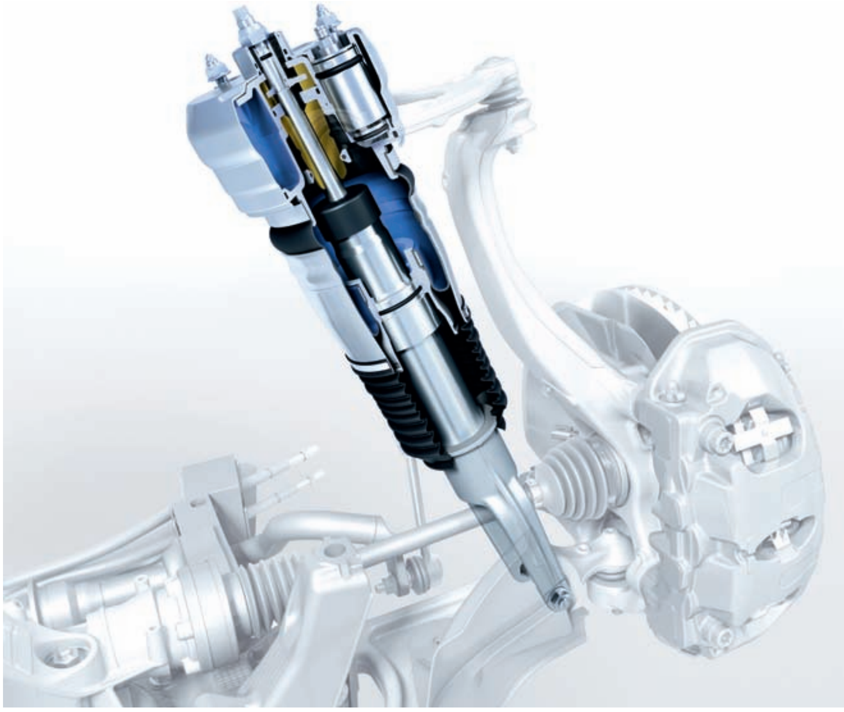
The Panamera 4S and Turbo come as standard with PDK and Porsche Traction Management (PTM). The PTM system in the Panamera consists of active all-wheel drive in the form of controlled “hang-on” all-wheel drive, which is integrated into the housing of the PDK. The electronically controlled multiplate clutch is responsible for the fully variable distribution of the propulsion force between the permanently driven rear axle and the front axle. There is no fixed distribution pattern. This ensures increased agility and dynamics, improved traction and stability, greater control over the vehicle and increased safety as the vehicle reaches its handling limits. In addition, this system is lighter in weight and uses less fuel than conventional all-wheel drive systems, because it is particularly compact. It also offers improved performance as a result of its low centre of gravity.

Start/stop saves fuel

One of many engineering highlights in the Panamera and a first in the premium class is the start/stop system combined with an automatic gearbox, which comes as standard in all versions of the Panamera with the PDK. This system automatically switches off the engine when the vehicle comes to a stop, for example at a red light, and starts it again immediately when the brake pedal is released. All of this is fully automatic with no need for intervention from the driver. The start/stop process is accompanied by a new rapid engine starting function,



Electronically controlled all-wheel drive with integrated front differential



PASM – the active suspension system with additional air volume on demand

which starts the engine very quietly and quickly. The main benefit of this system is obvious; it improves efficiency. The automated start/stop system results not only in a reduction in emissions but also in a significant drop in fuel consumption in particular in urban driving. The improvement in fuel consumption in the New European Driving Cycle (NEDC) brought about by all the technical solutions in the Panamera amounts to an excellent figure of 23 percent. Alongside the start/stop system, these solutions include the PDK, improved aerodynamics, optimum operating strategies and reduced friction and hydraulic losses. Combined with other selective measures to improve the efficiency of the entire vehicle, such as low rolling-resistance tires and reduced residual braking torque, this results in a fuel consumption figure for the Panamera S with PDK of only 10.8 liters per 100 kilometers in the NEDC.

Focused on the future

Right at the start of the development process for the Panamera, it was clear that the chassis must not be a compromise, but instead must offer the perfect combination of sportiness and comfort. The Porsche developers have provided the ideal solution for this technically demanding balancing act. The basic set-up of the Panamera chassis provides the occupants of the vehicle with high levels of comfort. However, the chassis can be transformed at the press of a button into an agile sports chassis, with the help of the PASM (Porsche Active Suspension Management) active damper system. In addition, the highly innovative adaptive air suspension system with additional air volume on demand which is available as standard on the Panamera Turbo and as an optional extra on the other models further improves the comfort of the ride. The chassis characteristics can be changed from the driver's seat with the simple press of a button. Other features of the newly developed lightweight chassis include very high levels of stiffness, agile handling for active safety and sensitive steering allowing high-precision control.

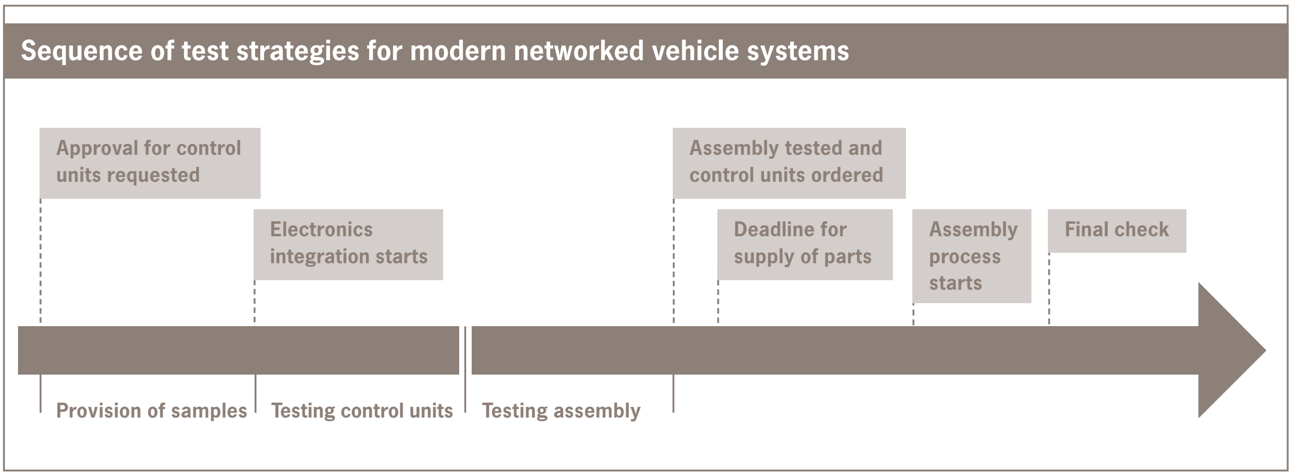
The driving dynamics and comfort can be further increased on all models using the active anti-roll system PDCC (Porsche Dynamic Chassis Control) which improves the vehicle's response to uneven surfaces in a straight line and is supplied in conjunction with a controlled rear axle differential. The PDCC results in an eight percent increase in maximum lateral acceleration, high levels of active safety as a result of its active anti-roll features and improved control of the vehicle in particular as it reaches its handling limits. The developers in Weissach have not only succeeded with style in achieving the perfect balance between comfort and performance. By reducing friction they have also been able to cut fuel consumption.

The Sport Plus button of the optional Sports Chrono package enables the driver to select the uncompromising high-performance set-up of all drivetrain and suspension systems at the press of a button.

Flexible control center

Porsche has entered a new dimension with the Panamera and is working on the evolution of the model. In future, the Panamera will be available with a hybrid drivetrain and a V6 engine. You can find out more in future issues.

To test or not to test – that is beyond question!



The proportion of electronic components in modern vehicles is rapidly rising. Increasingly sophisticated test procedures are needed in order to ensure that all these components interact with one another without problems.

Complex electrical networks consist of decentralized control units and the accompanying sensors and actuators which ensure that everything functions perfectly. Faults often occur not just in individual components or control units but in assemblies with components from more than one system. As a result, the engineers at Porsche Engineering not only carry out conventional component and function tests, but also test components in these assemblies. The test strategies are specially designed and implemented to meet customers' requirements.

Individual control unit tests

The functions and interfaces of the individual control units can be tested using a hardware-in-the-loop (HIL) test bench or a domain test environment. In this case the test systems simulate the interfaces to the vehicle and the other systems. By selectively changing one or more parameters, the test specimen can be artificially stressed and exposed to faults.

Integration testing in the vehicle assembly

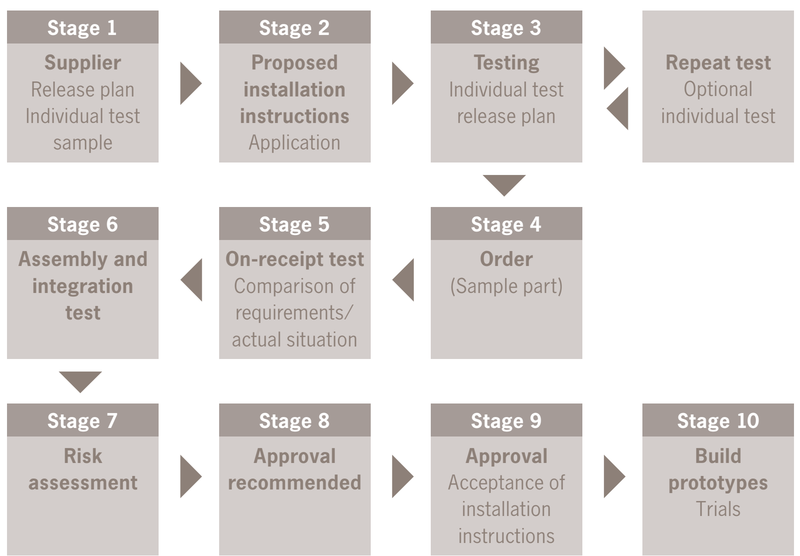
An additional test can be carried out within the normal vehicle assembly, by changing the test conditions to cover all the control units. The important factor here is to ensure that all the electrical components are assembled in an environment as similar as possible to that in the vehicle. The use of a breadboard with an original vehicle wiring harness has proved particularly successful in this context. At Porsche Engineering this is also referred to as CANmobil (mobile controller area network). A complete vehicle is created from an electrical perspective, but the individual components are much more easily accessible than they would be inside a normal vehicle body. This makes it much easier to manipulate control variables selectively and to connect the systems to the measurement devices.

Testing the electrical interface on a network test system (also called a domain test environment) is an essential part of the design process for new control units and is also important for integration testing of carry-over parts (COP) systems in a new vehicle assembly. This allows automatic checks to be carried out of components' compliance with standards. In addition, by using standard macros, complex test sequences can be created which allow control units' responses to the aging process, discharged batteries and cold starting behavior to be simulated, together with the simulation of short circuits. Hardware-in-the-loop tests are ideally suited for ensuring that control functions and algorithms in new vehicle systems are correct right at the start of the development process. They are therefore an essential component of all modern test strategies. Porsche engineers also use HIL tests to carry out "no-risk simulations" which would involve significant safety risks for the test driver in real-life situations. In time-critical development processes where HIL tests cannot be used because deadlines are too tight or where the creation of an HIL system no longer makes sense because of the stage of development already reached, the Porsche Engineering Creator for Measurement in Auto-Network (PEC-MAN) is used. This system, developed by Porsche Engineering, makes it possible to carry out automatic function testing of the CAN and its accompanying database (CAN matrix) in order to check physical variables, such as sensor values and control unit responses. Analog measurements are compared with CAN telegrams, responses to messages or signals sent to digital and analog inputs are monitored and the results combined with the personal assessments made by the tester.

All the steps in the process are carefully logged and evaluated and the resulting test sequences are compared with the function definitions using computer systems. In future, standards such as function definitions in the AUTOSAR format will also be supported. The result is a reduction in the time and effort needed to create the test catalog and therefore a shorter time-to-market, accompanied by improvements in product quality.

Other tools even allow measurements in the form of trace files from data bus systems, such as CANs or LINs (local interconnect networks), to be tested automatically for common faults or protocols to be evaluated in real-life situations. At Porsche Engineering the physical interface between the individual control units is tested fully automatically to ensure that the quality and timing of the signal sequence is correct. The initial evaluation has even been completely automated.

Integrating the test strategy into the approval process



Test strategy

Porsche Engineering ensures that the test strategy is incorporated into the customer's development model at an early stage. Whether the customer uses V models or a different method, the strategy is adapted to the schedule, the implementation plan and the depth and sequence of the testing process. As well as automating standard tasks, the test engineer can also combine his experience with a detailed analysis of the possible effects for each specific product.

This networked approach allows for a qualification process which is not only based on specified standards and critical values, but also takes into account the specific requirements of the most important environment to which a vehicle is exposed, in other words, everyday use on the road.

From inner conviction

The Porsche RS Spyder has a whole succession of victories behind it. The story of its success is uninterrupted. One decisive factor in all of this is the engine which lies at its heart.

The version of the engine in the Porsche RS Spyder which was used in the American Le Mans Series (ALMS), among others, until 2008 is a true masterpiece. The initial versions of the engine, which is referred to at Porsche as the MR6, clearly indicated the goal of the developers, which was not just to take part in the Le Mans Prototype class (LMP2), but to lead it. Despite the ambitious nature of their goal, the developers were successful in achieving it. The eight cylinders of the 3.4 liter engine, which make up a 90 degree V8 configuration, when combined with the four overhead camshafts, the individual throttle valves and, most recently, direct fuel injection, form a unit in which every component is in perfect harmony.

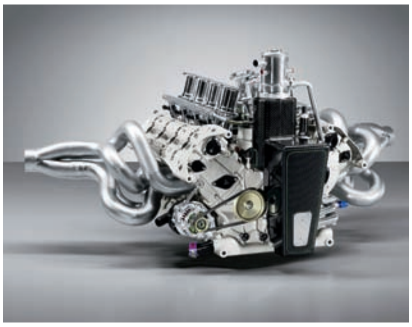
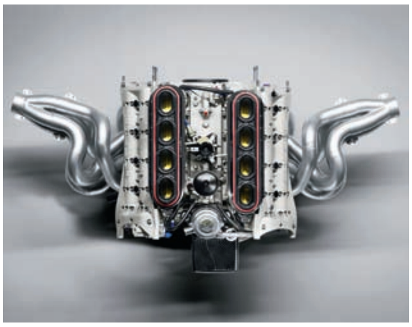
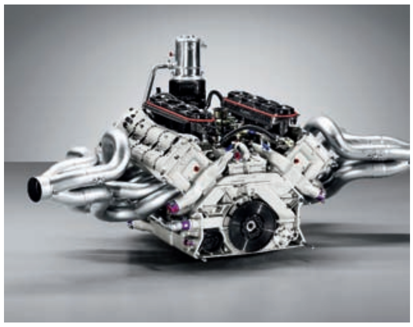
Increasing performance

The Porsche engineers have succeeded in increasing the performance of the MR6 from 476 bhp (351 kW) to 503 bhp (370 kW) as a result of the introduction of direct fuel injection. The maximum torque has been increased from 370 Newton meters (Nm) at 7500 revs to 384 Nm at 8500 revs. Taking into account ALMS regulations, this increase in power is even more remarkable, as the regulations require among other things a restriction on the volume of air available to the air intake. This puts a limit on the possible engine power. However, the Porsche developers identified areas for improvement and were able to increase the power, while at the same time reducing fuel consumption. The requirement was to achieve the highest possible level of efficiency in combination with maximum endurance.

Engine highlights (2008)

Type	Porsche MR6 (2008)
Concept	endurance racing engine, compact and lightweight, very low center of gravity, integrated into the chassis as a load-bearing component
Engine type/Number of cylinders	90 degree V8
Displacement	3397 cm^3
Performance	478 bhp or 503 bhp (DFI) at 10,000 revs
Torque	370 Nm or 385 Nm (DFI)
Air volume restrictor	1 x 42.9 mm Ø
Fuel management	intake manifold fuel injection or direct fuel injection (DFI)
Intake system	with individual throttle valves
Gas exchange	4 valves per cylinder, each with double overhead camshafts (DOHC)
Lubrication system/Oil supply	Dry sump lubrication, oil/water heat exchanger
Lubricant	Mobil 1 (0W-40)
Engine management	Electronic engine management
Exhaust system	High-performance exhaust manifold, silencer in accordance with the regulations

A glance at the engine components indicates the special features which are responsible for the performance of the MR6. A bore of 95 mm, combined with a stroke of 59.90 mm, gives the MR6 a displacement of 3399.5 cubic centimeters (3.4 liters). The noteworthy features of the combustion chamber include flat piston crowns, small valve angles of less than 25 degrees in accordance with requirements and the special shape of the chamber itself, which allows enough space for four valves per cylinder. The engine of the RS Spyder uses ACO (Automobile Club de l'Ouest) E10 racing fuel, which consists of ten percent bioethanol, at a compression ratio of 15:1. In order to keep the weight of the engine as low as possible, lightweight, very tough aluminum was used to make the engine block and the cylinder head. The Porsche developers decided to dispense with cylinder liners and instead used a nickel-silicon-carbon coating inside the cylinders to reduce friction. Titanium connecting rods are responsible for transferring the power from the pistons to the steel crankshaft which has five main bearings. Titanium is known for its high strength, stiffness, durability and light weight. The parameters relevant to the operation of the engine, such as injection timing, injection volume and ignition timing, are controlled by a sophisticated electronic engine management system. The specially developed combustion procedure allows the engine to run on a very lean petrol/air mixture during long safety-car phases or in the pits, resulting in a significant reduction in fuel consumption. Exxon Mobil 1 oil with a viscosity of 0W-40 is used to lubricate the individual components of the MR6 engine. The same oil is used in Porsche RSR, Cup and production vehicles. The perfect symbiosis of all the components, combined with the newly developed direct fuel injection system, allows the engine to reach speeds of up to 11,000 revs. During the development process of the RS Spyder engine, extensive use was made of synergies with volume production and motorsport at Porsche. In particular when simulating internal

The MR6 engine of the RS Spyder with DFI technology

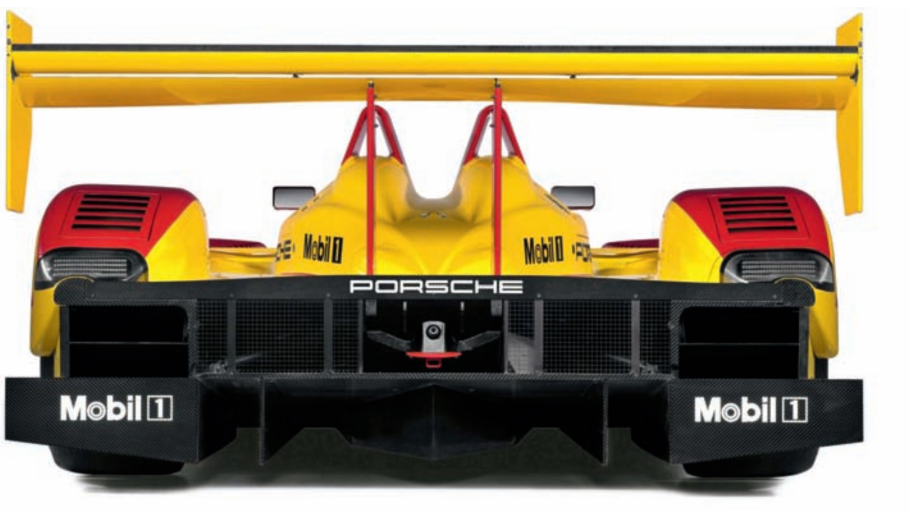
The Porsche RS Spyder: direct injection reduces fuel consumption and improves performance

engine flows and the gas exchange, the teams worked closely together on the important details. For the process of integrating the motor into the vehicle as a whole, the Porsche developers from Weissach were able to make use of all the experience which they had acquired on other projects. In order to ensure an ideal distribution of weight and the stability of the vehicle, the drivetrain of the Porsche RS Spyder was designed as a load-bearing component and was fully integrated into the chassis.

Life in the fast lane

The MR6 engine was specially developed for use in the Porsche RS Spyder in the LMP2 class. Vehicles in this class must weigh at least 775 kilograms (since 2008: 825 kilograms) and the 8-cylinder naturally aspirated engines must have a maximum displacement of 3400 cubic centimeters. The concept behind these regulations is to give the teams a platform for top-class prototype racing. A glance at the previous successes of the RS Spyder indicates how carefully the developers from Weissach have followed these regulations. The RS Spyder's series of successes in 2006 and 2007 continued uninterrupted in the 2008 season. For the third time in a row, the RS Spyder won the manufacturer's, team and driver's championships. One particular highlight at the start of the season was a historic 18th overall victory at the 12 hours of Sebring, exactly 20 years after the last overall victory.

And as if that wasn't enough, the Porsche RS Spyder also won the first Green Challenge of the ALMS in 2008, which



The RS Spyder is one of the first racing cars to exercise almost complete domination over the ALMS series is awarded to the most efficient sports prototype. The factors under consideration in the Green Challenge included fuel consumption, environmental friendliness and average speed. "Direct fuel injection (DFI) has significantly reduced the fuel consumption of our RS Spyder both at normal racing speeds and in yellow flag phases. Porsche customers who have chosen one of the new models with DFI engines will experience the same results in normal driving," says Green Challenge winner Sascha Maasen.

The Porsche RS Spyder won all the efficiency challenges in the 2008 season, not only in the American Le Mans series, but also in Europe. At the Le Mans 24 hours the sport prototype won the Michelin Energy Endurance Challenge with the largest margin. In 2009 it was also the winner of the Le Mans efficiency challenge.

Since the MR6 engine was first used, the Porsche RS Spyder has had a constant string of successes. The engineers in Weissach have implemented all the restrictive changes in the regulations with apparent ease, while at the same time making the engine even more competitive.

The RS Spyder took part in the Le Mans 24 hours race in the hands of customer teams in 2008 and 2009 and won the LMP2 class on both occasions by a very convincing margin.