Bosch Automotive
A product history

Journal of Bosch History
Supplement 2

BOSCH
Invented for life

Foreword

Title illustration:
Bosch and automotive technology are inseparably linked. The title illustration from 1955 shows Bosch testing equipment at work, checking the ignition system of an Opel Olympia Rekord.

The magneto ignition device for motorized carriages that was first delivered to a customer in 1898 marks our first major milestone as an automotive supplier. There were numerous other important milestones on our way to becoming a global automotive supplier with a wide range of automotive systems, components, and services. Examples include the diesel injection pump, the Jetronic electronic gasoline-injection system, the ABS antilock braking system, the ESP® electronic stability program, and common rail. Today, our products help a lot to cut fuel consumption and emissions, and to make driving safer and more comfortable. Bosch technology can be found in virtually every vehicle on the road, whether helping to stabilize vehicle dynamics in critical situations, automatically maintaining a safe distance from the vehicle in front, finding the most economical way to reach a destination, or improving visibility at night.

With his finely honed entrepreneurial instinct, Robert Bosch was quick to latch on to good ideas. He then used his technical flair and commercial expertise to turn them into high-quality products that represented excellent value for money. The principles that he formulated and lived by still shape our company, our values, and our actions today. They help us turn challenges into opportunities. Examples in automotive engineering include recognizing the potential for growth in Asia, realizing the potential of the electric car, supporting the associated emergence of new concepts of mobility, as well as participating in the trend toward smaller vehicles.

Although Bosch is now a technology and services company that is active in many other areas, our automotive business sector has always been at the heart of what we do. No other business sector can look back on such a long or multifaceted history. The purpose of this brochure is to relate this history, and I hope it makes for interesting reading.

Best regards
Bernd Bohr
Member of the Board of Management
and Chairman of the Bosch Automotive Group

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Left:
A car with no Bosch parts? As this advertising poster from 1998 indicates, only toy cars fulfill this criterion.

Right:
A car with Bosch parts. With X-ray vision, you would see the multitude of Bosch electrical, electronic, and mechanical components in a car.

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We have ignition!
Bosch becomes an automotive supplier

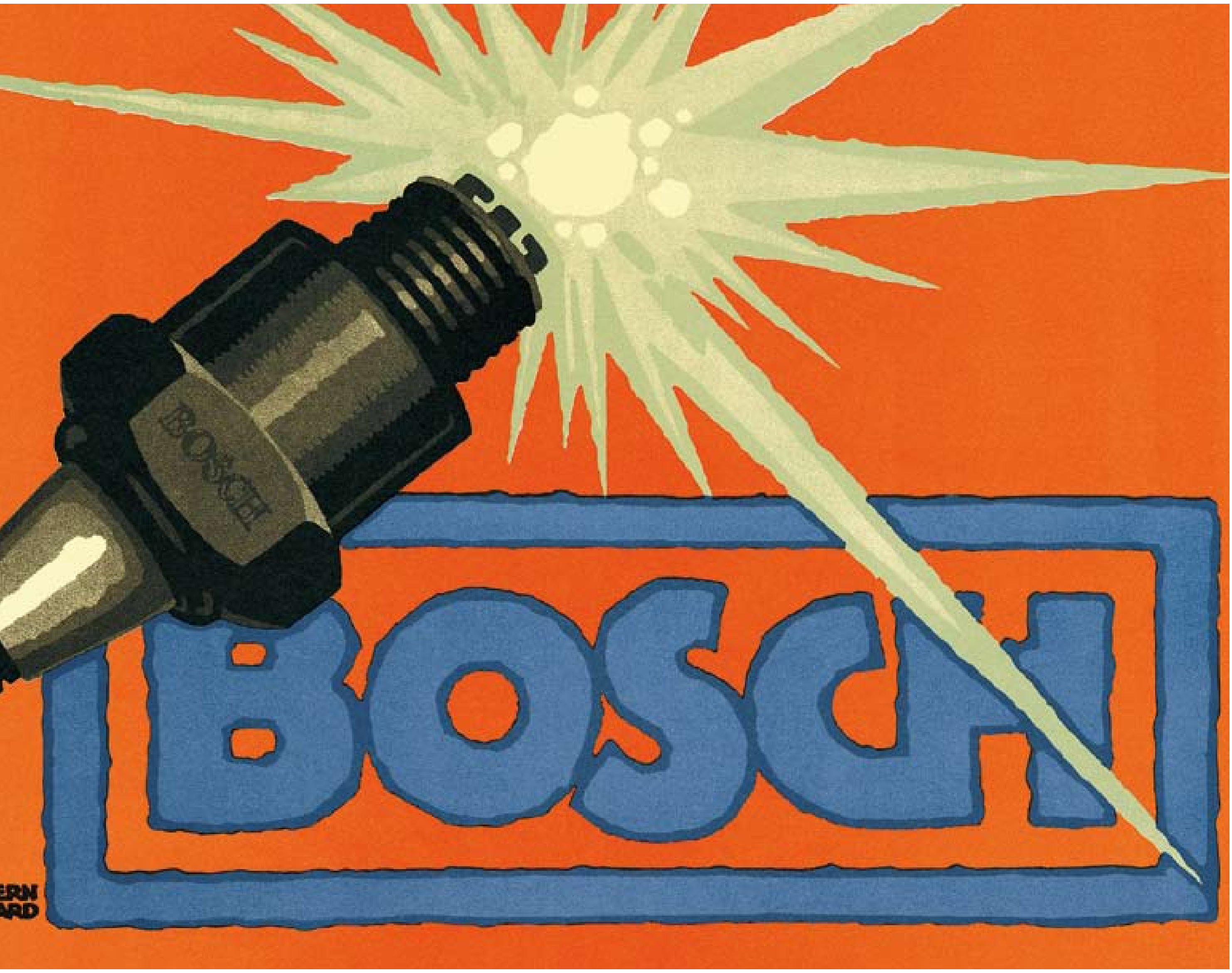
In the company's early days, the directors still performed tests themselves. From left to right: Gustav Klein, head of sales; Gottlob Honold, head of development; Ernst Ulmer, head of commercial affairs; and Arnold Zähringer, technical director

Spark emitter and trademark
Bosch magneto ignition

The origins of Bosch as a supplier of automotive equipment go back to 1887. This was the year in which, on behalf of a customer, the 25-year-old electrician and precision mechanic Robert Bosch built a product that was later to play an important role in the automobile – a magneto ignition device for a stationary engine. In 1897, Bosch installed one of these devices in a motorized three-wheeler to see whether it was suitable for everyday use in motor vehicles. This unwieldy apparatus became a key product of the company. It turned Bosch into an automotive supplier both inside and outside Germany. Ignition systems have undergone further development since then, and are now integrated into complex engine management systems. But one thing has remained the same. Even today, an electric spark ignites the air-fuel mixture and keeps gasoline engines running.

The high-voltage magneto ignition system with spark plug was suitable for universal use and made Bosch highly successful virtually overnight.

Magneto ignition is based on a double-T armature around which a wire coil has been wound. It moves in a magnetic field, thus generating a current. Robert Bosch was by no means the inventor of this principle. As early as 1866, Werner von Siemens used it in his dynamo-electric machine. And in 1876, building on this basis, Nicolaus August Otto developed the break-spark ignition device. He needed this to generate ignition sparks in his four-stroke engines. Nine years later, at the request of a customer, Robert Bosch first built a magneto ignition device for a stationary engine. When testing the device, however, he found that it was not really suitable for everyday



The flaring spark plug, designed by Lucian Bernhard in 1912, was the most enduring motif in Bosch advertising. It appeared on spark-plug packaging until the 1970s.

use. So he set about making improvements, for example by using more robust U-shaped magnets (also called horseshoe magnets). Further orders followed, and some five years later magneto ignition devices already accounted for roughly half the young company's sales.

Magneto ignition in the car

In automobile manufacturing, which in those days was still in its infancy, ignition was proving to be the "trickiest problem" facing automakers – as automotive pioneer Carl Benz observed. The naked flame in Gottlieb Daimler's glow-tube ignition system constituted a constant fire hazard, while safe battery-powered ignition systems restricted the range of cars to a few dozen kilometers, since the battery soon needed recharging and the system did not have a generator to accomplish this task while driving.

In 1897, Robert Bosch installed one of his magneto ignition devices in a vehicle engine. This was something completely new. His customer was the English engineer Frederick Simms, a member of Daimler's supervisory board. He asked Bosch to install a magneto ignition device in a De Dion-Bouton three-wheeler. Robert Bosch found that, in the design that had existed

The Daimler Phoenix truck was the first motor vehicle to be equipped with a Bosch magneto ignition device as standard equipment.

hitherto, the magneto ignition device was unsuitable for such an engine. The device itself was capable of delivering a maximum of 200 sparks per minute, yet the small De Dion-Bouton engine ran at a maximum speed of 1,800 rpm and thus required 900 ignition sparks per minute.

The solution for high-speed engines

Arnold Zähringer, Bosch's factory manager, came up with the solution. Instead of moving the ponderous armature itself through the magnetic field, he left this job to a lightweight metal sleeve which he laid around the armature. Zähringer's invention was patented for Bosch. The innovative ignition device had in theory solved a major problem for the young automotive industry – ignition in high-speed internal-combustion engines in vehicles. However, the complicated break-spark rodding needed to create the ignition spark in the combustion chamber remained a weakness in its design. This rodding had to be redesigned for every engine. It also required considerable maintenance and was prone to breakdown.

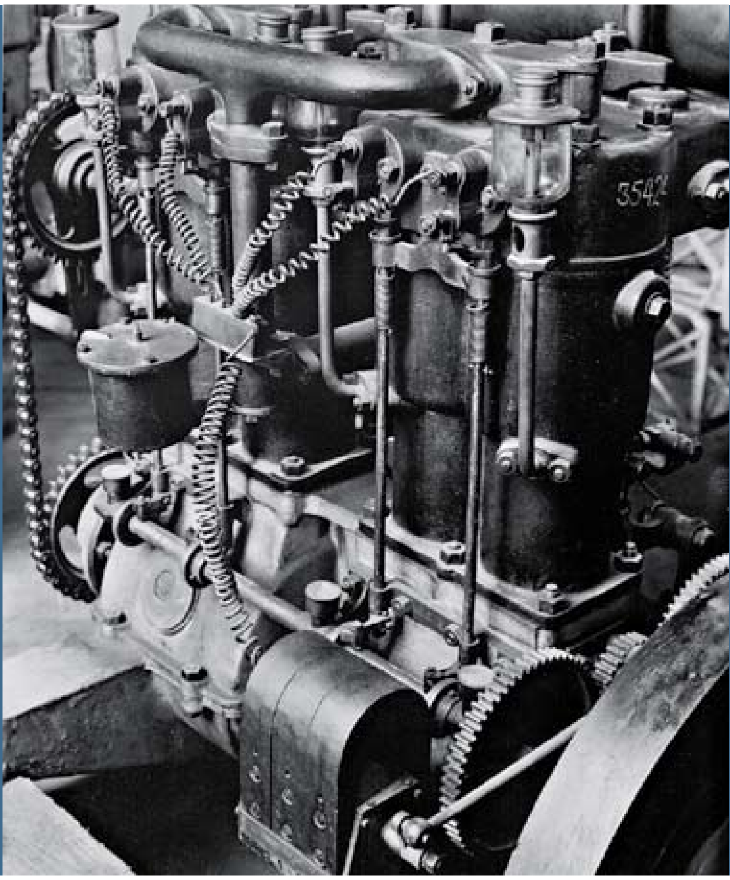
High voltage and spark plugs

In the summer of 1901, therefore, Robert Bosch gave his colleague Gottlob Honold the brief of designing a magneto ignition system without break-spark rodding. After just a few months, Honold presented his high-voltage magneto ignition system, based on what was known as electric arc ignition. By means of two coils on the armature, it generated a high-voltage current. This was conducted to a spark plug via a simple cable connection. The high-voltage current jumped the gap between its electrodes in the form of a spark.

A spark plug design with fixed electrodes had been around since about 1860. Carl Benz, for example, already used spark plugs for gasoline engines, but with little success. The materials used for both the insulation and the electrodes proved unsuitable. Honold developed a better ceramic for the insulating body and a heat-resisting alloy for the electrodes. This brought magneto ignition up to a technological standard that guaranteed it success.

The spark plug itself was in fact only a by-product that Bosch had to manufacture in order to be able to offer a complete system. Events took an interesting turn, though. While magneto ignition has long since disappeared, Bosch still manufactures spark plugs – more than 300 million each year.

Magneto ignition became established in automobiles even before the first world war. Thanks to modern manufacturing methods, such as assembly-line production from 1925 on, millions of these systems were manufactured to a high quality standard. Nonetheless, the automotive industry began to call for less expensive ignition systems. After all, around 1930, a magneto ignition for a mid-size automobile cost roughly 200 reichsmarks – twice the salary of a Bosch worker, and a tenth of the cost of a small car.



Spectacular application: the very first Zeppelin LZ1 airship in 1900 was equipped with a magneto ignition device from Bosch. It was the most reliable ignition device available, and did not pose a fire risk, unlike other systems.

Bottom:
Camille Jenatzy driving a Mercedes in the 1903 Gordon Bennett Race in Ireland. Jenatzy won the race using a Bosch ignition system, establishing its reputation for especially high quality.

Battery ignition offers a less expensive solution

This cost issue was why Bosch started refining battery ignition, which was a less expensive solution, as from 1920. Although ignition systems that worked with a current from batteries existed prior to 1900, the batteries of the time had little storage capacity and could not be recharged while the car was on the move. This ignition system was thus impracticable for everyday use. Magneto ignition systems, by contrast, worked independently of any source of current. They generated their voltage with the help of kinetic energy from the engine with which they were connected.

As from 1910, however, it became technically feasible to produce a battery ignition system that was suitable for everyday use. The electricity that was used up by ignition could be replaced by the generator (which Bosch began manufacturing in 1913) while the car was on the move. This allowed Bosch to meet customers' demands for cost-effective solutions. At first, the company mainly supplied battery ignition systems – comprising ignition coil, ignition distributor, spark plugs, and cables – for small and standard-sized cars. The ignition coil generated high-voltage current, and the distributor transferred this

Milestones

1887	1897	1902	1908	1910	1921
Low-voltage magneto ignition for stationary engines	Low-voltage magneto ignition for motor vehicle engines	High-voltage magneto ignition system with spark plug	Buzz ignition coil	Ignition distributor	Magneto-generator ignition unit

ignition energy via a cable to the spark plugs, whose electrodes produced the ignition spark. Electricity was supplied by the existing on-board network, with its generator and battery. One of the first cars to be equipped with this system as a standard feature was a four-cylinder passenger car made by the Berlin-based carmaker NAG (Nationale Automobil-Gesellschaft).

Battery ignition takes hold

At first, expensive sedans made by Horch or Maybach continued to feature magneto ignition systems, since the price of the ignition system was not so important in cars of this price category. By the middle of the 1930s, however, battery ignition had also finally established itself in this area. Indeed, as early as 1930, 36 out of 55 German car models had battery ignition. It was only in aviation that magneto ignition kept its prime role. Its independence of any source of current was the main argument in favor of this ignition system. Magneto ignition remained dominant until the end of the heyday of piston-driven aero-engines in the 1960s. It was not needed for jet engines.

Bottom left:
Internationally, Bosch ignition systems soon found favor with vehicle manufacturers, including Indian, the legendary U.S. maker of motorcycles (1921).

Bottom right:
The “Red Devil,” a stylized figure based on the racing driver Camille Jenatzy, was also used in advertisements linked with specific makes, in this case Ford (1917).

1925	1926	1932	1932	1964	1965
Battery ignition	Dynamo-battery ignition unit	Combined generator, starter, and ignition unit	Flywheel-triggered magneto-generator ignition unit	Breaker-triggered TI transistorized ignition	Breaker-triggered high-voltage CDI capacitor-discharge ignition

New ignition systems

Automotive ignition systems also continued to evolve. In the 1950s, the automobile business began to use semiconductor devices – the predecessors of today's electronic components – as standard equipment. In 1958, Bosch had installed its first electronic device in a product – a Variode regulator for a generator. Then, in 1964, ignition followed the trend – with transistors that allowed maintenance-free ignition. The main aim in all this was to make the periods between service stops longer and, in the long term, to have cars that could be driven 100,000 km without the need for a major service – with the exception of such indispensable things as oil changes, of course. The ball was now rolling, and the changing of ignition contacts was a thing of the past. At the same time, the foundation stone had been laid for the development of today's electronic ignition systems, which are not only maintenance-free, but whose precise management allows compliance with the strictest emissions standards and a significant reduction in fuel consumption.

Transistorized ignition was the first step in this direction, and was followed by a variant in which the mechanical contact was replaced by an electronic pulse generator, known as the Hall generator. From then on, there was no need for the ignition distributor contact, which was prone to wear. Today, the high voltage is commonly generated by individual coils, which transmit power directly to the spark plugs. But in all this, one thing has remained unchanged. Even today, no gasoline engine will run without the ignition spark that Bosch brought into the car.

1974	1979	1982	1983	1987	1989
Maintenance-free, breakerless TI-i transistorized ignition	Motronic (combination of L-Jetronic gasoline injection and electronic ignition)	Electronic map-controlled ignition	Electronic ignition with knock control	Electronic ignition with adaptive knock control	Motronic with 16-bit microprocessor

Far left:
The Junkers W 33 flown by Hünefeld, Köhl, and Fitzmaurice in the first East-West crossing of the Atlantic was equipped with the Bosch magneto ignition system (1928).

Left:
The Bosch spares kit with replacement spark plugs and ignition contacts was popular with all truck drivers (1955).

Bosch ignition systems

The beginnings
The principle of magneto ignition has been around since 1866. It was initially designed for stationary engines. Bosch first manufactured its own magneto ignition device in 1887. First use in the automobile in 1897.

Development history
Reliable, with a long service life, and suitable for universal use in all common engines, it was the standard automotive ignition system until c 1930. From 1925 on, it was displaced by more cost-efficient, battery-based systems. Today, battery ignition is still the basis for all automotive ignition systems.

How it works
The air-fuel mixture is ignited in the combustion chamber. The ignition spark was initially triggered by a break in an electric circuit, and then by a luminous spark discharge between two spark-plug electrodes under high voltage.

First use
Used on stationary engines from 1887, on a trial basis in a De Dion-Bouton three-wheeler in September 1897, and in small-series production for Daimler trucks (Phoenix) from 1898.

The present day
Today, ignition systems made by Bosch are an integral part of electronic engine management systems for gasoline engines. Called “Motronic,” these systems regulate injection and ignition by means of a single central control unit. This business unit is now part of the Gasoline Systems (GS) division.

1989	1996	1998	2001	2004	2007
Static high-voltage distribution	Motronic in micro-hybrid design	Cylinder-head module with complete integrated ignition	Rod coil	Mini Compact rod coil	Power Mini Compact rod coil

“Safe night-time driving at last!”
Bosch automotive lighting systems

Picture with the Bosch searchlight, used for advertising purposes (1925)

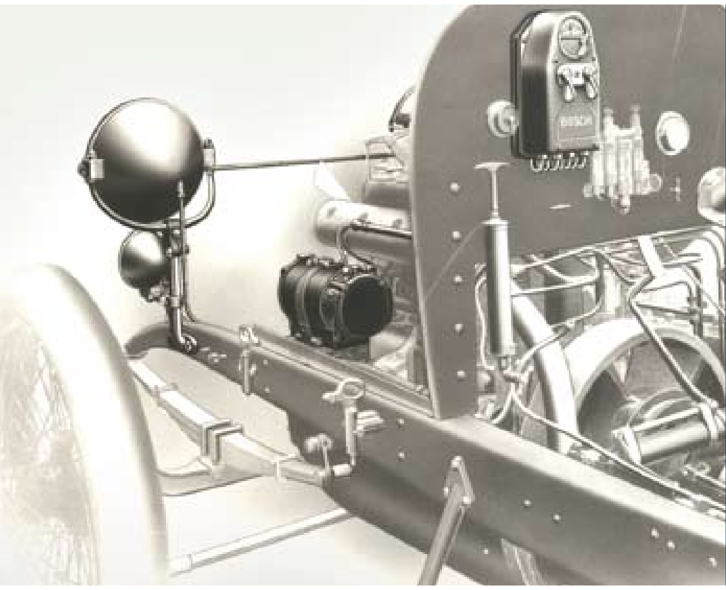
Up until 1913, Bosch manufactured practically nothing but ignition devices or systems. This focus on a single product was a very risky business strategy. At the same time, the automotive market was changing – the vehicles on the road were no longer simply luxury vehicles and sports cars, but also articles of everyday use. Robert Bosch recognized that the prospects for electrical automotive lighting were good. Development work started in 1910, and the Bosch automotive lighting system was ready for series production in 1913. The system comprised headlights, a generator, a battery, and a regulator. This lighting system paved the way for Bosch as a universal automotive supplier and formed the basis for today's vehicle electrical systems.

In 1912, the only products Bosch manufactured were magneto ignition systems, spark plugs, and Bosch oilers. By that time, the company's workforce already exceeded four thousand, and global sales were in the region of 33 million German marks. More than 83 percent of sales were generated outside Germany, a figure that rose to 88 percent just one year later. However, Robert Bosch was aware that such a narrow product base was not a healthy situation for a company of this size. Focusing solely on the main sales driver – magneto ignition systems – made the future unpredictable. If the automotive industry switched to diesel or electric drives, for example, magneto ignition systems would no longer be needed.

An urgent task

There were many good reasons to push ahead with the development of electrical automotive lighting for series production. First, motor vehicles were also widely used for commercial purposes after around 1910 and needed to be available at any time, day or night. Second, electrical lighting was already standard equipment in the U.S. – the world's largest automotive market. Third, regulations such as the requirement in Germany to equip all motor vehicles with two headlights from 1909 and similar laws in neighboring countries created the basis for a rapid spread of this technology in Europe as well. And fourth, the carbide and acetyl lighting common at the time was

Top from left to right: Milestones of an evolution. Bosch headlights on a fire truck (1919), on a Horch (1924), and on an Opel Olympia Rekord (1957)



The Bosch automotive lighting system comprised headlights, generator, battery, and regulator. It formed the basis for today's vehicle electrical systems.

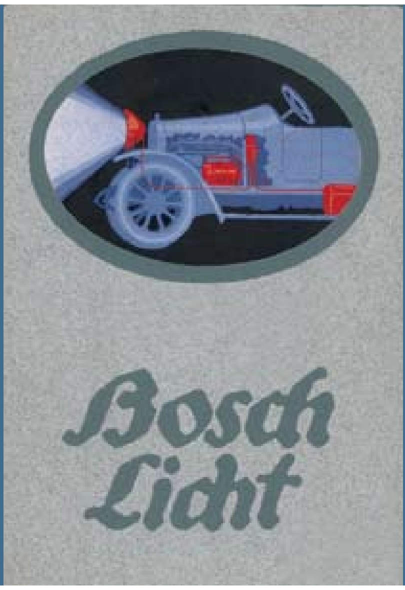
not really suitable for everyday use. Its light output was far inferior to electrical lighting. What's more, the driver had to use a complicated procedure to ignite and extinguish the light.

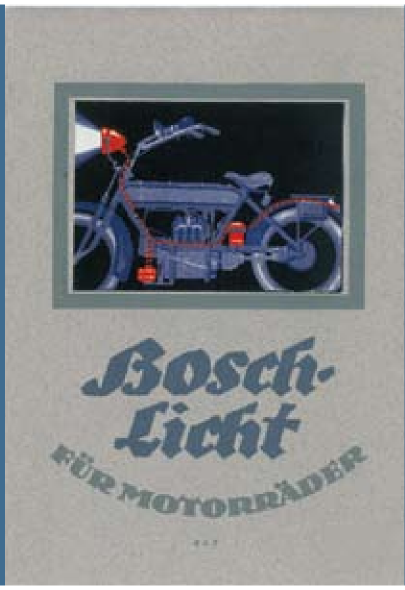
Bosch as a systems supplier

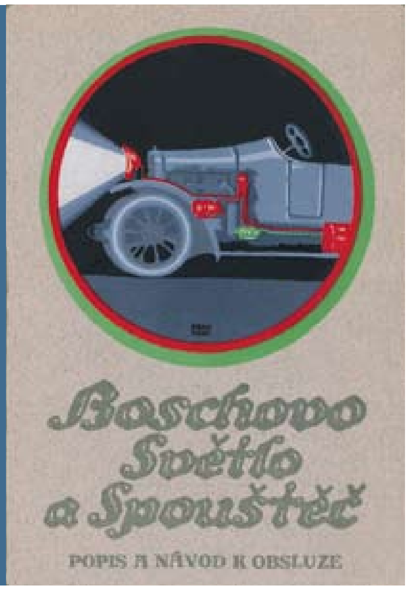
Electrical lighting needed a current, but this was something a battery could only supply for a limited period of time. Robert Bosch's idea was to use a generator to produce sufficient energy to provide a constant supply to the battery, where it was stored and transmitted to the headlights. The heart of the system was thus the generator for providing electric current. In the form of the alternator, this is still the basis of today's vehicle electrical systems. Bosch produced the headlights, generator, and regulator (then known as a "regulator box") in-house. At first, the battery was purchased from other manufacturers, but a switch was made to in-house production in 1922. The launch of the Bosch automotive lighting system was a milestone for Bosch. In the past, Bosch had offered individual components such as magneto ignition devices. The Bosch automotive lighting system, by contrast, was an all-in-one system that saved customers the irksome task of piecing together the parts they needed. Instead, they now got all they needed from a single source, and could be sure that all the parts were perfectly matched. It is

Milestones

1913	1930	1935	1935	1939	1952
Bosch automotive lighting system, comprising headlights, a generator, and a regulator	Fog lights	Long-range headlights	Fitted headlights	Headlight aiming device	Quartz vapor-coated headlight reflector







evidence of considerable foresight that this idea of producing systems – a concept essential to Bosch as an automotive supplier today – was already mapped out in 1913.

Completion of the range, innovations

After 1921, Bosch added products specifically for motorcycles to what was now an extremely successful range. From 1923, even bicycles were catered for. These products were followed in the 1930s by further special applications such as fog lights, long-range headlights, tail lights, and brake lights. Bosch became the world's leading manufacturer of vehicle lighting, introducing new developments that we take for granted today. Examples included low-beam headlights, which illuminated the road ahead without blinding oncoming traffic; fitted headlights that were perfectly integrated in the front of the car, both visually and aerodynamically; asymmetrical lighting, which illuminated the driver's side of the road more than the other side and thus reduced glare for oncoming traffic; halogen lights with a 50 percent higher light output than double-filament lamps; and finally Litronic for gaseous-discharge lamps, an electronically controlled system with increased light output, reduced energy consumption, and a longer service life.

Left to right:
Brochures for the Bosch automotive lighting system, with the advertising motifs designed by the Stuttgart-based artist Lucian Bernhard, underscore the early significance of business outside Germany for Bosch.

1957	1957	1966	1971	1986	1991
Low- and high-beam headlights, side-marker lights, parking lights, and turn signals in one unit	Headlights for asymmetrical low-beam light	Headlights with H1 halogen light	Headlights with H4 two-filament bulb	Polyellipsoid headlights	Litronic headlight system with gaseous-discharge lamp

Top:
Extensive tests in the light channel also helped Bosch to improve light output (1930).

End of a long era

In 1999, the Bosch Lighting Technology division was transferred to Automotive Lighting GmbH, a joint venture with the Italian company Magneti Marelli S.p.A. Bosch gradually scaled down its interest in this joint venture and was no longer involved at all by 2003. So what remains of the Bosch automotive lighting system introduced in 1913? The generator for one. Now in the form of an alternator, it is an integral part of the vehicle electrical system and is essential for the operation of electrical consumers ranging from airbag control to ignition systems. This is not all. Other Bosch products still ensure good visibility to this day. The infrared technology of the “Night Vision” driver assistance system, for example, enables drivers to see obstacles sooner than they would with conventional lights at night.

1993	1995	1996	1998
Headlights with homogeneous reflector surface	Headlights with variable light distribution	Dynamic headlight leveling control	Bi-Litronic for low- and high-beam headlights

Bosch automotive lighting systems

The beginnings
The Bosch automotive lighting system, comprising headlights, a generator, a regulator, and a battery. Marketed from 1913 on. It replaced the carbide and acetyl lighting that was commonly used up to that time, which required considerable maintenance and had a relatively weak output.

Development history
For everyday use, motor vehicles need reliable lighting. The electrical system developed by Bosch quickly became the most favored solution. To make vehicles more visible at night and in adverse weather conditions, Bosch developed tail lights, position lights, fog lights, and later even tailor-made lighting systems for all common vehicle models.

How it works
A filament bulb in a reflector housing illuminates the road, drawing its current from a battery. The battery is fed by a generator that receives dynamo-electric power when the crankshaft of the running engine turns. A regulator ensures an even supply of power to the battery.

First use
Developed from 1910 on; first use in production automobiles in 1913 and for motorcycles from 1921 on; bicycle lights from 1923 on.

The present day
Generators are now called alternators and are produced in their millions at a number of plants. Today, this product area belongs to the Bosch Starter Motors and Generators division (SG). The Bosch Lighting Technology division, which produced headlights and lamps, was gradually spun off between 2001 and 2003.

Bottom left:
Around 1950, integrated headlights were a sign of modernity. The Volkswagen Beetle shown here has all its status symbols at the front: fog lights and two supertone horns, all made by Bosch.

Bottom right:
The “Litronic” lighting system with gaseous-discharge lamps was available in the BMW 7 Series from 1991. Two-and-a-half times brighter than halogen light, and with a light color similar to daylight, it improved road safety by ensuring better illumination.

Well equipped, whatever the weather
Equipment for day-to-day driving

In 1900, Robert Bosch had a range of twelve different products for motor vehicles – all of them variants of the magneto ignition device. One hundred years later, this number had risen to more than 355,000 product variants. This diversity is a response to the increasing variety of different vehicle models, as well as to how customers expect modern vehicles to be equipped. Magneto ignition was the first step on the company's path to becoming an automotive supplier. However, it was not until 1913 and the Bosch automotive lighting system that a battery and a generator guaranteed a reliable supply of electricity. This was the basis for an on-board electrical system to which numerous other components – such as a starter, horn, windshield wipers, direction indicators, and a car heating system – could be connected.

After laying the foundation with magneto ignition and the Bosch automotive lighting system, Bosch went on to expand its expertise as an automotive supplier step by step. One particular example of this process is the electric starter, which became rapidly widespread in the U.S. after 1910, even being fitted as standard equipment in some cars. The starter with an overrunning clutch made by the U.S. manufacturer Rushmore was a very promising concept. Bosch bought the company, together with all rights to manufacture these starters, in 1914. It was determined to turn the impressive idea into a high-quality, reasonably priced product that could be produced in large volumes. Bosch subsequently also used other starter designs, but in the beginning its sole objective was to find the fastest way of entering this area of business. Electric starters made life considerably easier for motorists. Firstly, drivers were spared the strenuous task of cranking up the car. Secondly, after 1900 there was a significant rise in the number of people who wanted to drive their own car, but were not prepared to crank up the car themselves. Thirdly, when cranking up the car, there was a risk that the starter crank could fly back in the opposite direction. This was known as "crank kickback" and led to numerous fatal accidents. The electric starter, on the other hand, was initially activated at the press of a pedal and later at the touch of a button. This made it an innovation with a real future.

Left:
With this Mercedes 170, engineers tested automotive lighting, signaling equipment such as turn signals and direction indicators, and electric horns (1954).

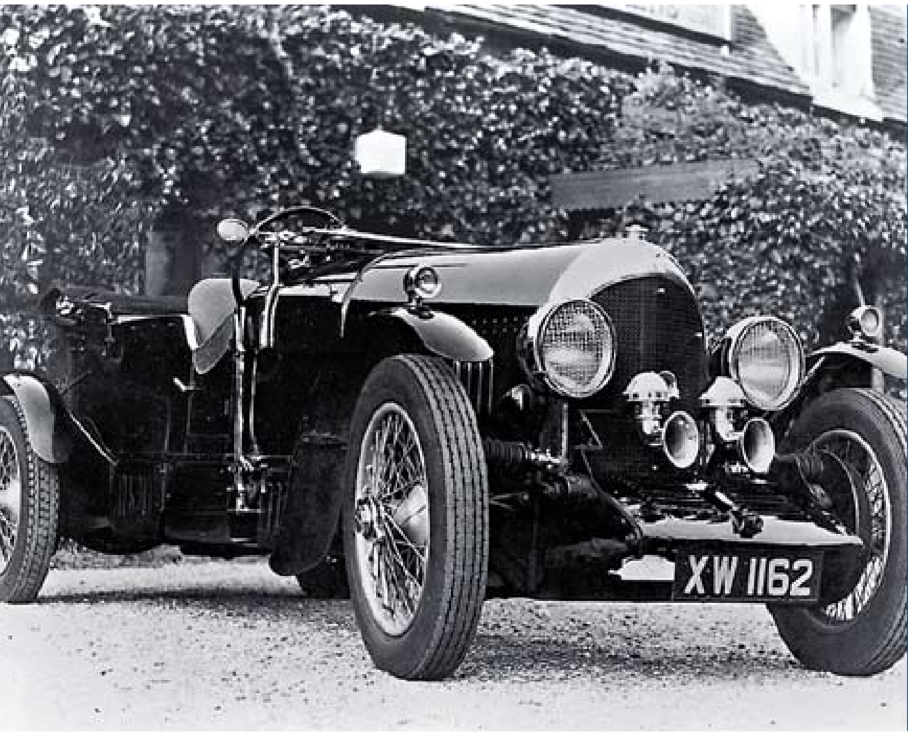
Motorization fuels demand

The starter has the features typical of many products brought to market by Bosch in the period between the first world war and the first crisis in the automobile industry in 1926. Their aim was to eliminate the shortcomings in operation and safety that were coming to light as motorization really took hold. Wherever these shortcomings became apparent, Robert Bosch looked for new ideas that he then optimized, or inventions were made in-house that were then developed until they were ready for series production. The manually operated rubber wiper, developed by Prince Heinrich of Prussia, became the electric windshield wiper, the electric horn replaced the rubber bulb horn, and car heating systems consigned the hand warmers and long johns resorted to in the winter to the history books. Finally, the direction indicator – or turn signals, as they have been known since 1949 – carried out the function previously performed by the driver‘s outstretched arm.

Many of these products – such as the horn, the windshield wiper, and the turn indicator – can be attributed to the work of Gottlob Honold, who also developed high-voltage magneto ignition. He was the company’s first head of development, setting up a department whose potential quickly became clear to Bosch. There are currently some 33,000 people working in research and development at Bosch, and this department was where it all started.

Diesel and gasoline engine management

In the era up until the 1920s, the automotive business sector was dominated by electrical components. However, Bosch



It was not only the manufacturers of stolid family sedans that favored Bosch. Exclusive carmakers such as Bentley and Bugatti also opted for the southwest German automotive supplier (c 1935).

also built up other new areas. Injection technology for gasoline and diesel engines was one of these, with components including an injection pump, a governor, and nozzles. Electronic control units and sensors were also made available for injection systems from the late 1960s on. These areas of activity are now critical to the company's operations. Today, Bosch has two divisions devoted to gasoline and diesel injection systems.

As early as 1909, Bosch had already mastered the basic technology for fuel metering with the Bosch oiler. This was a lubricating pump that enabled precise metering and distribution of lubricants under high pressure in stationary and large vehicle engines, and thus performed the very task called for in fuel injection technology. However, the road to diesel injection was a long and difficult one. Manufactured from 1927, it entered the market in 1928, albeit initially only for trucks. Diesel components for passenger cars followed in 1936.

Unlike diesel injection, gasoline injection was at first developed solely for use in aircraft. It did not serve the road vehicle market until after the second world war, when the advantages it offered in terms of consumption, efficiency, and emissions matched the new market requirements. By contrast, the production of carburetors in the early 1930s was a marginal episode in the history of Bosch, which it soon discontinued. Since the beginnings of automobile development, carburetors had been the dominant system for air-fuel mixture formation in gasoline engines (indeed, for a while, they were the only such system). Bosch, though, branched off in new directions. Specialists at the company recognized the potential of injection systems for automobiles long before they appeared on the market.

Networking functions and international development work

Bosch has always invested significant time in researching, developing, and testing all areas of automotive technology before taking products into series production. But a new dimension of development has come to the fore over the past three decades. Right from the very start, engineers now look into the possibility of networking functions. And rightly so, since today's complex electronic systems would be unthinkable without networking. Sensor

Top left:
In order to show other road users which way the driver wanted to go, Bosch developed the direction indicator in 1928. From 1949, it was displaced by the turn signal that is common today.

Top right:
This advertising motif from 1926 promises clear visibility with the new Bosch windshield wiper.

data – from the brake control system, for example – can now be utilized for the functions of other systems. The control system of the ESP® electronic stability program, for instance, can intervene in engine management and reduce engine power if the car shows signs of skidding. And as a further way of preventing hazardous situations, the brake system can utilize the radar data from the adaptive cruise control system. It can then either perform automatic emergency braking or, if impact is unavoidable, can protect occupants by activating the airbags faster.

As late as the 1960s, Bosch automotive technology was still developed exclusively in Germany. To a large extent, it was also produced there. This situation has changed fundamentally over the past five decades. Today, Bosch has manufacturing sites on all continents of the world. By comparison, the development of Bosch products in various countries outside Germany is relatively new. Developing products in this way enables components and complete systems to be developed to meet specific market and regional requirements. The engine management system for a premium-class vehicle in Europe, for example, must meet highest quality standards in terms of performance, comfort, and handling. An inexpensive compact car in India or China, on the other hand, calls for basic functions at low cost and robust components that can cope with widely varying qualities of fuel and long-term operation on bumpy roads. This, too, calls for state-of the art technology. It's just another way of looking at it.

A divisional structure emerges

The increasing complexity and variety of components is reflected in the ongoing development of the organizational structure of the units that develop, test, manufacture, and market them. In 1959, a divisional structure was introduced at Bosch. The divisions are responsible for certain

Milestones

1897	1902	1909	1913	1914	1921
Magneto ignition device for automobiles	High-voltage magneto ignition system with spark plug	Lubricating pump (oiler)	Headlights, voltage regulator, generator (Bosch automotive lighting system)	Starter	Horn

Far left:
With his half-helmet and goggles, this friendly motorcyclist extols the virtues of the Bosch battery (1960).

Left:
Bosch offers a whole range of products for unhampered driving in the winter and fall (1954).

product areas. While they have entrepreneurial independence, they work closely with the board of management. The Automotive Technology business sector comprises the following divisions:

Gasoline injection

The Gasoline Systems (GS) division develops, manufactures, and markets systems and components needed for gasoline engines, such as engine control units, fuel pumps for intake-manifold and direct injection, injection valves, sensors, ignition coils, and spark plugs. This division is also responsible for the development of hybrid drives, all-electric vehicle drive systems, and components for the control of automatic transmissions.

Diesel injection

The Diesel Systems (DS) division develops, manufactures, and markets systems and components for the management of diesel engines, such as engine control units, high-pressure pumps, high-pressure rails, and injection valves for common-rail diesel injection systems, as well as conventional in-line and distributor injection pumps. Over recent years, exhaust-gas treatment systems for both passenger cars and commercial vehicles have been added to the portfolio.

Brakes and chassis

The Chassis Systems Brakes (CB) and Chassis Systems Control (CC) divisions develop, manufacture, and market chassis components such as brakes and brake actuation and control systems. These range from the ABS antilock braking system to the ESP® electronic stability program, driver assistance systems based on radar and video, and passive safety systems such as airbag control units.

1922	1924	1925	1926	1926	1927
Battery	Auxiliary starting system	Battery ignition	Windshield wipers	Dynamo-battery ignition unit	Diesel injection pump, injection nozzle

Energy and comfort

The Electrical Drives (ED) division develops, manufactures, and markets products relating to body electrics and electronics. These include components required for wiping the windshield, for cooling the engine, for regulating the temperature in the vehicle interior, and for adjusting windows and seats.

Engine start and energy generation

The Starter Motors and Generators (SG) division develops, manufactures, and markets alternators as well as electric starters for vehicles of all sizes. These components generate the energy required for electrical consumers such as the lights or ignition system. The division's products also include start-stop systems, which reduce fuel consumption.

Car multimedia

The Car Multimedia (CM) division develops, manufactures, and markets entertainment, navigation, and driver information products as original equipment for cars, ranging from conventional car radios through to complex navigation systems.

Automotive electronics

The Automotive Electronics (AE) division develops, manufactures, and markets semiconductor products such as microchips and sensors, as well as entire electronic control units for systems developed by other divisions.

Products for the end customer

The Automotive Aftermarket (AA) division markets automotive engineering products to the trade and end customers. This is a single source where the car-parts trade and workshops can find everything they need for their customers. Bosch spare parts for every segment, testing equipment, and

1927	1927	1928	1928	1930	1930
Shock absorbers	Vacuum brakes	Brake support	Direction indicators	Fuel filter	Fog lights

From the 1930s on, Bosch published slim brochures listing the recommended Bosch components for common vehicle models. From 1952, the brochures were published in color, too. The examples shown here are brochures for the Opel Olympia Rekord, Peugeot 203, and Renault 4CV from the period 1952 to 1957.

know-how are available round the clock all over the world, for every make of car. Bosch Car Service workshops will service, diagnose faults in, and repair even the most modern vehicles. This division also manages the worldwide technical after-sales service for vehicle products and systems. The division therefore ensures that all common Bosch components can always be replaced, even if the cars for which they were made have not been built for many years now. In addition, the "Automotive Tradition" department provides vintage car owners with parts and expertise. The establishment of this department in 2005 underpins the company's commitment to conserving important vehicles from the past.

Past and present

In 1900, Bosch recorded sales of around 295,000 German marks, with its 12 magneto ignition models. For all the vehicle components sold in 2010, this figure was more than 27 billion euros.

Equipment for day-to-day driving – the early years

The beginnings

After the magneto ignition and the Bosch automotive lighting system, Bosch extended its range of products for everyday driving. New developments included the electric starter (1914), followed by the horn (1921), windshield wipers (1926), and direction indicators (1928). Bosch became a one-stop supplier for automotive electrics – and from 1927 on, for brakes and diesel injection as well.

Development history

After the first world war, automobiles increasingly became less of a luxury and more an everyday product. When it rained, the windshield had to be wiped, and when it was dark, the vehicle needed lights to make it visible and illuminate the road. A horn and indicators became essential for warning other road-users and indicating direction. Bosch responded to these market needs, and in so doing created further areas in which the company could do business.

How it works

All the first electrical products replaced mechanical forerunners. The electric horn replaced the bulb horn, the manually operated wiper gave way to windshield wipers, direction indicators were used instead of outstretched arms, and the starter did away with strenuous cranking-up. The aim of these products was to relieve the burden on drivers, so that they were distracted as little as possible from their primary task of driving.

First use

The first equipment used included accessories that could be installed in any vehicle. Initially, each product was mainly installed in luxury cars. The higher the production volumes, the cheaper and more common the products became. From about 1930 onward, all the standard car makes were fitted with direction indicators, a horn, a starter, and lights as standard equipment.

The present day

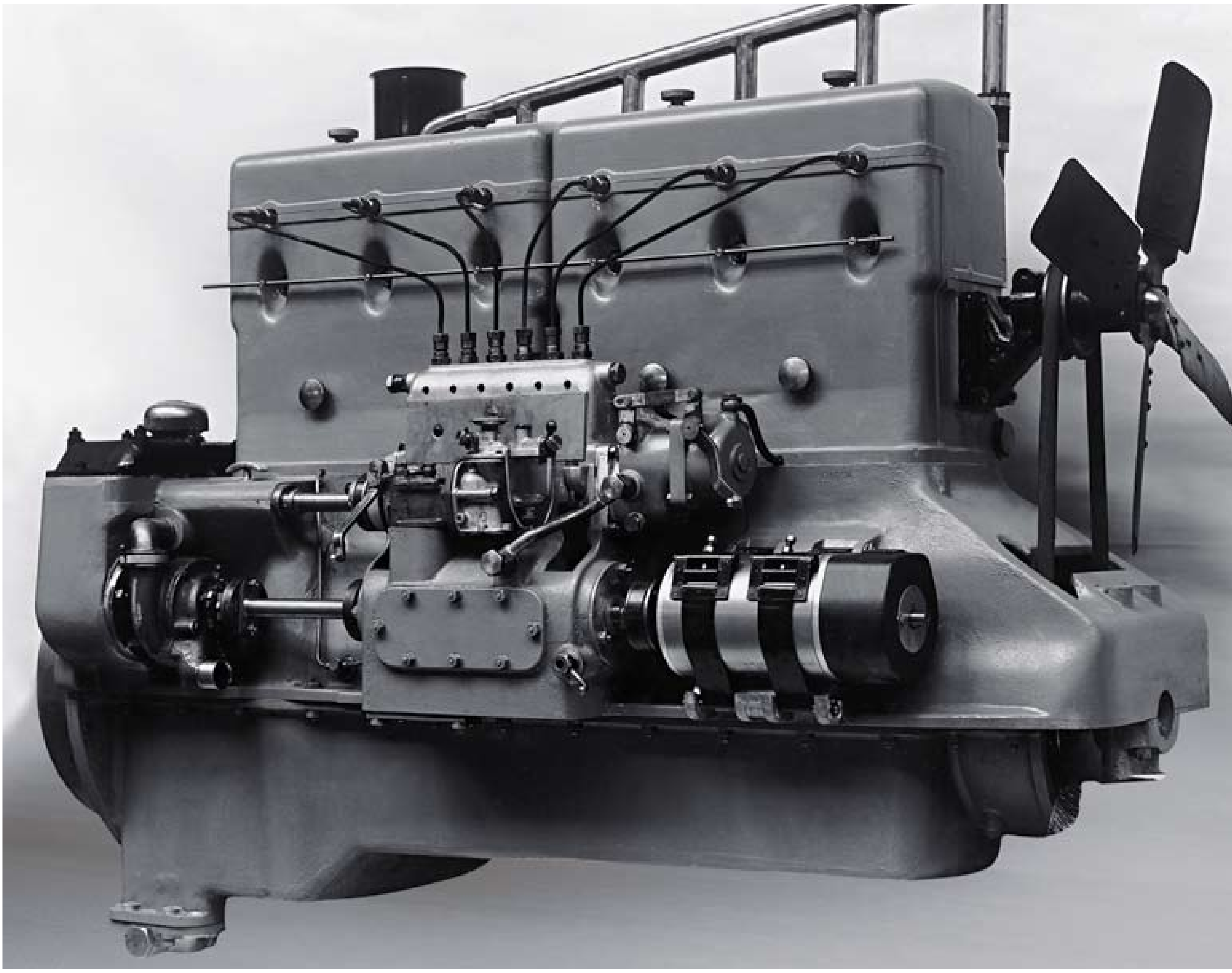
Several divisions now develop and manufacture electrical components and original equipment for new vehicles. These are also available to end customers, for example in the form of spare parts. Bosch today provides almost every automotive electric function, from power-window motors to airbag triggering units.

1931	1931	1932	1932	1933	1936
Steering wheels	Governor for diesel injection pumps	Combined generator, starter, and ignition unit	Car radio (Blaupunkt)	Steering lock	Car heating system

Bosch engine management – **not just for smooth operation**

A motor mechanic tests the ignition system of a Volkswagen Type 1 Beetle (1954). The EWAF41 engine testing device could be used to test all common electrical automotive systems and components. Apart from the ignition system, these included the alternator and the starter.


BOSCH
GERMANY
Elektro-
Tester



From heavy-oil pumps to multiple injection
Bosch diesel injection systems

In around 1920, experts were vaunting the diesel engine as the drive system of the future. Bosch was quick to latch on to this trend, and 1922 marked the official start of diesel injection pump development. Bosch started series production of in-line pumps for trucks on November 30, 1927. Production for passenger cars started in 1936. In the 1970s, Bosch solutions made the diesel engine a firm feature of the "Golf class." From the end of the 1990s, high-pressure injection systems such as common rail made the diesel into a high-performance, eco-friendly engine, as a result of which its market share in Europe rose to as much as 50 percent.

Left:
This six-cylinder truck engine from 1934 is an impressive sight. It is equipped with a Bosch fuel-injection pump.

Right:
The Bosch oiler, manufactured from 1909 on, was one of the technological pillars on which diesel injection was based. This brochure was published in 1914.

Robert Bosch first encountered the diesel engine as early as 1894. At the invitation of the inventor Rudolf Diesel, the young entrepreneur visited Augsburg to find out about this innovative engine design. However, the issue then was not yet one of injection systems. Instead, Rudolf Diesel was interested in Bosch magneto ignition, since the diesel engines of the time still needed an ignition system. They do not need any such system now, since in modern diesel engines the fuel ignites solely as a result of the high pressures and temperatures in the combustion chamber.

While the meeting with Rudolf Diesel came to nothing, the same cannot be said of Bosch's encounter with this new engine design. From 1920 on, Robert Bosch was forced to concede that diesel engines were so well developed that they presented a serious alternative to gasoline engines in vehicles. While they had lower specific power, they also consumed a lot less fuel – as much as 30 percent less. Robert Bosch feared for his main source of revenue – the magneto ignition system – since it was not needed in diesel engines. The time had come to develop components for this promising engine concept. Bosch had to be sure that the company was ready for this technological change and could benefit from the growth of the diesel market.

Green light for development

The official go-ahead for the development of diesel injection equipment was given in 1922. Bosch was able to benefit from its previous experience in the development of lubricating pumps. These pumps, also known as Bosch oilers, were capable of delivering precise quantities of fluid under high pressure to specific points in the engine – which is virtually what a fuel-injection pump does. Furthermore, the company pooled its own know-how with that of other diesel pioneers. Bosch acquired patents from Franz Lang, a development engineer who subsequently continued work on the new product on the company's behalf. However, disagreements led to his departure in 1926.

As early as 1924, initial trials with Bosch injection pumps took place in the first series-produced diesel trucks in Germany, and in 1926 Bosch delivered the first prototypes to interested customers in the automotive industry. The pump was ready for series production at the end of 1927. The production release for the first 1,000 units was issued on November 30, 1927, with the units being delivered to MAN, the first customer, early the following year. Other customers were quick to follow. In the 1930s, numerous European manufacturers equipped their trucks and agricultural

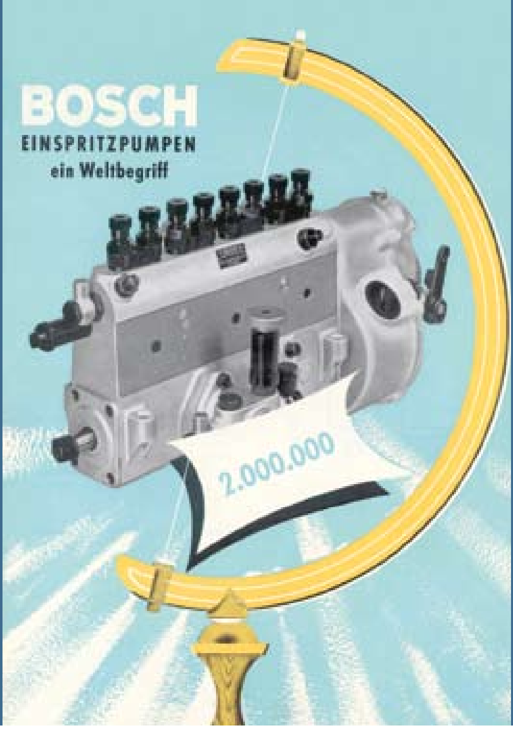
Right:
Sheet-metal advertising sign for diesel injection pumps for commercial vehicles, in a style common to the 1930s.

Far right:
Poster advertising diesel injection pumps, using the traditional advertising style for Bosch spark plugs (1949).

machinery with Bosch diesel injection systems. They included Alfa-Romeo, Asap (Skoda), Basse & Selve, Berliet, Bianchi, Borgward, Brossel Freres, Büssing, Citroën, Delahaye, Deuliewag, Fahr, FAMO, Faun, Gräf & Stift, Güldner, Hanomag, Henschel, Hürlimann, Isotta-Fraschini, Kaelble, Klöckner-Humboldt-Deutz, Krupp, Lanz, Mercedes-Benz, O.M. Brescia, Peugeot, Praga, Renault, Saurer, Scania-Vabis, Schlüter, Tatra, and Vomag. Many of these truck manufacturers had previously used designs of their own, but rapidly converted to the Bosch system. This quickly resulted in a strong market position, which is reflected in production volumes: some 100,000 fuel-injection pumps had already been produced by 1934.

Offering complete systems

For all these manufacturers, Bosch supplied a complete system, comprising injection pump, fuel lines, fuel-supply pump, fuel filter, injection nozzles, and nozzle-holder assemblies, as well as glow plugs for cold-start conditions. Because all these components were delivered from a single source, Bosch could rule out difficulties in getting the systems to work. All the products were carefully designed to work together. In 1931, a further innovation arrived in the shape of the diesel governor. This guaranteed optimum fuel metering in any driving mode – from idling to full throttle. The range of injection equipment grew both quickly and systematically. Not only trucks and tractors were equipped with



Advertisement celebrating the two-millionth Bosch diesel injection pump (1952). This is a very rare motif, since the diesel systems unit at Bosch traditionally supplied original equipment for new vehicles and therefore seldom advertised its own products.

Bottom left:
The Mercedes-Benz 260 D was the first car in the world to feature diesel injection as standard (1936).

Bottom right:
From 1960, Bosch supplied the first distributor injection pumps. The Peugeot 404 Diesel was the first car to feature this pump (1964).

Bosch diesel injection systems, but also diesel locomotives, ships, airships, and even airplanes.

Bosch was initially unable to enter the most lucrative product area of all – injection systems for passenger cars. Injection pumps were too large for this application, while smaller engines with smaller pumps would not have been powerful enough. But Bosch was also working in this area, and in 1927, unbeknown to the public, a sedan with a Stoewer engine converted to Bosch diesel technology clocked up more than 40,000 kilometers.

It was not until 1936, however, that the first manufacturers ventured onto the market. Mercedes-Benz presented its 260 D car and Hanomag a 1.9-liter diesel car engine, but it was 1938 before the latter was first installed, in the Hanomag Rekord. Before the second world war, however, diesel-powered passenger cars were not able to catch on. Car buyers were less interested in economy and more concerned with noise, vibration, and output – and these were the areas in which diesel cars still left much to be desired.

Milestones

1921	1922	1923	1927	1928	1930
Diesel injection trials using Bosch oilers	Official start of development for diesel injection technology	First prototypes of diesel injection pumps	Series manufacture of injection pumps and nozzles for commercial vehicles	1,000th diesel injection pump	10,000th diesel injection pump

The commercial success of the diesel engine in subcompact and compact cars dates from 1976, and the VW Golf Diesel. With its distributor injection pump, Bosch played a role in this success.

Market success and new areas of business

A further statistic demonstrates the spread of the diesel engine after 1945. By 1950, Bosch had manufactured one million units, and the trend showed no sign of slowing. At the same time, however, the traditional in-line pump was large and complex. For this reason, it was not really suitable for installation in small engines in inexpensive small cars. This was why Bosch also focused on distributor pumps from 1960 on. The company was helped by the expertise of French manufacturers such as Sigma, but developed these pumps further to satisfy its own requirements. The Peugeot 404 Diesel, the first car to feature a Bosch distributor pump, remained a one-off project since the pump still had a number of unresolved design problems. Moreover, there was still no broad customer base. Peugeot and Mercedes-Benz were the only companies manufacturing diesel cars in any great number. And both still displayed a preference for in-line pumps. When Volkswagen started showing an interest in small, economical diesel cars, however, the distributor pump's small size and low price brought it back into play once again. Bosch had never stopped working on improvements in the design, and had the VE type pump ready for series production in good time. The launch of the Golf Diesel in 1976 marked the start of a veritable boom in the number of diesel models in the compact class. Electronic control units were added to distributor pumps from 1986 and to

1931	1934	1936	1950	1960	1975
Introduction of injection pump governor	Pneumatic injection pump governor and 100,000th diesel injection pump	Diesel injection system for passenger cars	1,000,000th diesel injection pump	First VM distributor pump	VE distributor pump

Left to right:
A look inside the engine compartment of an Audi 100 TDI (1989). This model was the first diesel car in large-scale series production to feature high-pressure direct injection. As a result, the car reached a top speed of 195 kph, with an average fuel consumption of 6 liters per 100 km.

Common rail, the diesel system most frequently used today, was first installed in the Alfa Romeo 156 JTD (1997). It achieved uniform injection pressures of up to 1,350 bar. This technology enabled multiple injections.

A look inside the combustion chamber of a modern four-valve diesel engine (2008)

in-line pumps from 1987. These ECU's optimized emissions, noise, power, and consumption. Moreover, they enabled injection systems to be linked with other electronic systems, such as the traction control system (TCS), which stops the wheels spinning by intervening in engine management or in the brake control system.

Bosch used this success to further extend its competence in both systems – in-line and distributor pumps. In the case of distributor pumps, collaboration with Audi resulted in the first systems capable of injecting fuel directly into the combustion chamber at a pressure of almost 1,000 bar. In combination with turbo-charging, this made the diesel engines built from 1989 on more economical. The engines also produced less exhaust gas and helped vehicles achieve remarkable driving performance. High-pressure fuel injection marked the diesel engine's breakthrough in Europe.

Common rail and multiple injection

The high proportion of passenger cars equipped with diesel engines – around 30 percent in western Europe in 2000 – came about as a result of crucial further developments in high-pressure diesel-injection technology. Bosch offered a number of variants, including the radial-piston distributor pump (1996), the common-rail system (1997), and unit-injector technology (1998). They all achieved injection pressures of up to around 1,500 bar (and have even exceeded 2,200 bar in subsequent generations), and were thus characterized by both economy and performance.

Eventually, the common-rail system won through. The Fiat subsidiary Elasis was responsible for the basic idea, but Bosch refined the system to make it ready for series production. This system offered crucial advantages over the other two. Although the peak pressures of the common-rail system were lower than those of the unit-injector system (which could

1986	1989	1993	1995	1996	1997
EDC electronic diesel control system	VP 37 axial-piston distributor pump for direct injection in passenger-car engines	Control-sleeve fuel injection pump	Unit-pump system (UPS)	VP 44 radial-piston distributor pump	Common-rail system for passenger-car engines

achieve values of well over 2,000 bar and thus ensured very low consumption levels), the consistently high pressure at which the fuel is stored in the common rail for all cylinders enables multiple injection – up to eight injections in a single injection cycle. Common rail thus not only boosted the popularity of diesel engines among customers because of their quieter operation – it also offered the greatest potential for reducing emissions. Thanks to the success of the common-rail system in diesel engines, every second newly registered car in western Europe was a diesel by 2006. This made a significant contribution to reducing CO_2 emissions from cars.

In 1922, Robert Bosch himself gave the go-ahead for the development of diesel systems so as not to miss out on opportunities in the automotive sector. His instinct did not deceive him. Today, Diesel Systems generates more sales than any other division in the Automotive Technology business sector.

Bosch diesel injection systems

The beginnings
Rudolf Diesel presented the first diesel engine in 1893. From about 1920, truck manufacturers tested diesel engines with injection pumps. Bosch experimented with diesel injection pumps from 1921, and their development began officially in 1922. On November 30, 1927, approval was given for the first series production of 1,000 units.

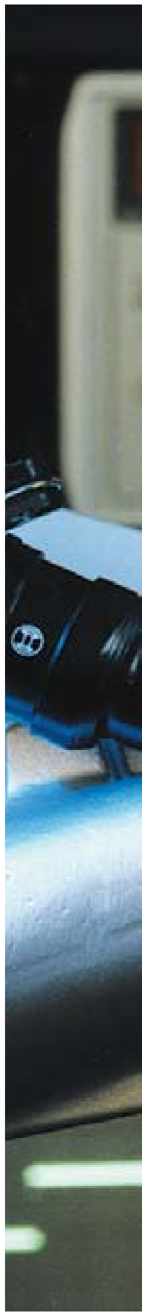
Development history
Up to around 1920, the gasoline engine dominated the motor vehicle industry. After that time, experts began debating whether the diesel engine would replace the gasoline engine due to its advantages in terms of torque and fuel consumption. Since magneto ignition, its main source of sales, was superfluous in the promising diesel engine, Bosch responded quickly and began development work. Bosch developed injection pumps and accessories such as governors, injection nozzles, nozzle-holder assemblies, and glow plugs.

How it works
Driven by the engine, the diesel injection pump introduces a precisely measured amount of fuel via a nozzle into the combustion chamber of each cylinder at the appropriate time. Due to high pressure and great heat alone, the fuel ignites in the cylinder and drives the piston. There is thus no need for a spark plug. Only for a cold start does the air-fuel mixture in the combustion chamber have to be heated by a glow plug.

First use
The first trials were performed with Mercedes and MAN trucks from 1924. There are records of initial trials with a Stoewer passenger car in 1927. The first customers for the series-produced injection equipment were Büssing, Klöckner-Humboldt-Deutz, MAN, Mercedes-Benz, and Saurer. First series application in a passenger car: Mercedes-Benz 260 D (1936) and Hanomag Rekord (1938).

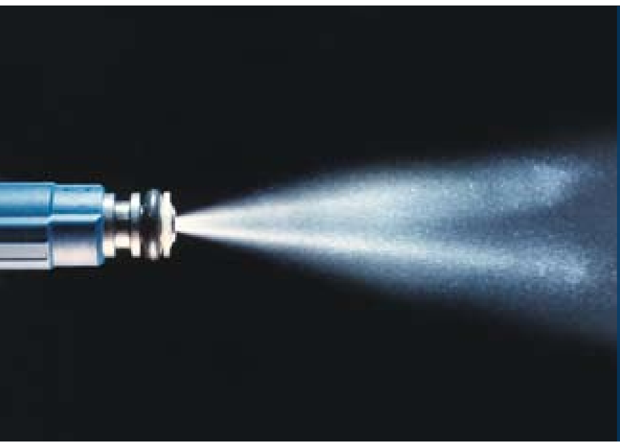
The present day
Diesel injection components are today products of the Bosch Diesel Systems (DS) division. Bosch develops, applies, manufactures, and markets diesel components and systems for virtually all diesel engines. Their use ranges from cars and trucks to ships and stationary machinery. Projections indicate that the diesel engine still has the potential to cut consumption by a further 30 percent, while also complying with the latest emission standards.

1998	1999	2004	2004	2009	2010
Unit-injector system (UIS) for passenger-car engines	Common-rail system for commercial-vehicle engines (CRSN)	Common-rail system with piezo injectors for passenger-car engines	Denoxtronic metering system for exhaust treatment in commercial vehicles	Denoxtronic metering system for exhaust treatment in passenger cars	Establishment of Bosch Emissions Systems GmbH & Co. KG



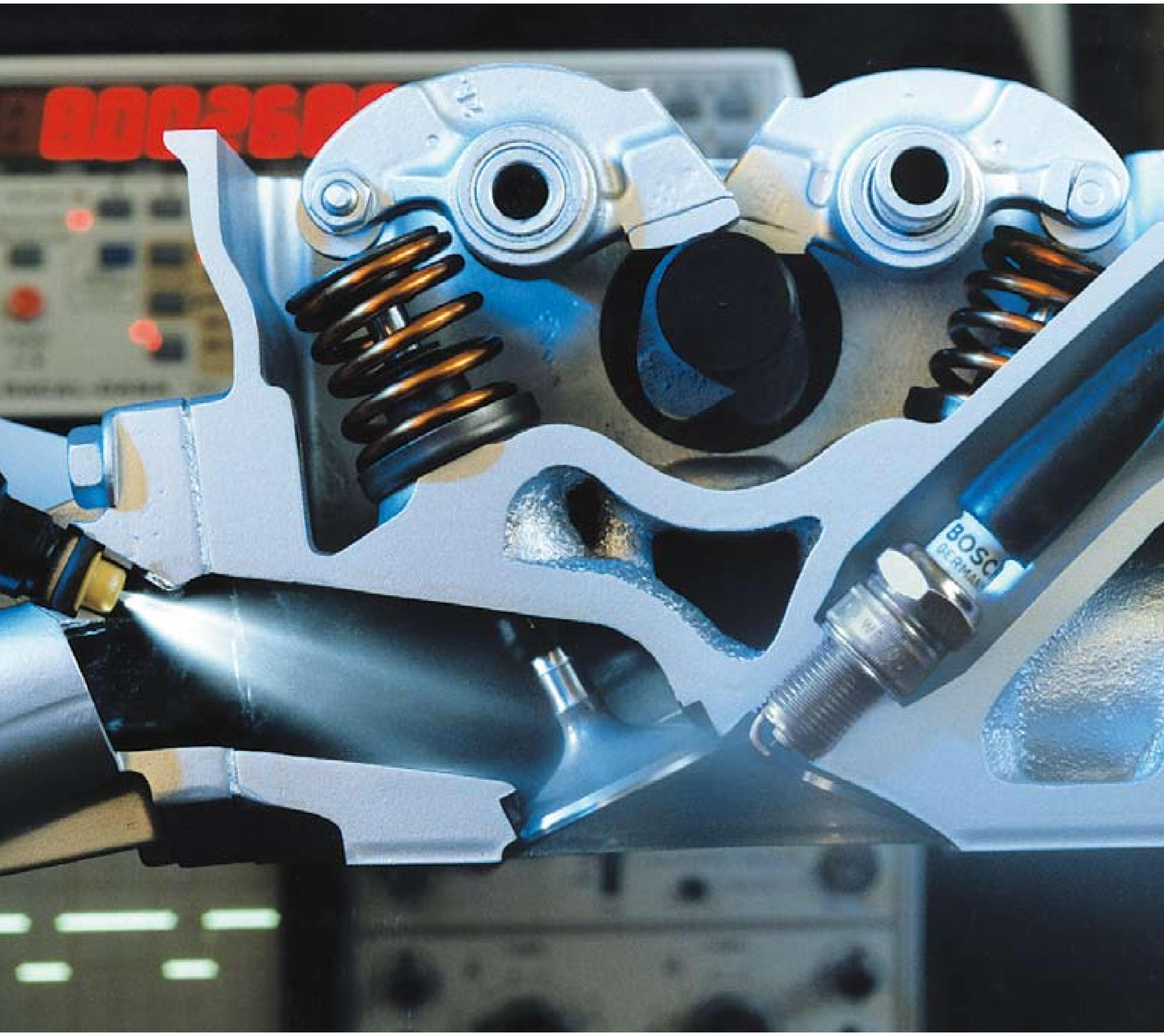
Not just a matter of horsepower
Bosch gasoline injection systems

As early as 1912, Bosch began experimenting with gasoline injection. From 1935, its safety and superior performance made it the obvious choice for aircraft engines, which until then had generally used carburetors. Gasoline injection was still too costly for cars, though, and the less expensive carburetors remained the standard solution for the time being. Series production of gasoline injection systems for motor vehicles was not possible until the 1950s, following further progress in their development. Gasoline injection's performance-boosting features were a point in its favor as far as motor-racing and high-performance sports cars were concerned. From the mid-1960s, however, its other strengths – lower consumption and reduced emissions – counted even more. Together with its successor models, the electronic "Jetronic" system launched by Bosch in 1967 made gasoline injection the dominant system in the market, completely displacing the carburetor. In conjunction with electronic control, gasoline injection in cars paved the way for the widespread installation of controlled three-way catalytic converters, which in turn made it possible to comply with the toughest environmental standards.



The jet from an injection nozzle for the Bosch DI-Motronic gasoline direct injection system (2005).

In 1912, researchers at Bosch began to take a closer look at gasoline injection. What they wanted to achieve was a precise metering of fuel to stationary and vehicle engines. By that time, the spark-ignition engine had already become the standard drive technology in motor vehicles. It had long been acknowledged that the steam drives favored around 1900 had no future for road traffic, and diesel engines had not progressed far enough in their development to be an option. The experiments with gasoline injection were not a focal point, though, and soon lost impetus. The com-



pany was more interested in developing new electrical components for the car, from the starter to the windshield wiper – components that were becoming indispensable for everyday driving.

Experiments, setbacks, and initial successes in the air

From 1921, Bosch engineers began testing an injection system for a gasoline turbine. The injection assembly was a modified Bosch oiler, which was normally used as a grease pump to keep lubricating points in the vehicle oiled. However, these experiments proved disappointing, and after a long series of unsuccessful tests they were provisionally discontinued in 1928. This was mainly because engine performance had not met expectations, and because there was not enough lubrication in the pump. Unlike diesel, gasoline had no lubricating effect, with the result that the pumps frequently broke down during operation. The same problem cropped up again in experiments after 1927, in which Bosch tried using gasoline in diesel injection pumps. Lubrication failed, and the pump plungers jammed.

A look inside a gasoline engine with manifold injection. Fuel is injected through the nozzle on the left. This is drawn in through the intake manifold and past the open valve into the combustion chamber. Here, the spark plug (on the right of the picture) ignites the air-fuel mixture (1988).

Advertising brochure for the Gutbrod Superior (1952). The first car to feature Bosch gasoline injection was 20 percent more economical than its carburetor version.

Gasoline injection's opportunity finally arrived with the demands of aviation. The commonly used carburetors were in danger of icing up at altitude, of overflowing during banking, and even of catching fire in unfavorable circumstances. Gasoline injection, by contrast, ensured greater reliability, as well as more power. Correspondingly, it became increasingly established from the mid-1930s on. The first trials with BMW and Daimler-Benz engines took place in 1932, and the first 8-, 9-, and 12-cylinder pumps went into series production from 1937.

Start of series production for cars

After the second world war, the Allied authorities in Germany banned any further development of such systems for aircraft engines. It was for this reason that developers now took a second look at gasoline injection for passenger cars, and this time their efforts were successful. While the quest for reliability and power had driven its development in aircraft engine design, in the case of cars Bosch engineers were above all motivated by the economies gasoline injection offered. The design-related scavenging losses of as much as 20 percent of the fuel had long been an annoying defect in standard two-stroke engines. With its precise fuel metering, the Bosch gasoline direct injection system for cars – presented in a two-stroke Gutbrod Superior 600 at the 1951 Frankfurt Auto Show – used up to 20 percent less gasoline and increased the output of the vehicle from 22 to 27 horsepower. In the same year, Goliath equipped its GP 700 with this system.

Bosch, however, was focusing increasingly on solutions for the four-stroke engines that were to become dominant. From the 1950s on, this engine design, which is standard today, began to oust the simple two-stroke engine. Engine performance was the main selling point of the gull-winged Mercedes-Benz 300 SL, the first series-produced four-stroke vehicle with gasoline injection. An indirect injection system for large-series six-cylinder engines from Mercedes-Benz was launched as an alternative to expensive

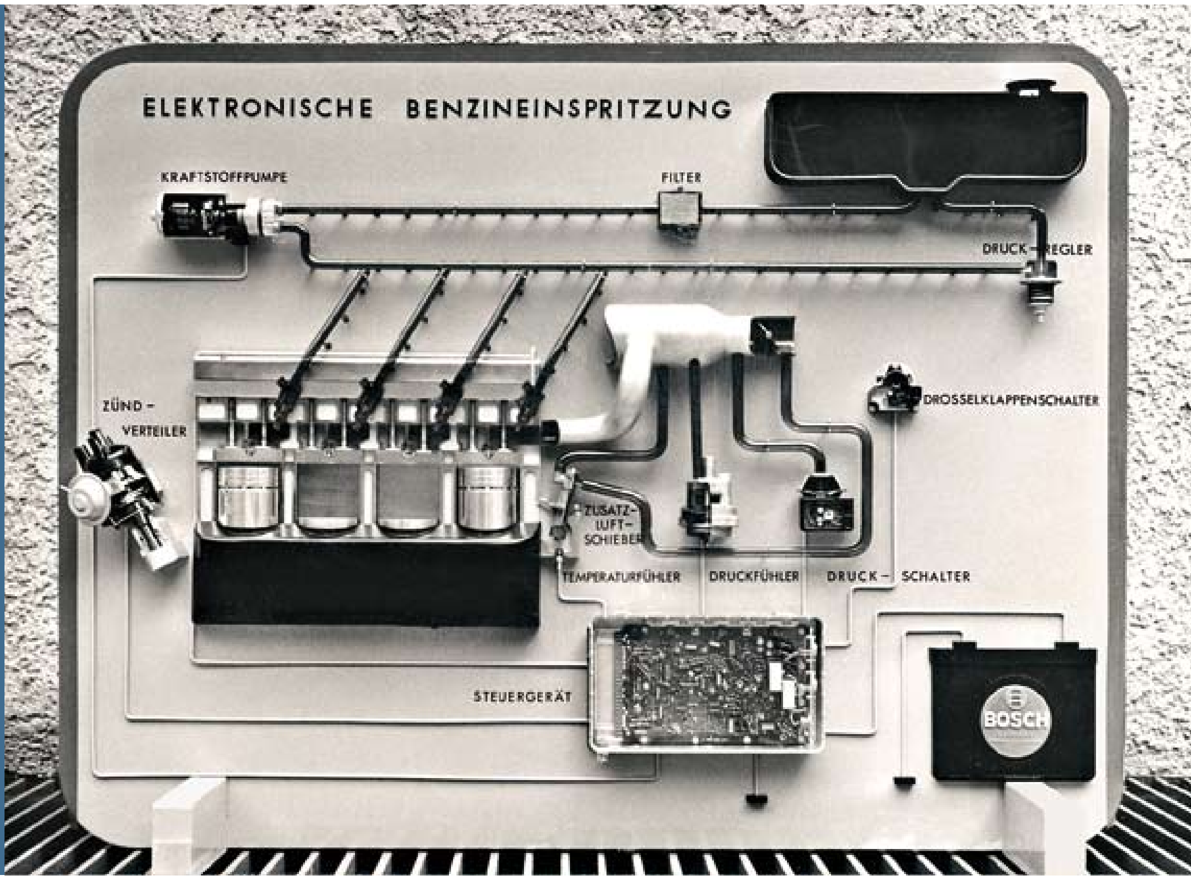
direct fuel injection in 1957. Instead of gasoline being injected directly into the combustion chamber, as was the case with its predecessors, it was injected into the intake manifold upstream of the intake valves, where the air required for formation of the air-fuel mixture was drawn in. Injecting gasoline into the intake manifold allowed a consistently good mix to be created. While the increase in power was less dramatic than in the case of direct fuel injection, the system still had the advantage of lower fuel consumption, as well as needing less maintenance than the carburetor. That same year, Bosch launched another variant that cut the cost of the system considerably. Two smaller metering pumps each supplying three cylinders replaced the one large in-line pump for six cylinders. This development paved the way for gasoline injection to move from the luxury segment into midsize cars. The system was first installed in the Mercedes-Benz 220 SE.

Electronic versus mechanical systems

At first, sales of gasoline injection systems were hampered by their relatively high price. The key breakthrough was only made from 1967 on as a result of tougher legislation on emissions when the "Clean Air Act" was passed in the state of California. Only with electronic gasoline injection were many models able to comply with these emission standards. The expertise Bosch had gained in electronics gave it a decisive boost. As early as 1959, tests had begun on converted vehicles, and the first systems were practically ready for series production by 1965. The concept that Bosch presented in 1967 was a promising one. The electronic D-Jetronic paved the way for electronic open-loop and closed-loop control systems to become established in the automotive industry. For example, the Volkswagen 1600 E – launched in the U.S. in 1967 – was only able to comply with the new U.S. emission standards thanks to the Bosch Jetronic system. It is hardly surprising that manufacturers such as BMW, Citroën, Mercedes-Benz, Opel, Porsche, Renault,

Gull-winged Mercedes-Benz 300 SL with Bosch gasoline injection (1955). It was the first car with a four-stroke engine to be equipped with gasoline injection in large-scale series production. The focus was on output: 215 horsepower compared with the 115 to 160 achieved by the Mercedes-Benz Type 300 sedans of that period.

Schematic diagram of the "Jetronic" electronic gasoline injection system with original Bosch components (1967). This diagram was displayed at international motor shows.



Saab, and Volvo had already turned to D-Jetronic by 1972, and that this contributed to the system's success – first in the U.S., and then in Europe.

D-Jetronic was suitable for all passenger-cars equipped with a gasoline engine. For automakers who preferred mechanical systems, and who still had their misgivings about electronics despite their reliable operation, Bosch launched K-Jetronic, which featured a continuous fuel supply, in 1973. For customers who preferred electronic engine management, L-Jetronic – the successor to D-Jetronic and also available from 1973 on – was the right choice. In contrast to the pressure-controlled D-Jetronic, L-Jetronic gauged precisely the right amount of fuel by measuring the volume of air drawn into the intake manifold of the engine. These electronic injection systems had one remarkable side-effect in that they were maintenance-free over the entire service life of the vehicle. This marked the end of the irksome adjustment work that was so common for the carburetors used up to that time.

In 1981, these two systems were succeeded by the modified KE and LH Jetronic designs. Both systems were electronically controlled and were able, in conjunction with the lambda sensor, to supply an optimum air-fuel mix for operation with three-way catalytic converters.

Milestones

1912	1927	1932	1937	1951	1954
First gasoline injection trials using Bosch oilers	Field trials with gasoline in diesel injection pumps	Experiments with gasoline injection systems for aircraft engines	Delivery of gasoline injection pumps for aircraft engines	Gasoline injection systems as standard equipment in passenger cars (two-stroke engines)	Gasoline direct-injection systems as standard equipment (four-stroke engines)

Lambda sensor and integrated engine management

The lambda sensor, launched by Bosch as a world first in 1976 (after seven years of research), allowed operation of a controlled three-way catalytic converter. In the long run, this was the only way to satisfy the most stringent emission standards. Even in 1976, catalytic cleansing allowed pollutant emissions to be reduced by almost 90 percent. Volvo, the first manufacturer to use lambda technology, was to display the lambda symbol on its vehicles' radiator grilles for many years. None of this would have been possible without electronic gasoline injection. Only in the 1980s was it also possible, though expensive, to use catalytic systems in vehicles equipped with carburetors.

Three years after the market launch of the lambda sensor, Bosch presented another world first that decisively improved gasoline injection and has since been adopted by most automakers: Motronic, a combination of ignition and injection featuring integrated electronic management of the two functions. It led to further optimization of consumption, performance, and emissions, and resulted in even quieter, smoother operation. By processing all the available data, such as engine temperature and operating status, the control system enabled synchronized control of injection and ignition. Improvements to these systems reached new heights in the 1980s. Injection and ignition were linked electronically with chassis systems, such as the traction control system (TCS) that prevents wheel spin.

Bottom left:
The Volkswagen VW 1600 LE was the first model in large-scale series production to feature "Jetronic" electronic injection. In 1968, the first model year (available from late summer 1967), the LE was initially only on sale in the U.S. It was also available in Europe from 1969.

Bottom right:
Under its long hood, the DS 21 injection, Citroën's "Goddess," featured Bosch technology. Jetronic increased its output and reduced consumption (1971).

1967	1973	1976	1979	1981	1983
D-Jetronic electronically controlled gasoline injection system	K-Jetronic and L-Jetronic gasoline injection	Lambda closed-loop regulation allows three-way catalytic converters to be used	Motronic: Jetronic and fully electronic ignition in one control unit	LH-Jetronic, improved L-Jetronic with hot-wire air mass meter	KE-Jetronic and Mono-Jetronic central injection unit

This system required an intervention in the Motronic system to reduce engine speed until wheel spin ceased – something that would be inconceivable without electronic control of injection and ignition. To ensure that these increasingly complex controls worked properly, Bosch introduced additional self-diagnosis functions from 1987 on. These were capable of recognizing and correcting malfunctions.

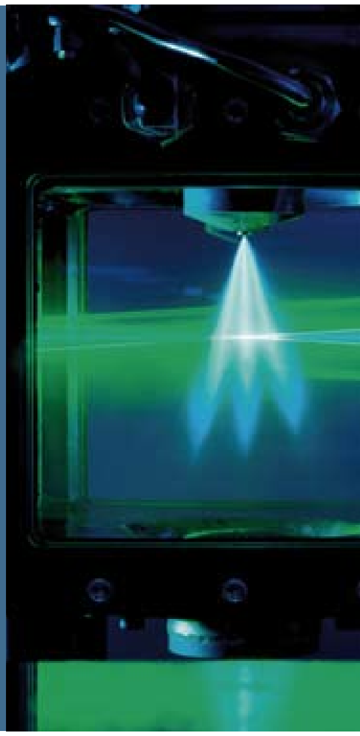
Direct injection, stratified fuel charge, and downsizing

In 2000, Bosch returned to an idea that had caused a stir when it featured in the Mercedes-Benz 300 SL of 1954: direct injection. The innovative thing about the "DI-Motronic" at the time was its stratified fuel charge. This process involved the burning of a small amount of rich air-fuel mixture close to the spark plug, which in turn allowed the burning of a lean mixture in the rest of the combustion chamber and a subsequent reduction of fuel consumption by as much as 10 percent.

Downsizing is another way of reducing fuel consumption. In this case, the engine displacement or the number of cylinders is reduced while a turbocharger increases power. A combination of variable valve control, turbocharging, and gasoline direct injection reduces fuel consumption considerably while the engine's power and torque remain the same. In conjunction with further measures, such as the start-stop system, fuel consumption can be reduced by as much as 30 percent as compared to conventional engines.

Left:
Testing "Motronic" at the Automotive Engineering Center in Schwieberdingen, near Stuttgart (1984). In 1979, the Motronic installed in the BMW 732i was the first system to manage injection and ignition from a single control unit.

Right:
A laser process enables the injection jet to be measured precisely. Optimizing the injection valve in this way lowers consumption, increases output, cuts emissions, and results in smoother operation (2005).



1987	1991	1995	2000	2001	2005
On-board diagnosis for exhaust-gas monitoring	Motronic with CAN bus	Motronic with "electronic gas pedal" (EGAS)	Motronic and injection components for gasoline direct injection (GDI)	Motronic with 32-bit microprocessor	Electro-hydraulic transmission control module

Today, Bosch gasoline injection systems are manufactured in various markets to meet specific local requirements. One particular example is the provision of systems for low-price vehicles in Asia's emerging markets. Bosch gasoline injection technology developed in the Indian city of Bangalore can be found in India's Tata Nano, for instance – the cheapest automobile in the world. This technology is pared down to the absolutely essential functions and therefore keeps costs down while still complying with the most stringent emission and consumption criteria.

Carburetors in cars have been consigned to history, and they are now scarcely found in cars. Today, electronic engine management systems made by Bosch and other manufacturers are fitted as standard in gasoline engines worldwide. This success can be attributed to the fuel savings, lower emissions, and improved performance and handling brought about by these systems. With hindsight, however, it is safe to say that – as is so often the case with innovations – the road to success never runs quite as smoothly as one might think. The inventive spirit of engineers is frequently inspired by quite different motivations. For example, the idea for gasoline injection did not come about in the search for a solution to cut fuel consumption, reduce pollutant emissions, or improve performance. Some 80 years ago now, engineers were more concerned with finding a solution to prevent aircraft carburetors from icing up. And that was where the seed for future solutions was sown.

2006	2008
Direct injection with piezo injectors	Bosch Mahle Turbo Systems joint venture set up

Bosch gasoline injection systems

The beginnings
First experiments in 1912. First series application in 1937 in aircraft engines, where they were successful because of superior performance and safety in all flying situations. First series application in cars in 1951, when they were manufactured in small numbers for two-stroke engines. Produced in small numbers for four-stroke engines from 1954, with production rising from 1958.

Development history
Development of gasoline injection for passenger cars began in 1949. Up to that time, the air-fuel mixture was predominantly prepared by a carburetor. As two-stroke vehicles were not a commercial success, nor were the injection systems developed for them. 1954 saw the start of series production of injection systems for four-stroke engines following their first use in racing cars from 1953 on. High cost meant only premium vehicles were equipped with injection systems at first. With the advent of electronics from 1967 on, they were also installed in midsize and compact vehicles.

How it works
Preparation of an air-fuel mixture that is drawn into the combustion chamber and caused to explode by the ignition spark. In direct injection systems, gasoline is not mixed with air until it reaches the combustion chamber. The electronic control systems introduced from 1967 on allow the air-fuel mixture to be varied in its richness depending on driving situation and engine temperature, thus optimizing performance, consumption, and engine operation.

First use
In trials with gasoline-driven turbines (1921) and trucks (1927), in NSU starter engines (1928), first experiments in aircraft engines (1932), series deployment in aircraft engines (1937), series deployment in the Gutbrod Superior (1951) and Mercedes-Benz 300 SL (1954) passenger cars.

The present day
Bosch gasoline systems are an integral part of electronic engine management systems for gasoline engines. Called Motronic, these systems regulate injection operations and ignition by means of a single central control unit. They have displaced the traditional carburetor. Nearly every modern car with a spark-ignition engine has gasoline injection.

A future for electric vehicles
Alternative drive systems from Bosch

Bosch is not just a leading supplier of diesel and gasoline injection systems. For over four decades, the company has been researching electric drives for road vehicles and, since 2010, it has been supplying solutions for hybrid systems, which combine an internal-combustion engine with an electric motor. The internal-combustion engine will remain the predominant technology in cars for private transport for many years to come. Nonetheless, engineers at Bosch are working to make sure that mobility also remains affordable when the electric drive displaces gasoline or diesel engines in cars in the future.

With the exception of idyllic islands where internal-combustion engines are banned, electric cars have not yet become a common sight on our roads. But this situation is set to change in the decades ahead as the rapid pace of motorization, particularly in the fast-growing economies of Asia, makes the search for alternatives a must. Any new concepts must take environmental impact into account, as well as the limited supply of crude oil. The internal-combustion engine is currently still the most cost-effective solution in the market, and Bosch engineers are working on improving it further still. But they are also working in parallel on making the vision of electric driving a reality. They are focusing on three main areas. First, on developing and manufacturing high-performance lithium-ion batteries. For this purpose, Bosch has set up the SB LiMotive joint venture together with the Korean manufacturer Samsung SDI. Second, on improving the power electronic components. These components are the link between the battery and electric motor, and convert the battery's DC voltage into the AC voltage required by the electric motor. And third, on pushing forward with the development of the electric motor itself, a key area in which Bosch has accumulated almost 100 years of expertise.

A record-breaking start

The history of hybrid and electric drives at Bosch starts in the 1960s, with research into all-electric drives. The first prototypes equipped with a Bosch electric drive were already being driven in 1967. On May 17, 1971, test drives in an Opel GT sports coupé on the Hockenheim Ring racetrack in Germany demonstrated the potential of the electric drive. The driver Georg von Opel immediately broke several acceleration world records. Technicians at the Schwieberdingen location near Stuttgart had developed the sports car's power electronics and the two DC motors, each with an output of 44 kilowatts. The first large-scale trial with electric, zero-emission buses kicked off in Mönchengladbach as early as 1974.

Widely acclaimed prototype

In the case of hybrid drive – that is to say, the combination of an internal-combustion engine and an electric motor – the start of activities was marked by a research vehicle based on a Ford Escort station wagon. It was equipped with a series-produced gasoline engine and an electric motor that powered the vehicle up to speeds of 30 kilometers an hour. The alternator of the gasoline

Left:
Cockpit of the Ford Escort Hybrid. The production vehicle was converted by Bosch engineers in 1973. The first prototype of a hybrid automobile combining a gasoline engine with an electric motor, it made a great impression on the trade press. It could drive at a speed of up to 30 kph on electric power alone.

Left:
Since 2010, Bosch has been supplying hybrid drives to several automakers. They differ from other concepts in being designed for conventional vehicles with gasoline or diesel engines. The picture shows a quality test on hybrid components.

Right:
The BMW 1602 Elektro. This car was used to accompany long-distance races during the 1972 Munich Olympics. To protect the athletes from harmful emissions, BMW converted the vehicle to an electric drive. The 144-volt direct-current motor from Bosch had an output rating of 32 kW and enabled the car to reach speeds of up to 100 kph.

engine recharged the batteries. A concept familiar from hybrid drives today – recovering braking energy to charge the batteries – was not yet integrated in the system. This process – known as recuperation – had, however, formed part of research activities at Bosch since 1966. The technology was first applied in the summer of 1979, in a large-scale trial for hybrid buses featuring combined diesel and electric drives.

Renaissance and breakthrough

Today, nearly four decades after Bosch unveiled the first prototype, more and more automakers are looking to produce vehicles with hybrid drives. In view of the growing environmental awareness among customers, strict emissions legislation, and dwindling raw materials, the spotlight is being trained with ever greater intensity on alternatives to the traditional internal-combustion engine. The hybrid will, however, be a transitional technology en route to an all-electric car. The question as to when the breakthrough of the all-electric drive will come is inextricably linked with the further development of battery technology. At present, the costs still far outweigh the benefits.

Future prospects

Hybrid projects with automotive customers are one pillar of the company's activities for alternative drives. The first models made by Volkswagen and Porsche are already in series production. They feature a world first – the "parallel strong hybrid." In addition to enabling all-electric operation, this Bosch development with very sophisticated control technology is also less complicated than "power split" technology, which relies on several electric motors and is the solution favored in Japan and the U.S. For the customer, this means lower fuel consumption and lower emissions than with conventional models. This is because, in this hybrid model, most of the energy used for all-electric driving over short distances is recuperated during braking. On the other hand, for customers who still need to drive longer distances, this hybrid is still equipped with a regular internal-combustion engine.

Milestones

1967	1971	1973	1974	1988	1998
Presentation of research on electric automotive drives	Opel GT equipped with Bosch electric motors and power electronics breaks world records	Hybrid prototype based on a Ford Escort is unveiled	Large-scale trials featuring all-electric urban buses in Mönchengladbach	Field test with 30 VW Golf hybrid cars, equipped with Bosch technology	Electronic components developed for Volkswagen's "City Stromer" test vehicle

One further concept for hybrid drive is the “plug-in hybrid.” To enable all-electric, and thus emission-free driving over long distances, these hybrid vehicles are equipped with a more powerful lithium-ion battery and a charger. This charger allows the vehicle to be recharged at a power outlet – hence the name “plug-in hybrid.”

The second pillar of the company’s activities in this area is all-electric drives, which in the long term will gain in significance, particularly in the world’s fast-growing megacities. To cut pollution from traffic emissions in these metropolises, Bosch is also working on concepts to drive vehicles on electrical power alone. Projects include an all-electric car in which the battery is charged from a socket and an electric vehicle with range extender – a small internal-combustion engine for generating and supplying electrical power that is activated on the move when the battery is running low.

Alternative drive systems

The beginnings
Bosch started conducting trials with electric vehicles in the 1960s. They were intended to serve as test vehicles for urban areas. In addition to cars, developers at Bosch focused on commercial vehicles such as emission-free electric buses for local public transport.

Development history
Internal-combustion engines (diesel and gasoline) are still the dominant and most cost-effective drive systems, and will remain so over the next few years. Despite significant growth, hybrid vehicles remain a niche market and electric vehicles are still too expensive given current battery costs. Nonetheless, Bosch is continuing its development work in both areas to ensure its technological leadership when electric or hybrid drives make their breakthrough.

First use
Bosch presented the results of its research on electric automotive drive systems at the 1967 automotive press briefing, an annual event for journalists in this field. Initial test vehicles with all-electric drives – in buses for Mönchengladbach’s public transport network – were unveiled in 1974. One year prior to this, Bosch presented its first hybrid test vehicle, a Ford Escort with a 40-kilowatt gasoline engine and a DC electric motor with a peak output of 32 kilowatts (rated output 16 kilowatts).

The present day
The first hybrid vehicles with Bosch drive technology went into series production in 2010. In parallel to these hybrid activities, Bosch is also investing in the development of electromotive drive systems. In addition to an electric motor, this concept includes power electronic components, which play the key role of converting the battery’s DC voltage into the AC voltage required by this motor. It also incorporates the battery technology developed and series-produced by SB LiMotive, a joint venture set up by Bosch and Samsung.

2000	2005	2008	2009	2010
Fiat EcoDriver hybrid vehicle equipped with Bosch technology	Bosch project unit for hybrid technologies established	SB LiMotive joint venture set up with Samsung SDI to develop lithium-ion batteries	Establishment of the Electric Vehicles and Hybrid Systems business unit	Start of series production of the world’s first parallel strong hybrid

Drives like a dream – **safety, guidance, and comfort**

Sitting more safely thanks to iBolts. The bolts securing the passenger seat use built-in sensor technology to measure the weight of the passenger and adjust the force with which the airbag is released, depending on whether a child or adult is in the seat (2008).


BOSCH
AIRBAG

Past every obstacle
Braking and chassis systems made by Bosch

In the 1920s, cars were already reaching speeds of 80 kilometers an hour and more, and brakes were finding it hard to keep up. Bosch addressed this problem in 1927, bringing out the "Bosch servo brake," which reduced braking distances by one-third. To help increase the braking effect, the system used the vacuum that arises in the induction tract of the engine when the driver releases the accelerator. In the following decades, Bosch went on to systematically expand its work on brakes and braking systems. One of the highlights of this work was the ABS antilock braking system, launched in 1978. This also laid the foundation for further systems: traction control (TCS) to prevent the driven wheels from spinning, and the ESP® electronic stability program to stop vehicles from swerving and skidding.

Anyone who thinks of Bosch and brakes will automatically think of the abbreviation ABS. What is not as widely known is that Bosch has not just developed systems to prevent wheels from locking and skidding during braking, but also the brake systems themselves. Bosch was already producing servo brake systems for commercial vehicles as early as 1927, manufacturing the Dewandre servo brake under license. Customers could order the retrofitted "Bosch brake support" for installation in passenger cars from 1928. Fritz Seitz, the head of advertising at Bosch at the time, had the following to say when asked to explain why drivers needed better brakes: "The fast speed of modern cars has a special attraction that nobody can resist and no motorist wants to do without." Although this quote dates from 1927, it is still basically true today. The only difference, albeit a crucial one, is that the brakes available in the 1920s achieved nowhere near the level of effectiveness and comfort that is possible today. These earlier brakes were purely mechanical and were cable-actuated. To stop the car quickly by applying the brakes fully, drivers had to apply both feet and their entire body weight.

Left:
The comparison demonstrates the effect of the ABS antilock braking system. The picture from 1978 shows the Mercedes-Benz S-Class W116, the first to be equipped with the Bosch ABS.

In Arjeplog, northern Sweden, Bosch tests chassis systems on frozen lakes. The picture shows an Audi 100 GL featuring a pilot version of ABS (1975).

Bottom left:
The Bosch-Dewandre servo brake was available for commercial vehicles from 1927 on. It reduced braking distances by one-third.

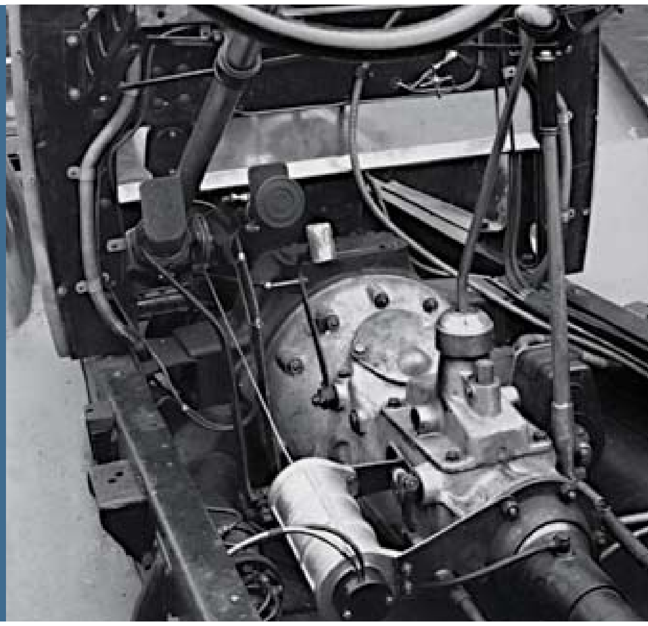
Bottom right:
The Bosch brake support (1928, small cylinder at the bottom of the picture in the center) was a brake booster that could be retrofitted in cars.

Rest your calf muscles

The Dewandre system was continuously improved and the name Dewandre disappeared from the brochures, which proclaimed the "Bosch compressed-air brake" from the mid-1930s on. Dewandre's idea was good, but it was Bosch that turned it into a reasonably priced ready-for-market quality product, once more demonstrating its frequently used strategy. The compressed-air brake worked by using the vacuum generated in the induction tract of an engine when the driver releases the accelerator. A valve was used to connect the tract to a brake cylinder, enabling the vacuum to increase pedal force when braking. This principle increased pedal force by 30 kilograms. By boosting the available braking force, it also enabled drivers to brake sharply without the need for physical exertion. Experiments showed that the braking distance of a passenger car was reduced by 30 percent thanks to this development. "Rest your calf muscles" read an apt Bosch advertising slogan at the time.

Enhancing competence in braking systems

Bosch constantly expanded its competence in the area of braking systems. Pneumatically controlled systems such as compressed-air brakes underwent further development, as did the hydraulic systems with which all of today's passenger cars are equipped. An important milestone was taking over the brake business of the U.S. company Allied Signal Inc. in 1996. This turned Bosch into a systems supplier of complete braking and brake control systems for vehicles. From today's perspective, one event from the early days of brake development at Bosch is particularly interesting. It marks the origins of Bosch as a manufacturer of brake control systems such as the now well-established ABS antilock



Milestones

1927	1928	1936	1969	1973	1975
Pneumatic power brake license from Dewandre	Bosch brake support	Patent for antilocking system	Start of development of antilocking system at Bosch	Bosch acquires a share in Teldix	Pooling of ABS activities at Bosch

braking system. In an effort to make brakes even more effective, engineers carried out research into an antilock system, and patented it in 1936. The aim of this system was to prevent the wheels from locking when the brakes were applied with force – a phenomenon which made it impossible to steer the vehicle. The idea was still unfeasible at the time, as it was not technically possible to achieve the split-second reaction to locking that the system called for. With the benefit of hindsight, it is clear that the advent of electronics was necessary to bring the system to market, both with respect to reaction speed and to practical everyday use.

The project to create an antilock braking system

From 1964 on, researchers at Teldix GmbH had been working on an antilock system for vehicles. The idea was presented to Daimler-Benz AG in 1966, and close collaboration between the two companies ensued. Comprehensive winter trials demonstrated that the product (known as “ABS 1”) worked, but the durability of its electronics left a lot to be desired. After acquiring a 50 percent holding in Teldix in 1973, Bosch became involved in the project. Developers at Bosch had also been working on an electronically controlled antilock system, and the company

Top:
In 1984, Bosch founded the joint venture Nippon ABS with a Japanese partner. That very same year, the Mitsubishi Galant and the Nissan Fairlady were available with ABS.

1975	1978	1985	1986	1986	1986
ABV antilock system for trucks presented by Knorr and Bosch	Bosch ABS 2 antilock braking system	Bosch ABS in U.S. vehicles for the first time	ABS 3: ABS and brake booster in one component	TCS traction control system	One million ABS

had a wealth of experience in the area of automotive electronics – as a result of developing the Jetronic electronic gasoline injection system, for example.

In 1975, Bosch took over full responsibility for ABS development. It bought up the remaining Teldix shares in 1981. The main contribution made by Bosch was its development and manufacturing experience with electronic components, which had reached a stage where they were robust enough for use in vehicles. For example, Bosch had long been using them in regulators for alternators and in injection systems. These components significantly improved the computing performance of the ABS central control unit, dramatically reduced the number of components in the control unit itself by employing highly integrated circuits, and at last ensured the level of reliability that was needed. The result, in 1978, was known as "ABS 2." After an initial phase when it was only available as special equipment in luxury sedans, the system and its successors gradually found their way into all vehicle segments. A comparable system was introduced for commercial vehicles in 1982, based on the standard pneumatic brakes used in this segment.

By 1986, the first million systems had been delivered. Bosch also supplied an ABS for motorcycles from 1994. In 2009, the company launched the first ever system designed specifically for motorcycles. This was followed in 2010 by the world's smallest system for motorcycles.

Eight years after the ABS was introduced in 1978, Bosch launched TCS (or traction control), which had been the subject of intense research since 1980. Just as ABS stops brakes from locking during braking, TCS prevents wheels from spinning during start-up and acceleration.

ESP® prevents skidding

Yet the story of innovation in brake control systems does not end here. In 1995, Bosch introduced the ESP® electronic stability program. This program uses sensor signals to continuously compare the actual movement of the vehicle with the direction specified by the driver. These data are analyzed rapidly in the control unit. If the analysis indicates that a dangerous – and uncontrollable – situation is imminent (e.g. skidding), ESP® intervenes to correct this. By reducing engine torque and braking each wheel individually, the system helps the driver

1992	1994	1995	1996	1999	2001
Ten million ABS	ABS for motorcycles	ESP® electronic stability program	Acquisition of brake business of Allied Signal Inc. (U.S.)	50 million ABS	EHB electrohydraulic brake

Far left:
Testing the ESP® electronic stability program at the test site near Arjeplog in northern Sweden (1995). At the time, the system was still called vehicle dynamics control (VDC).

Left:
If a vehicle suddenly has to swerve, ESP® prevents uncontrolled breaking away or skidding, thus helping to prevent accidents (2008).

prevent the vehicle from breaking away or skidding. A further stand-out feature of this development is its networking with other electronic control units. Like TCS, ESP® can intervene in the engine management system that controls injection and ignition. It can automatically cut off fuel in order to stabilize a vehicle. This sets it apart from the ABS that was launched 17 years before.

Today, passenger cars and commercial vehicles are fitted with Bosch brake control systems as standard. And ABS and ESP® systems are widespread. In fact, it is not possible to imagine modern cars without ABS. Since July 2004, every new car sold in Europe has had an antilock braking system as standard equipment. Many of these ABS systems are made by Bosch. In the years to come, this will also be true for ESP®. In 2009, around 80 percent of new cars in Germany were already equipped with this system. From 2014, ESP® will be mandated for every new car produced in the EU member states, the U.S., and Australia. This will help cut the number of accidents, thereby increasing safety for vehicle occupants and other road users.

Braking and brake control systems from Bosch

The beginnings

Bosch began working on vehicle braking systems in the 1920s. Mechanical systems were no longer able to cope with the vehicle speeds already being achieved in those days. The servo brake was a pneumatic or hydraulic system that increased braking power while reducing the force needed to actuate the brakes. The roots of modern brake control systems such as ABS can be found here and, in particular, in a Bosch patent for an “antilocking system” dating from 1936.

Development history

Bosch initially had a license to manufacture the Dewandre servo brake, but this was subsequently replaced by products designed by Bosch itself. Work to produce brake control systems such as ABS was based on this knowledge. However, ABS and its successor systems TCS and ESP® were not technically feasible until the advent of digital electronics from the end of the 1970s.

How it works

Early servo brake systems from Bosch made use of the vacuum generated in the induction tract of the engine when the driver releases the accelerator. By applying this previously unused vacuum to the brake cylinder when the brake pedal was actuated, braking power was increased, despite a lower pedal force. Modern brake control systems such as ABS use the hydraulics of the braking system to influence the braking effect, increasing or reducing brake fluid pressure to prevent locking, for example. This requires an electronic management system that uses sensors to detect incipient locking of the wheels and take corrective action.

First use

Bosch launched the Dewandre servo brake in 1927 for use in all types of trucks. This was followed in 1928 by the smaller brake support for passenger cars, which was available for all standard makes of passenger car. Modern brake control systems were introduced for luxury-class cars. The first models to have ABS were the Mercedes-Benz S-Class and the BMW 7 Series. The ESP® electronic stability program made its debut in 1995, also in the Mercedes S-Class.

The present day

Today, hardly any car can manage without hydraulic power-assisted brakes. And almost 100 percent of cars in Europe are now fitted with ABS. Brake control systems such as ESP® will be standard equipment in all automobiles in the next decade. This system is already installed in 58 percent of all new vehicles in Europe. Bosch alone now manufactures more than 20 million brake control systems each year. Braking and brake control systems are developed, manufactured, and marketed by the Bosch divisions Chassis Systems Brakes (CB) and Chassis Systems Control (CC).

2003	2005	2006	2008	2009	2010
100 million ABS	ESP® Plus	ESP® Premium	ESP® with integrated inertia sensor	200 million brake control systems	World’s smallest and lightest motorcycle ABS

The ACC adaptive cruise control distance radar launched in 2000 is one of the first complex electronic driver assistance systems. It ensures that a constant safe distance is maintained, even when the vehicle in front brakes.

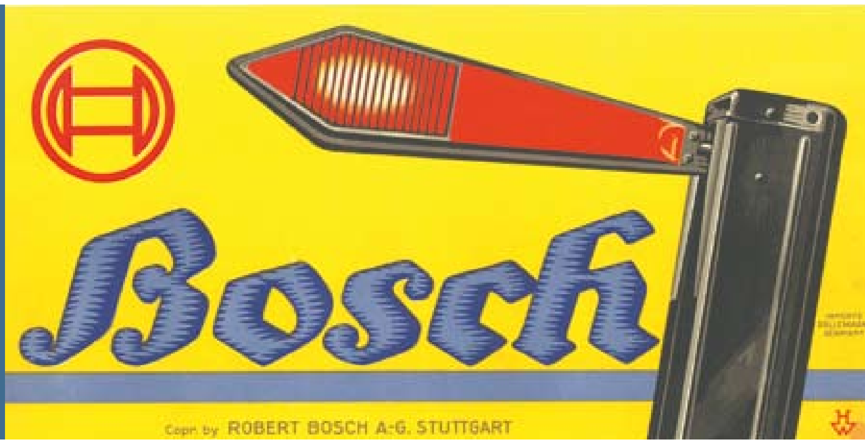
The sensitive car
Driver assistance systems made by Bosch

Many silent helpers are at work under a car's bodywork, and most go completely unnoticed by drivers. The electronic driver assistance systems made by Bosch are designed to make driving safer and more comfortable. Today, driver assistance systems can prevent collisions, mitigate the consequences of accidents for occupants and pedestrians, and perform parking maneuvers almost entirely independently. These functions are also aided by the incorporation of brake control systems such as ESP®, and by the networking and combined use of up to 80 sensors that act as a car's "sensory organs."

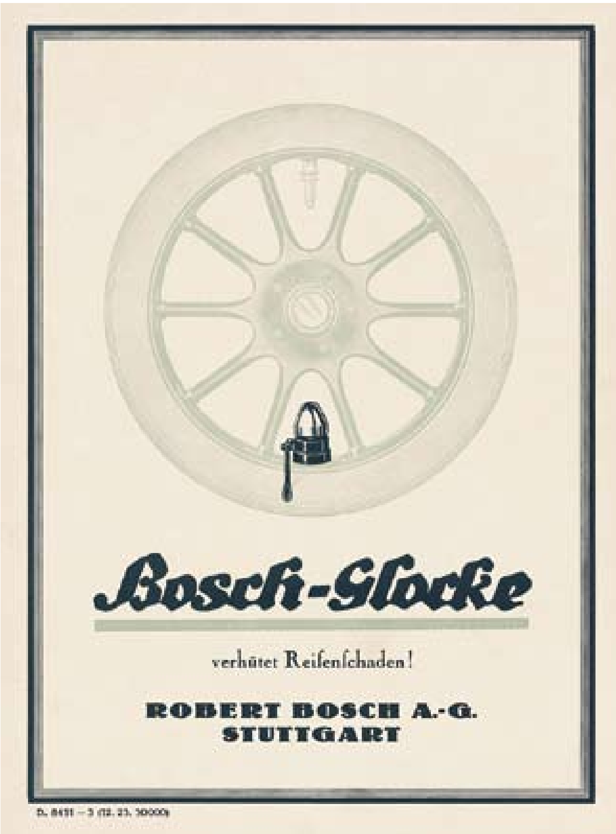
Two forerunners and the kick-off point – the Bosch bell, direction indicators, and a parking aid
Very simple mechanical forerunners to today's driver assistance systems – such as the "Bosch bell" that controlled tire pressure or indicators to signal a change in direction – were available as early as the 1920s. However, these examples do no more than show that Bosch recognized the importance of relieving drivers of distracting tasks and alerting them to imminent dangers.

The first real milestone en route to today's driver assistance systems – the parking aid – came about as a result of increasing traffic density, and coincided with the availability of powerful electronics. This aid made parking maneuvers – where a few centimeters can sometimes be crucial – much easier, and prevented damage to vehicles. In this system, sensors send out ultrasound signals and pick up their echo. The system then uses the time difference between these two signals to calculate the distance between the vehicle and obstacle, and informs the driver using visual or audible signals. This makes it possible to navigate even the smallest of parking spaces. Today, the parking aid is offered as an extra by virtually all automakers worldwide.

Driving with foresight – adaptive cruise control (ACC)
In 2000, Bosch launched the radar-based adaptive cruise control (ACC) system. This milestone primarily made driving more comfortable, but also helped improve road



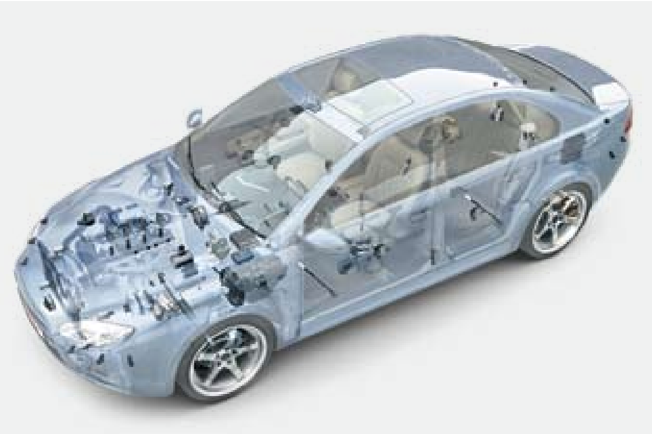
The predecessors of today's driver assistance systems: on the right the direction indicator (1927), the forerunner of the turn signal, and on the left the Bosch bell (1923), a tire-pressure warning device



safety. ACC is based on conventional cruise control, where a speed specified by the driver is maintained automatically. As well as this, ACC can accelerate or brake the vehicle independently, adjusting speed to match the prevailing traffic conditions. To do this, the system uses data from a radar sensor, which continuously monitors the area in front of the vehicle. If the car gets too close to a vehicle ahead or if another road user switches from another lane to cut in front, ACC brakes gently to maintain a specific minimum distance. When the lane is free again, ACC accelerates the vehicle to the speed chosen by the driver. The ACC Stop & Go function, which can brake all the way to a standstill and then move off again automatically, first went into series production in 2007.

Seeing in the dark – Night Vision system

Rather than relieving drivers of tasks, other systems help improve orientation considerably, especially when visibility is poor. One such example is the infrared Night Vision system, which was launched in 2005. This system increases the driver's field of vision by more than three times compared with conventional low-beam headlights – without dazzling other road users. The Bosch sys-



tem has two headlights that scan the road ahead by means of light cones that are invisible to the human eye. A video camera mounted behind the windshield records the details and transmits the image data via a control unit to a display on the instrument panel, where the traffic status is depicted as a high-resolution black-and-white picture. The Night Vision system thus provides valuable information on traffic situations, road users at risk, and potential obstacles and hazards on or around the road.

Guided by an invisible hand – the parking assistant

In 2008, Bosch developed a new product based on the idea of the parking aid. This time, rather than just making parking easier, the aim was to relieve the driver of much of the work. The parking assistant is equipped with two additional ultrasound sensors located on each side of the front bumper. Designed to work at speeds of up to 30 kilometers an hour, these sensors scan the side of the road looking for possible parking spaces. The parking assistant lets the driver know immediately when it finds a suitable gap. If the driver switches to automatic parking mode, the system takes just fractions of a second to calculate the optimum path into the space, the necessary steering maneuvers, and the number of parking maneuvers needed. Now the parking assistant takes control: The driver lets go of the steering wheel and simply controls the parking maneuver by accelerating and braking. With the support of electric power-assisted steering, the assistant automatically performs all the steering movements and guides the vehicle into even the tightest of spaces. The driver can stop the procedure at any time.

Automatic emergency braking – predictive sensor technology

In critical situations, a driver often only has a few seconds to take evasive action in order to avoid a rear-end collision. Accident research shows that in dangerous situations most drivers either brake too hesitantly or – in some cases – not at all. That is why Bosch developed the multi-level predictive emergency braking system, which went into series production in 2010. In this system, radar and video sensors are networked with ESP® to warn the driver of the threat of a rear-end collision, and help prevent an accident or at least reduce the speed of impact.

Top left:
As many as 100 sensors are used in a passenger car. They are indispensable for complex driver assistance systems, since they deliver the precise data that allow such systems to be controlled and managed (2008).

Top right:
At night, drivers can fail to spot pedestrians. Using a combination of infrared and thermal images, the “Night Vision” system picks up things that are missed by the light cones of even state-of-the-art headlights (2005).

A mere vision just a few years ago, the parking assistant has been a reality since 2008. It measures the parking space automatically and, as if by magic, the electronics do all the steering without the driver's intervention.

A collision warning system is the first level of this predictive emergency braking system. It recognizes potential collisions and prepares the braking system for an imminent emergency braking operation. That way, the driver has access to the car's full braking capacity fractions of a second earlier than normal. This extra time is crucial. The system's second level – the emergency brake assistant – calculates continuously how strongly the vehicle must brake to avoid a collision. If the driver brakes early enough after the warning but not with sufficient power, the emergency brake assistant increases the braking pressure as necessary.

In many cases, valuable time is lost before a driver reacts in a critical situation. This is where the third level of the system – automatic emergency braking – comes into play. Following the collision warning, the function automatically triggers a partial braking operation. This slows the vehicle considerably, giving the driver more time to react. As soon as he applies the brake, the emergency braking assistant steps in to help by increasing the braking pressure in order, where possible, to prevent an accident. If the driver still does not react, the system triggers emergency braking shortly before the collision. At this late stage, the system cannot prevent the accident, but it can significantly reduce the severity of the impact and therefore the risk of injury.

If the worse comes to the worst – passive safety reduces the consequences

If an accident cannot be prevented, passive safety systems such as airbags and seat belts offer the best possible protection for occupants. In the event of an accident, they minimize the acceleration and forces acting on the body and thus reduce the severity of injuries as much as possible. Networking airbag control with ESP® or surround sensors, such as a video camera or a radar sensor, gives rise to new functions that can identify an imminent accident at an earlier stage.

Milestones

1923	1927	1993	2000	2005	2005
Bosch bell	Direction indicators	Parking aid	Adaptive cruise control (ACC)	Night Vision system	Predictive brake assist

Outlook

In the coming decades, traffic density will continue to grow worldwide, increasing rapidly in emerging markets such as China and India and rising steadily in Europe, America, Australia, and Africa. At the same time, the demographic shift underway in many countries means that the number of older road users will increase, too. As a result, driver assistance systems for comfort, navigation, and safety are set to become ever more important. This is the only way to continue to reduce the number of accidents and victims and make sure that the traffic in and around large cities continues to flow.

Despite these developments, Bosch is certain that drivers will remain in charge of their vehicles in the future. Driver assistance systems will remain in the background. They must only be allowed to intervene when activated by the driver, or in response to a life-threatening situation in which the driver no longer has enough time to react.

Driver assistance systems

The beginnings

The forerunner to all Bosch driver assistance systems is the Bosch bell, an acoustic air-pressure warning device that was launched in 1923. If the tire pressure fell sharply, the clapper of the device attached to the tire struck the side of the tire and the bell rang. The history of modern-day electronically controlled driver assistance systems started at the end of the 1980s with the European Union's "PROMETHEUS" (PROgraM for a European Traffic with Highest Efficiency and Unlimited Safety) project. The driving force behind this program was the vision of automated driving.

Development history

Driver assistance systems make driving safer and more comfortable. They help drivers devote their full attention to the traffic situation without being distracted. These systems are a response to the dramatic increase in traffic density over recent decades, which requires drivers to be ever more vigilant. Other examples aside from the classic parking aid (1995) include the adaptive cruise control (ACC) system (2000), the Night Vision system (2005), the predictive brake assist (2005), and the parking assistant (2008), which measures parking spaces as the vehicle passes by and takes over the steering operations during the parking process. Navigation systems that offer route guidance and warn of traffic jams are also classed as driver assistance systems.

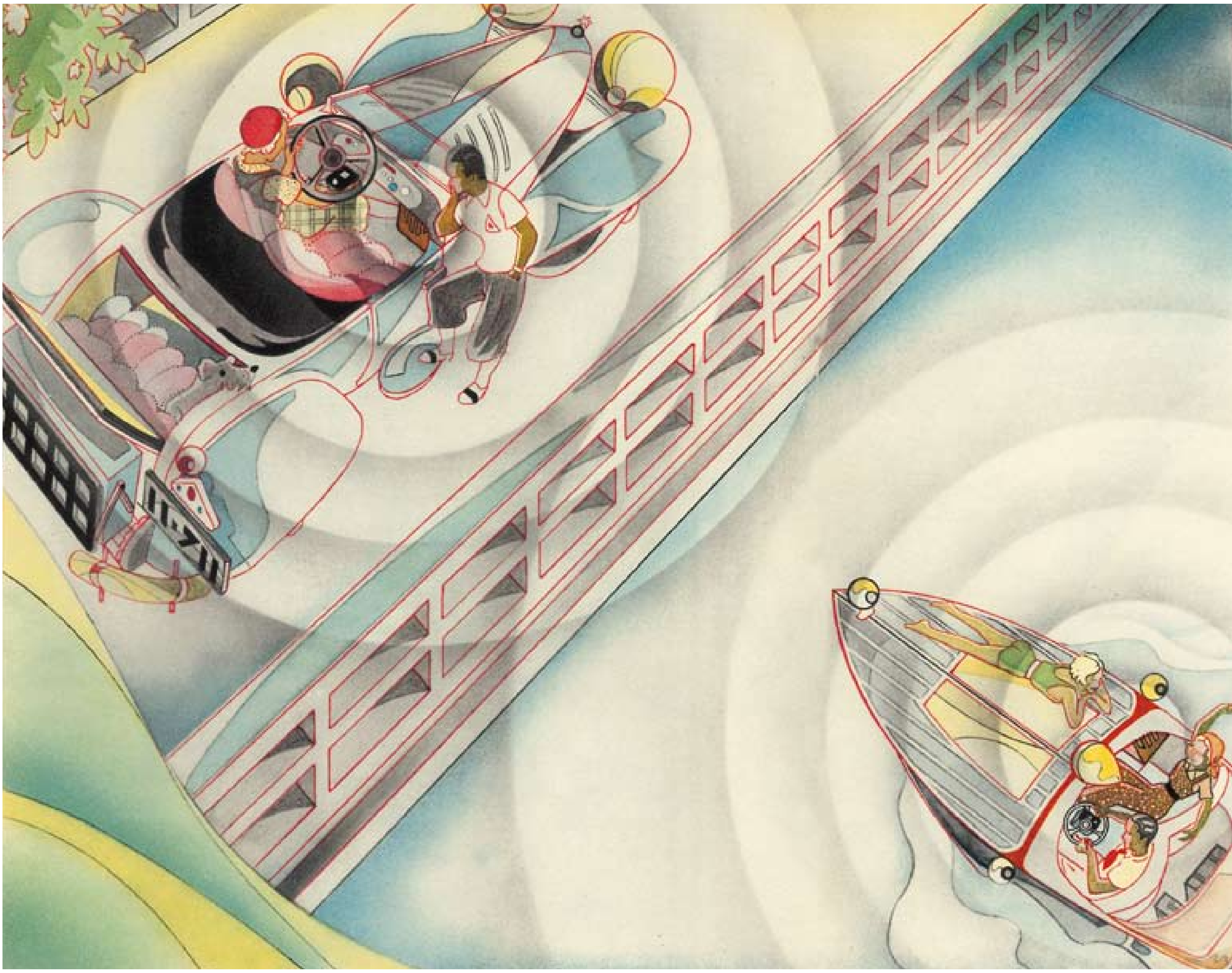
First use

Ignoring forerunners such as the Bosch bell and direction indicators, the history of driver assistance systems starts with the launch of the ultrasound-based parking aid in 1995. This system helps drivers park and maneuver their cars safely by monitoring the area immediately in front of and behind the vehicle and providing a graduated audible and/or visual warning of obstacles at distances of up to around 250 centimeters.

The present day

Nowadays, it would be hard to imagine cars without driver assistance systems. They make driving more comfortable and relaxing by taking over routine tasks. What's more, their sophisticated sensors help improve safety and prevent accidents, or at least lessen their severity, for example through automatic emergency braking if an impact is imminent or by triggering airbags earlier and more precisely.

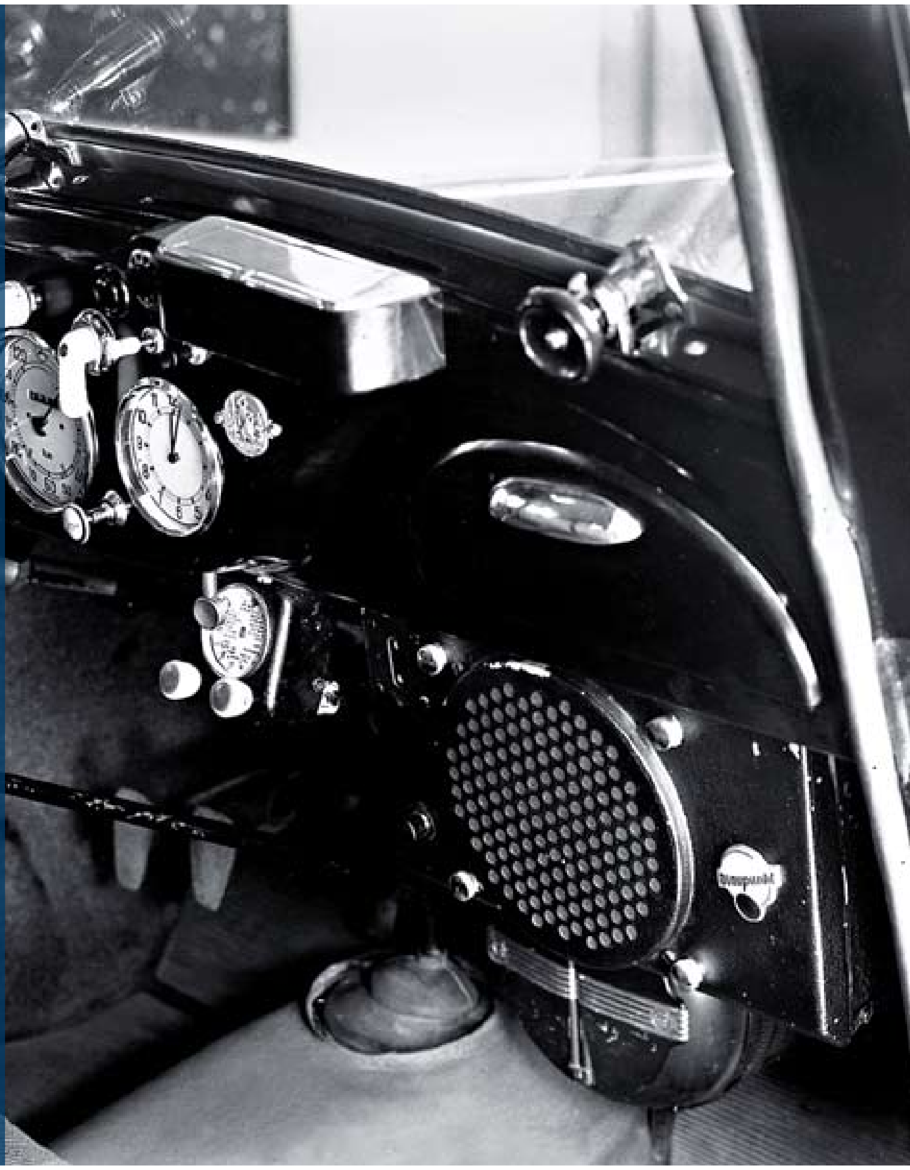
2007	2008	2009	2009	2010
ACC Stop & Go	Parking assistant	LRR3 long-range radar sensor	Night Vision plus with pedestrian detection function	Predictive emergency braking system



Entertainment combined with traffic and road information

Car multimedia

The first signs of crisis in the automotive industry in 1926 prompted Bosch, hitherto solely an automotive supplier, to start looking for new areas of business. As part of this strategy, Bosch took over the radio manufacturer Ideal-Werke Berlin in 1933 (renamed Blaupunkt-Werke in 1938). The first joint project between the two companies was the Autosuper 5, the first car radio in Europe to be series-manufactured. The Blaupunkt brand is no longer part of the company today, with Bosch preferring instead to focus entirely on car multimedia in its role as an original equipment supplier to automakers.



Weighing in at a hefty 12 kilograms, the Autosuper 5 only just about fitted under the dashboard. Nonetheless, the first series-manufactured car radio in Europe created quite a stir in 1932. At a price of more than 300 reichsmarks, though, its sales success was modest at first. After all, this was equivalent to the monthly salary of a well-paid engineer at Bosch. Technical problems also prevented more wide-scale distribution at first. The electron tubes were not yet able to withstand vibrations from bumpy country roads for any significant period of time.
By the time the successor model, the 5A75, came out in 1935, these problems had been solved.

After relocating its headquarters from Berlin to Hildesheim, Blaupunkt started production of the 5A649 model in 1949. The car radio was systematically developed into a mass-produced product. For example, by 1950 a radio had already been designed especially for the VW Beetle. 1952 saw the introduction of the first FM radio. This was followed by the first mechanical search tuning device in 1954 and the first transistor radios, which were much smaller and lighter, in 1957. In 1960, to cater to people's enthusiasm for day trips, Blaupunkt introduced a radio called "Westerland," which was fitted in the car but could be

Left:
Title page of the first advertising brochure for Blaupunkt car radios (1932). The "Autosuper 5" was available for cars, for motor boats, and for airplanes.

Right:
The bulky car radios of the 1930s were installed under the dashboard, and the remote controls (left) within easy reach of the driver. The picture shows the 7A78 model, and a Bosch vehicle heater beneath it (1938).

From 1951, there was a car radio specially designed for the Volkswagen Type 1 Beetle – the A 51 L. It was dimensioned to fit into the car's installation recess.

taken out for Sunday picnics. In 1969, the first stereo car radio was launched in Europe, followed by the first CD player in 1985, and the first MP3-enabled car radio in 2001.

Information and entertainment

In addition to entertainment, car radios began to feature something quite new in the 1970s: driver information. In 1974, Blaupunkt introduced the ARI traffic news decoder. This enabled drivers to find out where there were traffic jams on the highway, allowing them to divert to routes with less traffic in good time. The early-warning function also helped to improve road safety and prevent accidents. ARI picked up the additional signal transmitted by the stations that broadcast traffic news. By means of an LED, the decoder showed drivers whether they had selected a station that had this information. Drivers and their passengers could be sure that they would always hear traffic news on the full hour, following the news, even if the radio was turned down or a tape was playing.

Independent navigation

In 1983, Blaupunkt presented the first prototypes for vehicle navigation. The "electronic pilot for drivers," or EVA for

Milestones

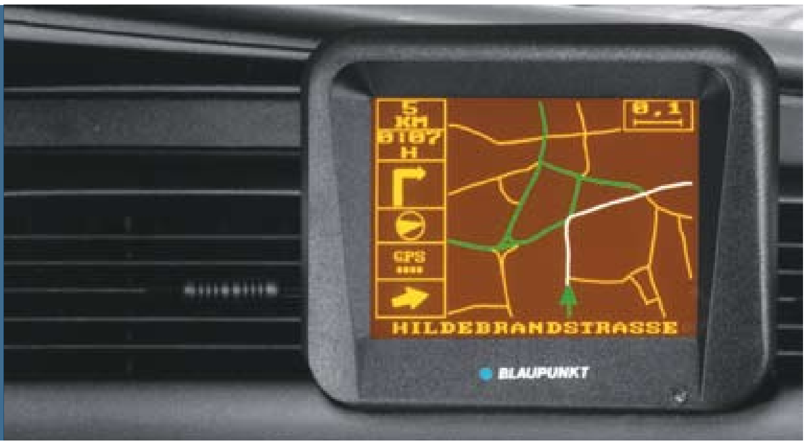
1932	1949	1952	1957	1960	1965
First car radio, the Autosuper 5 (AS 5)	5A649, the first post-war car radio, with two frequency ranges	FM car radio	"Köln," "Bremen," "Hamburg," and "Berlin" car radios with transistor technology	"Westerland" combined car radio and portable travel radio	Car cassette player

A different station perhaps? Blaupunkt car radios were available with front panels to match every common car model (1968).

short, allowed drivers to use an electronic map to find their way. All drivers had to do was enter the coordinates for start and finish, and a sonorous voice told them which turning to take in order to arrive directly at their destination. Wheel speed sensors recorded the routes taken and any changes in direction, and compared the vehicle's movements with the selected route.

The development still had to overcome a number of obstacles, but thanks to the new compact disc (CD) storage medium, which was able to store the quantity of data needed for all the roads in Germany, and to the satellite-assisted positioning system introduced in the mid-1990s, Blaupunkt was able to introduce its TravelPilot in 1995. As a result, drivers no longer needed to keep a traditional road atlas in their cars. The integrated voice output function meant that it was not necessary for drivers to glance at the display. They could keep their eyes firmly fixed on the road ahead. The TravelPilot, which cost more than 4,000 German marks back then, paved the way for the navigation systems that are to be found in such large numbers today.

1969	1974	1976	1979	1982	1985
"Frankfurt" stereo radio	ARI traffic news decoder	Car radio with integrated ARI traffic news decoder	Quartz tuning system, PLL synthesizer tuner	EVA electronic pilot for drivers	CD player



Top:
Introduced in 1989, TravelPilot IDS made precise route planning possible. It was not until speech output appeared, in the TravelPilot RG 05 (1995), that navigation systems became successful: while being guided to their destination, drivers could devote their full attention to the road ahead.

From the end of the 1980s on, technical developments for car radios were chiefly concerned with improving ease of use. Examples include the RDS radio data system to identify radio stations, the TIM traffic information memory to save and call up traffic information, and theft-deterrence features such as removable front panels and coded keycards. The 1990s saw further innovations in driver information and communication. The radiophone, for example, combined the functions of a normal car radio with those of a cellphone. And thanks to the new DAB digital audio broadcasting reception technology launched in 2002, the digital car radio ensures that reception is always crystal-clear.

Intelligent networking for greater safety and lower fuel consumption

Today, Bosch Car Multimedia develops solutions that integrate entertainment, navigation, and driver assistance functions for OEM business relating to both private vehicles and company fleets. The components are, as a rule, designed and produced for specific models in close cooperation with the automaker. One new development in this respect is the increased networking of navigation with other automotive functions that make driving safer and help reduce fuel consumption and exhaust emissions. For example, the navigation system can be used as a sensor, with on-board

1986	1987	1988	1989	1992	1995
Key code for theft deterrence	Dolby C noise suppression, removable front panel	RDS radio data system	TravelPilot IDS, first vehicle navigation system in Europe	TIM traffic information memory	TravelPilot RGS05, navigation system with GPS control, route guidance, and speech output

Left:
Today's Bosch infotainment systems can be used by carmakers worldwide. The system architecture can be adapted flexibly to the technical conditions and cultural features of the relevant country (2010).

digital maps informing drivers in good time of dangerous stretches of road ahead, such as sharp bends.

However, navigation can also help reduce fuel consumption and emissions by choosing the most economical route (the "eco route" function). This function doesn't just calculate the shortest route, but also takes other consumption-related parameters into account, such as avoiding frequent braking and acceleration, and traffic conditions that ensure a smooth run without traffic jams.

In-car music and information

The beginnings
In Stuttgart, one year before the acquisition of Ideal-Werke (subsequently known as Blaupunkt) by Bosch in 1933, engineers from both companies designed Europe's first series-manufactured car radio.

Development history
For the princely sum of 365 reichsmarks, "Autosuper 5," the first car radio, brought music into the car. Unlike radios for the home, however, it had to be rendered compatible with the car – by means of vibration-resistant radio tubes, for example. It was not until the 1950s that car radios became an affordable mass product. Tracking developments in home entertainment technology, Bosch introduced further innovations for automakers. Until 2008, these were still available in trade outlets under the Blaupunkt brand. Examples include transistor and stereo radios, cassette, CD, and MP3 players, and special functions such as traffic news recognition and units with a telephone or navigation system.

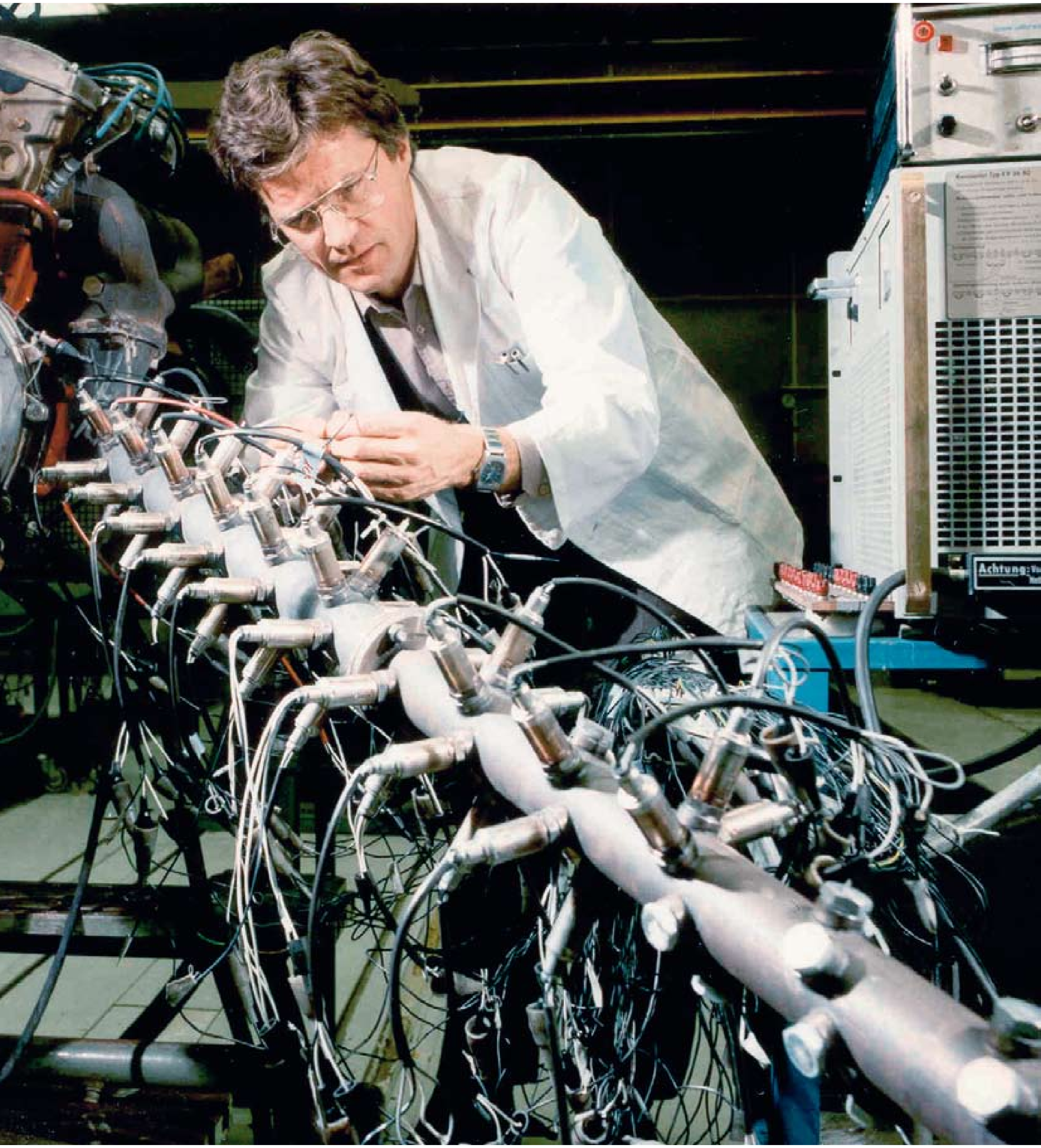
First use
The AS 5 could be installed in cars, aircraft, or motorboats. The entire number of AS 5 radios produced is estimated at just 400, making it a luxury article, five of which cost as much as a small car.

The present day
Bosch Car Multimedia develops solutions that integrate entertainment, navigation, and driver assistance functions for OEM business. The components are, as a rule, engineered for new models in close cooperation with the automaker.

1997	2000	2002	2003	2005	2008
Radiophone, a combined car radio and GSM cellphone	Dallas RDM 169 car radio with mini-disc drive	TravelPilot navigation system with online connection	Woodstock DAB53 digital car radio with MP3 drive and digital recorder	First radio navigation system with map zoom function and color display	First mobile navigation system with integrated camera for video navigation and recognition of speed-limit signs

"Safe, clean, economical" **as a development goal**

When it introduced the lambda sensor in 1976, Bosch set an important milestone in emissions reduction. In conjunction with a regulated three-way catalytic converter, it cut emissions by some 90 percent.



Safe, clean, economical
The Bosch 3S program

It was one year after the first oil crisis of 1973 that Bosch introduced the "3S" program (from the German words for safe, clean, and economical) to the public. This simple formula encapsulated the corporate philosophy pursued at Bosch for decades, a philosophy which still applies today: to protect people, to make vehicles economical, and to lower emissions.

Bosch has been testing brake and chassis systems near Arjeplog in northern Sweden since the 1970s. Here, the ABS and the traction control system (TCS), which was about to enter series production at the time, are being put through their paces in a bus and a truck (1986).

Safe

"Safe" relates to active and passive safety in vehicles. Examples include the ABS antilock braking system (1978) and triggering units for airbags (1980). Bosch set new standards in safety in 1995 with its ESP® electronic stability program. Research results showing the significant drop in the number of serious accidents involving vehicles with ESP® have justified the huge research and development spend on safety systems at Bosch. Systems such as ABS or ESP® are, or soon will be, standard equipment in nearly all new cars in Europe. Examples of the latest developments in the area of safety and comfort include Night Vision systems, the parking assistant, roll-over sensors, seat-occupancy

recognition for triggering airbags, and pre-crash sensors. Pre-crash sensors tighten the seat belt when the brakes are applied sharply and there is a risk of impact, and prepare for the airbags to be triggered. The automatic emergency brake mitigates the effects of accidents, while the ACC adaptive cruise control distance radar maintains a safe distance from the vehicle in front.

Clean

The “clean” part of the 3S program relates to the company’s commitment to reduce pollutant emissions. In 1967, Bosch launched a product that marked one of its first milestones in its commitment to “clean” cars. Thanks to the Jetronic electronic gasoline injection system, the Volkswagen 1600 E fulfilled the strict

The test bay at the Automotive Engineering Center for gasoline injection in Schwieberdingen near Stuttgart (1986). Here, engine management systems that are ready for series production are tested under the tough conditions they will encounter in practice.

emission regulations set by the California state government. This was the beginning of the successful application of electronic management systems for diesel and gasoline engines, which easily complied with all statutory regulations.

It was above all with the lambda sensor, which was produced from 1976 onwards, that Bosch responded to the aim of lowering emissions. This sensor, which is about the size of a finger, played a vital role in this respect. The lambda sensor made it possible to use a three-way catalytic converter, which cuts pollutant emissions from a gasoline engine by up to 90 percent.

Nowadays, nearly every gasoline-driven passenger car in the world has a lambda sensor, most of them made by Bosch. Even in today's diesel engines, the lambda sensor is effective in reducing emissions. This is another area where Bosch is a pioneer in environmental protection.

Economical

The third pillar of the 3S program is reducing fuel consumption. Even a good 20 years before the program was inaugurated, Bosch was setting standards with gasoline injection systems in small cars that reduced consumption by up to 20 percent. However, the initial systems were still expensive and gasoline was cheap, making it difficult to

Left:
Safer or cleaner? In 1950, the focus was more on the safety risk of poor visibility than on emissions. Bosch recommended that diesel injection pumps be serviced regularly.

Right:
Driver assistance systems can help drivers pace their driving more evenly and thus lower fuel consumption. They can also help prevent accidents, as is the case with the video sensor technology that is being tested here. It helps drivers to recognize traffic signs (2000).

Milestones

1976	1978	1979	1980	1986	1995
Lambda sensor	ABS antilock braking system	Motronic electronic engine management system	Airbag control	TCS traction control system EDC electronic diesel control	ESP® electronic stability program

establish the systems in the market. From the 1960s onwards, however, against the backdrop of fluctuating oil prices and fuel consumption regulations, the concepts developed by Bosch began to bear fruit. Bosch was especially successful with gasoline injection systems that allowed fuel to be metered precisely. From 1967, these systems were also controlled electronically. When Motronic – a combination of an ignition system and an injection system – was introduced in 1979, these functions were combined in an engine management system. These systems constantly monitor numerous parameters ranging from engine temperature to fuel quality, and meter the gasoline to match the needs of the engine.

In the 1990s in particular, Bosch launched a number of innovative systems for diesel engines. It was the common-rail system that really made a mark. It saves on fuel thanks to multiple-injection technology and to high injection pressures of up to 2,000 bar and more, which atomize the fuel and ensure effective combustion. In addition to lowering pollutant emissions and helping diesel engines to operate to their full potential, this also saves fuel and thus has a direct impact on the amount of carbon dioxide emitted.

Safe, clean, economical

The beginnings
The program was launched in November 1974. Bosch pooled its expertise to make cars safer, more eco-friendly, and more economical. Even before that time, Bosch had offered products that reduced consumption, provided protection against and during accidents, and lowered emissions. The 3S program brought these efforts together under a single slogan.

Development history
More stringent exhaust regulations, heavier traffic, increasing numbers of accidents, and the rise in fuel prices forced automobile manufacturers to act. Bosch was able to preempt many requirements, as demonstrated by a number of examples. Jetronic and the lambda sensor for gasoline engines, for instance, made it possible to comply with very stringent exhaust regulations from an early stage, while high-pressure diesel systems such as common rail lowered consumption and CO_2 emissions. New engine management systems such as the start-stop system launched in 2007 also help cut consumption and emissions by stopping the engine at a red light, for example.

The present day
The 3S program has lost none of its relevance. Launching new products that optimize consumption, emissions, and safety is a recurring theme throughout the history of Bosch, and will continue to shape the company's future: piezo injectors, exhaust-gas treatment, and forward-looking technologies such as hybrid and electric drives are just a few examples of how Bosch technology will make automobiles safe, clean, and economical in the future. The 3S program now has a further objective, that of making driving "comfortable" with driver assistance systems that facilitate everyday journeys on the roads. The product portfolio ranges from the parking assistant to the distance radar.

1997	2000	2005	2007	2010
Common-rail diesel injection system	ACC adaptive cruise control (radar-based distance and speed control system)	Night Vision driver assistance system	Start-stop system	Hybrid system for passenger cars

What's what?

ABS	(see antilock braking system)
ACC	(see adaptive cruise control)
Adaptive cruise control (ACC)	Adaptive speed control. Series production from 2000. ACC is a driver assistance system based on a cruise control which enables a desired speed to be set. ACC brakes and accelerates a vehicle depending on traffic flow. To be able to do this, it uses a radar sensor to monitor the area in front of the vehicle. If the system detects a slow vehicle ahead, it reduces the speed of its "own" vehicle until a defined safe distance to the vehicle ahead has been achieved. Once the lane is clear again, ACC accelerates the vehicle to the pre-set speed.
ALI	(see driver guidance and information system)
Antilock braking system (ABS)	Series production from 1978. ABS ensures that wheels do not lock up during braking, and that control is maintained over the vehicle. Wheel sensors monitor the incipient locking of the wheels and transmit this information to an electronic control unit. As soon as there is a risk that a wheel will lock, this control unit initiates a reduction of the braking force on the wheel within milliseconds by lowering the braking pressure. Once the incipient lock has passed, the full braking force becomes available again. This process can take place up to 50 times per second.
Antilocking	(see antilock braking system)
ARI	(see traffic news decoder)
ASR	(see traction control system)
Battery ignition	Series production from 1925. Battery ignition systems took the place of magneto ignition systems, which were very effective but relatively expensive. While magneto ignition is powered by the engine, battery ignition needs a current produced by a battery. This is used to generate an ignition spark. The battery is charged by the generator (alternator), which produces dynamo-electric power with the help of the movement of the engine (turning of the crankshaft).
Bosch-Dewandre servo brake	(see servo brake)
Bosch automotive lighting system	System comprising headlights, a generator, a regulator, and a battery. Series production from 1913. First complete electrical system from Bosch. The Bosch automotive lighting system replaced carbide and acetyl lighting, which involved a laborious kindling procedure and required a lot of maintenance. With the Bosch automotive lighting system, the electricity for the headlights (protected from overvoltage by the regulator) is supplied by the battery, which receives the current from the dynamo-electric generator.
Brake support	(see servo brake)
CAN	(see controller area network)
Capacitor	Current storage device comprising two separate electrodes. Series production from 1930. Mainly used in car ignition units, where it produces large amounts of current quickly. Also used in radios, TVs, and coolers.
Common-rail system (CR, CRS)	Diesel direct injection. This innovative system was brought to market by Bosch in 1997. The diesel fuel is subjected to high pressure in a cylindrical pipe (rail). The rail is connected to the injection valves, through which the fuel is injected into the combustion chamber at high pressure (up to 2,000 bar). Thanks to a constant level of high pressure, the common-rail system lowers consumption. A constant supply of fuel in the rail facilitates multiple injections, allowing the engine to run more smoothly.
Combined generator, starter, and ignition unit	Triple unit comprising a generator (alternator), a starter, and a battery ignition system. Series production from 1932. Mainly used in vans that needed all three electrical functions at low cost. Hardly any motorcycles had an electric starter in those days.

Controller area network (CAN)	Series production from 1991. Concept for the transfer of data in vehicles with complex equipment and a large number of interlinked electronic components (e.g. ABS, Motronic, ACC, pre-crash sensors, airbag control, air conditioning control, electronic transmission control). Instead of individually allocated data lines, which would make a traditional cable harness much too large and complicated, transfer of the data for the different components takes place via a data bus system to which all the components are connected. The content and priority of each message is indicated by an "identifier" assigned to it. Each station stores the messages that can be received. This ensures reliable sending of messages.
CR	(see common-rail system)
CRS	(see common-rail system)
D-Jetronic	First electronic gasoline-injection system to be made by Bosch. Series production from 1967. The "D" stands for the German word for pressure control (Drucksteuerung), as the amount of fuel injected is determined by the pressure in the intake manifold. In addition, the electronic control unit varies the amount of fuel injected on the basis of engine-related parameters (engine temperature, engine speed, load alternations, full throttle, etc.). This optimizes power output per unit of engine displacement, fuel consumption, emissions, torque, and warm-up behavior. D-Jetronic is maintenance-free. The tuning work carried out on traditional carburetors is no longer necessary. D-Jetronic was succeeded by L-Jetronic.
Dewandre servo brake	(see servo brake)
DI-Motronic	Series production from 2000. Various forerunners were series-produced for passenger cars from 1951 (two-stroke engines) and 1954 (four-stroke engines). Unlike the more common indirect injection (manifold injection, D-Jetronic, K-Jetronic, KE-Jetronic, L-Jetronic, LH-Jetronic), the air-fuel mixture is not prepared in advance and then drawn into the cylinder. Instead, fuel is injected directly into the combustion chamber via a nozzle. Fuel consumption can be reduced by as much as 10 percent. With DI-Motronic, fuel can be burned on a stratified charge basis in the case of part loads. A relatively small amount of air-fuel mixture is kept near the spark plug, and this vapor is surrounded by air and other gases, with the result that consumption drops considerably. Only when high power is needed, e.g. during full acceleration, is a homogeneous mixture burned, which takes up the entire combustion chamber. This delivers the high level of power desired. DI-Motronic is supplied exclusively in Motronic configuration, i.e. as a common control unit for injection and ignition.
Double-T armature	Core component of the magneto produced by Bosch from 1887 on (for motor vehicles from 1897 on). It induces current by means of oscillating or rotating motions, and the current produces the ignition spark for fuel combustion. Since 1919, an image of this double-T armature sketched in 1918 has been registered as the company's symbol. It has been used worldwide since 1920.
Driver guidance and information system (ALI)	Introduced on a test basis in 1978 but not manufactured in series production. Induction loops inserted in the surface of the road measured traffic density and passed on the data to central computers. Vehicles with ALI receivers were informed of increases in traffic density (risk of traffic jams) and supplied with alternative routes. No nationwide network due to the high costs of construction work the system would have entailed. Traffic density information and warnings of traffic jams are now two of the parameters used by modern navigation systems (TravelPilot) to calculate routes.
Dynamo-battery ignition unit	Combination of generator (alternator) and battery ignition system. Series production from 1926. Unlike self-sufficient magneto ignition, which did not need any external current, battery ignition was not available until systems were introduced in series production that were suitable for charging car batteries in everyday use (current-regulating generators, see also generator). The dynamo-electric generation of current by the alternator component also serves to generate the current required for ignition.
EDC	(see electronic diesel control)
ETC	(see electronic throttle control)
EHB	(see electrohydraulic brake)

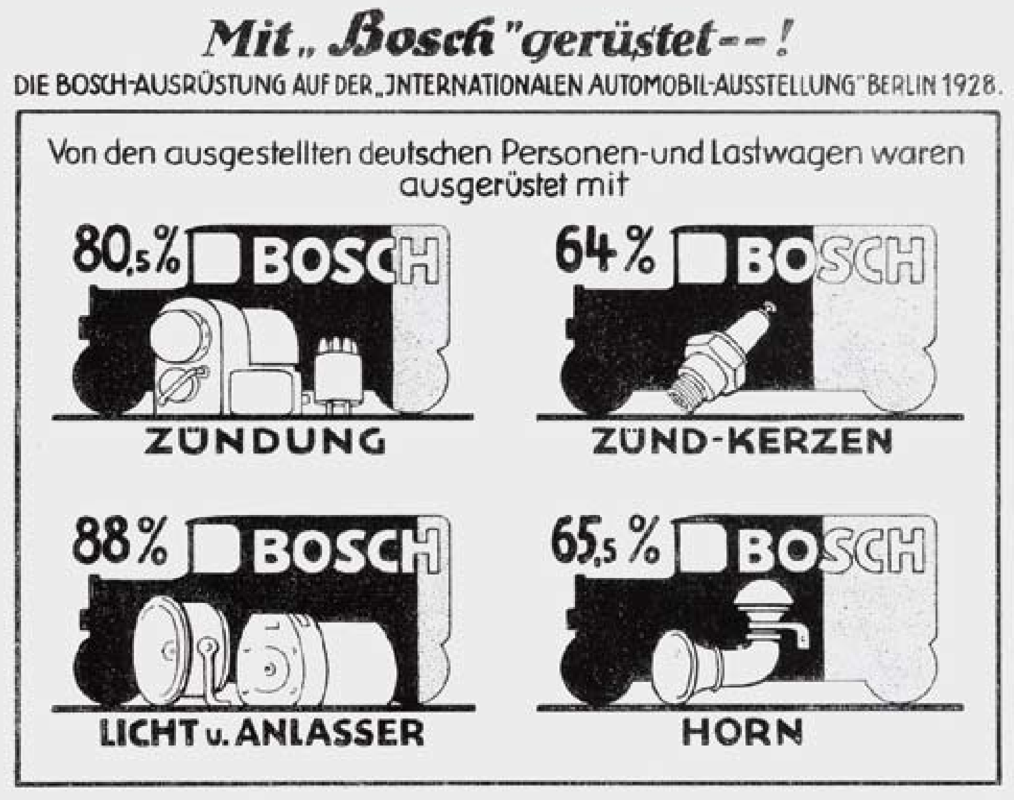
Electrohydraulic brake (EHB)	Electrohydraulic braking system. Series production from 2001. EHB involves the electronic transmission of the pedal force to the hydraulic braking system (brake-by-wire). Sensors register the force used to actuate the brakes and calculate the necessary braking pressure for each individual wheel. The electronic control system makes it possible to include information from chassis systems such as ABS or ESP®. The integrated "Brake Assist" interprets rapid actuation of the brake pedal as the start of emergency braking and automatically increases braking pressure to the maximum. The name "Sensotronic Brake Control" is a registered trademark of Daimler AG.
Electronic diesel control (EDC)	Series production from 1986. Electronic diesel control regulates the injection action of a diesel engine on the basis of the position of the accelerator, engine temperature, air, water, and fuel temperature, charge-air pressure, atmospheric pressure, etc. This data is used to calculate and set the amount of fuel injected, the timing of injection, and other factors for optimizing consumption, engine power, and noise (e.g. advanced injection), all within a few thousandths of a second.
Electronic throttle control (ETC)	Series production from 1995. Component of Motronic engine management system. The position of the accelerator is detected electronically by a pedal-travel sensor. ETC, the "electronic gas pedal," allows idle-speed control, reduction of engine output for TCS, and cruise control.
Electronic pilot for drivers (EVA)	Tested from 1982 on. First experimental system for independent navigation using an electronic map, entry of destination, and route guidance with speech output. EVA was not ready for series production, as it would have been necessary to create digital data for large areas, which would have been too expensive. Also, high-volume, high-performance storage media were not available until later. After entering the start and destination, the route was calculated. The system recorded the vehicle's movements (speed and change of direction) via sensors on the wheels. By comparing the route calculated by the system with the movement of the vehicle, it was also possible to update the data in response to driving errors. The fundamental principle of EVA is the basis for all navigation systems used today.
Electronic stability program (ESP®)	Series production from 1995. Originally known as "vehicle dynamics control" (VDC), ESP® prevents dangerous skidding. Its sensors register potential loss of control over the vehicle in critical situations. As far as the laws of physics will allow, ESP® recovers the stability of the vehicle by intervening in the brake control or engine management system – if necessary, for each wheel separately.
ESP®	(see electronic stability program)
EVA	(see electronic pilot for drivers)
Gasoline direct injection (GDI)	(see DI-Motronic)
GDI	(see DI-Motronic)
Generator (alternator)	Generates current in a vehicle. Series production from 1913. Generators were launched onto the market as the current-generating component of the Bosch automotive lighting system. Driven by the engine, dynamo-electric processes generate the current. The generator converts mechanical energy into electrical power. The electrical current is stored in the battery and transmitted to the electrical consumers (ignition, lighting, etc.) as required. Generators are generally designed to maintain an even charge balance, so that they supply as precisely as possible the amount of energy used. While (direct-current) generators were used in the early years, (three-phase-current) alternators have become more common since the 1960s due to their higher efficiency and smaller size. Today's alternator generation can cover an output range of up to 3.8 kilowatts. The reason for this is the constant rise in the number of electrical consumers. In 1915, only lighting and ignition needed electrical power. Nowadays, passenger cars have as many as 140 small-power motors that require electrical current (sliding roof panel, power seats, air conditioning regulation, power windows, etc.).
Glow plug, sheathed-element glow plug	Series production from 1922. Metal plug with spiral-type filament. Glow plugs are fitted in diesel engines. The glowing of the filament allows the diesel-air mixture to ignite during a cold start. While the preheating time for starting a cold diesel engine was in the region of 30 seconds in 1975, nowadays it is less than one second.

Halogen lights	Series production from 1966 (H1) and 1971 (H4 two-filament bulb). As with the forerunner double-filament lamps, light is produced using a glowing tungsten wire. However, in halogen lights the glass bulb of the light bulb is filled with a halogen (iodine or bromine). This allows the filament to reach a temperature close to the melting point of the tungsten wire, thus producing greater light efficiency and increasing the service life of the light.
High-voltage magneto ignition system	Series production from 1902. Unlike the previous model, the low-voltage magneto device, the coils in the high-voltage magneto ignition system produce high-voltage current that is conducted to the spark plug via cables. This current generates an electric arc between the electrodes of the spark plug, which ignites the air-fuel mixture. The high-voltage magneto ignition system made the universal use of magneto ignition in vehicles possible. Unlike low-voltage magneto ignition with its delicate break-spark rodding prone to breakdown, high-voltage magneto ignition systems could be easily installed in any engine. High-voltage magneto ignition is thus one of the most significant technical steps in the progress of Bosch ignition systems, and helped the company to develop into a major automotive supplier.
Jetronic	(see D-Jetronic)
K-Jetronic	Further development of the mechanical manifold injection system (1958). Series production from 1973. K-Jetronic is a cost-effective, mechanical driveless system. Unlike traditional systems with injection pumps, fuel is continuously injected through metering slots into the induction tract, upstream of the intake valve, in accordance with the volume of induced air. It was succeeded by KE-Jetronic.
KE-Jetronic	Further development of K-Jetronic. Presented in 1981, series production from 1983. KE-Jetronic enables greater flexibility by incorporating an electronic control unit (e.g. lambda closed-loop control for three-way catalytic converter).
Lambda sensor	Metal-ceramic device the size of a finger. Series production from 1976. Lambda sensors are the prerequisite for exhaust treatment using three-way catalytic converters. Lambda sensors determine the amount of oxygen in exhaust fumes upstream of the catalytic converter. On the basis of the values measured, the electronic injection control changes the composition of the air-fuel mixture to obtain a lambda value of 1 (14.66 kg of air to 1 kg of fuel). Only with a value of 1 or a value as close as possible to 1 is complete combustion of the mixture ensured, enabling optimum emission treatment by the catalytic converter.
L-Jetronic	Electronic system with intermittent injection. Series production from 1973. L-Jetronic is based on D-Jetronic (rather than on the mechanical K-Jetronic system with its continuous injection). Unlike D-Jetronic, however, fuel metering is not determined by the pressure in the intake manifold, but by the volume of air drawn in, which is measured by an air-mass meter. It is considerably more reliable than D-Jetronic due to the use of integrated circuits, which allowed the number of parts to be reduced from 220 to 80. Injection is controlled electronically in accordance with the parameters registered by sensors, such as engine temperature or load status (e.g. full throttle, part-load, or reduced throttle). Changes in the engine (wear, deposits in the valves) are detected and taken into account by the electronic control unit. Successor systems: LE-Jetronic and LH-Jetronic.
LH-Jetronic	Further development of L-Jetronic. Series production from 1981. Air-mass meters measure the amount of fuel needed (unlike the L-Jetronic, which measures the volume of air drawn in). This means that air temperature and air density can also be taken into account, thus allowing optimum injection.
Litronic (abbreviation for Light Electronic)	Gaseous-discharge lamp for headlights. Series production from 1991. Litronic works by creating a voltage between two electrodes in a glass bulb filled with xenon gas. The gas atoms excited by the voltage release energy in the form of light. Litronic generates considerably more light than halogen lights, but with lower energy consumption. The light has a high color temperature similar to sunlight, but with larger portions of blue and green. Litronic is more suited to modern vehicles than halogen light, as the system produces a lot of light even when the front surface of the glass in the headlight is small. The service life of the light is normally long enough for the total service life of a car.

Low-voltage magneto ignition device	Ignition device for internal-combustion engines. Built by Bosch (for stationary engines) for the first time in 1887. Tested in vehicles from 1897. Series production from 1898. Magneto ignition is based on the principle of a double-T armature – around which a wire coil is wound – moving in a magnetic field to generate a current. The movement (and thus generation of a current) is dependent on engine speed, and is independent of any external source of current such as a battery. This allows an ignition current to be generated to ignite the air-fuel mixture in the cylinder at the right time (depending on engine speed). Low-voltage magneto ignition (initially called ignition with break-spark rodding and later referred to as touch-spark ignition) produced the spark by suddenly separating two contacts in a closed circuit. These contacts were positioned within the combustion chamber, with the result that the break spark ignited the air-fuel mixture. Low-voltage magneto ignition dominated the market for ignition systems until around 1910, after which time it was gradually replaced by high-voltage magneto ignition.
Lubricating pump (oiler)	Device to lubricate moving parts in engines. Series production from 1909. Initially, licenses were acquired to produce lubricating pumps. Later these were further developed for use in all vehicle engines ranging from those in motorcycles to commercial vehicles, including ship and aircraft engines. The principle of evenly metered and precise distribution of fluids under high pressure later proved to be a practical basic technology for the development of diesel and gasoline injection pumps. Production was discontinued in 1959.
Magneto-generator ignition unit	Combination of generator (alternator) and magneto ignition system. Series production from 1921. The current generated is used for ignition and to supply the remaining on-board electrics. Installed in cars and – from the 1930s – in motorcycles.
Magneto ignition	Ignition device for internal-combustion engines. Bosch built its first magneto device – for stationary engines – in 1887. It was tested in vehicles from 1897. Series production from 1898. Magneto ignition is based on the principle of a double-T armature – around which a wire coil is wound – moving in a magnetic field to generate a current. The movement is dependent on the rotational speed of the engine. This allows an ignition current to be generated to ignite the air-fuel mixture in the cylinder at the right time (depending on engine speed). Low-voltage magneto ignition (also called ignition with break-spark rodding or touch-spark ignition), the more common approach to ignition up until 1910, produced the spark by suddenly separating two contacts within a closed circuit. In the case of high-voltage magneto ignition systems (also known as electric arc magneto ignition systems), developed in 1902, the vital spark was produced by the arc of a current, i. e. by a luminous electrical discharge between the electrodes of a spark plug within the combustion chamber. High-voltage magneto ignition systems carried the day because the break-spark rodding in low-voltage magneto ignition required a great deal of maintenance and repair work, leading to complaints. It was also very difficult to install.
Mono-Jetronic, Mono-Motronic	Electronically controlled centralized injection system arranged as a combined engine management system for ignition and injection, for special use in three- and four-cylinder engines. Series production from 1983. The technology of Mono-Jetronic is based on D-Jetronic, while Mono-Motronic is based on Motronic. However, both systems comprise a single unit from which the fuel is injected above the throttle valve, instead of in front of the intake valve of each cylinder – as is customary for all other Jetronic and Motronic versions. Mono-Jetronic and Mono-Motronic are compact and competitively priced, and are therefore mostly used for small, inexpensive passenger cars.
Motronic	Combined engine management system comprising gasoline injection and ignition. Series production from 1979. Motronic is based on a combination of L-Jetronic technology and electronically controlled transistorized ignition. Both functions are combined in a single control unit in order to ensure optimum engine management that takes account of all important parameters (engine temperature, load, engine speed, and changes in the engine, such as wear). This ensures minimum consumption and low emissions together with the best possible performance. Motronic is maintenance-free and designed to last for the entire service life of a vehicle. The only parts in the entire engine management system that are subject to wear are the spark plugs.

SBC	(see electrohydraulic brake)
Sensotronic Brake Control	SBC (see electrohydraulic brake)
Servo brake (power-assisted braking system)	Series production from 1927. Initially produced for trucks by Bosch under a license from the Belgian developer Dewandre. Later improved by Bosch and replaced with its own inventions. The servo brake works pneumatically. The vacuum generated in the induction tract of the engine when the driver releases the accelerator is used to increase braking force, so that the driver achieves a greater braking effect with the same braking pressure. These improvements were necessary in order to keep pace with increased engine performance and vehicle speeds, for which the power of mechanical brakes alone was no longer sufficient. In 1928, the smaller "brake support" for passenger cars was launched. Since the 1950s, pneumatic servo brakes have been gradually replaced by hydraulic servo brakes, which are now standard for passenger cars. Pneumatic systems are still used in trucks, though. Since the 1970s, hydraulic servo brakes have been supplemented by pneumatic brake boosters. Bosch know-how in this product area was extremely useful in the pioneering development of ABS, ESP®, and EHB.
Spark plug	Ceramic device with at least two electrodes. Series production from 1902. The spark plug was produced as an additional component for the high-voltage magneto ignition developed and launched by Bosch in 1902. The plug is screwed into the cylinder head so that the electrodes protrude into the combustion chamber. The high voltage induced by the magneto ignition or by the ignition coil creates an electric arc, i.e. a luminous electrical discharge from the outer electrode to the middle electrode, which ignites the air-fuel mixture. To date, Bosch has developed and produced approximately 20,000 different types of spark plugs for all kinds of applications, ranging from model planes to emergency power units.
Starter-generator	Combination of generator (alternator) and starter. Series production from 1933. Used for motorcycles and small cars. The advantage over separate components is its reduced size.
Starter ignition	Combination of starter and magneto ignition. Series production from 1932. Both functions are combined in order to reduce the size. Used for motorcycles and microcars.
Traction control system (TCS)	Series production from 1986. Traction control prevents the driven wheels from spinning. The electronic control unit reduces the speed of the wheels until they recover their grip. The system is an extension of ABS, and is generally combined with it in a single unit. Traction control is an early example of networking diverse electronic control units. When traction control is activated, it intervenes in the engine management or brake control system. Despite actuation of the accelerator, engine power is thus continuously lowered, or the brake is actuated, until the wheels recover their grip. Traction control can also brake one drive wheel individually in order to divert engine power to the other wheel if the latter offers better traction.
Traffic news decoder (ARI)	Series production from 1974. Traffic news was first broadcast in 1969. An ARI decoder (available separately from 1974, integrated in various car radio models from 1976) locates stations with traffic news so that the driver can always preset the stations that regularly broadcast traffic news.
Transistorized ignition (TSZ, TSZ-i)	Series production from 1964. The breaker-triggered transistorized ignition (TI) contains electronic elements called transistors. These ensure greater efficiency and a longer service life than mechanical breakers. Since its further development to a breakerless transistorized ignition with an electronic ignition impulse sensor instead of an ignition contact (TI-i, series production from 1974), transistorized ignition has been a completely maintenance-free system. It is no longer necessary to replace those parts that used to be subject to wear, such as the mechanical contacts. The precision of transistorized ignition also enables it to be integrated in electronic engine management systems (Motronic). Today's emission and consumption limits would not be possible without TI and its successors.

TravelPilot	Navigation system for vehicles comprising destination entry, route guidance, and speech output. Series production from 1995. The latest dynamic systems can also take into account the current traffic situation, e.g. traffic jams, or calculate the route with the lowest fuel consumption. Forerunner technologies included the experimental "electronic pilot for drivers" (EVA) and TravelPilot IDS. However, the latter did not include satellite-based navigation or voice output.
TSZ, TSZ-i	(see transistorized ignition)
Unit injector system (UIS)	Diesel injection system. In series production for passenger cars from 1998 to 2008. Unit injector systems combine a high-pressure pump and a nozzle in a single unit (one pump-nozzle unit per cylinder). This contrasts with traditional systems with a distributor or in-line injection pump, which transfer the fuel to the injection nozzles on the engine via a line. UIS allows maximum pressures of up to 2,050 bar, which are transferred one-to-one from the pump components to the nozzle that forms part of the unit. As far as design is concerned, this means that no space is needed for a pump or a rail system (as is the case with common-rail technology). However, the cylinder head needs to have an appropriate design, as the UIS elements on the head require more space than injection valves. The VW Group used the system in VW, Audi, Skoda, and Seat automobiles. "Pumpe-Düse" was the term used by the VW Group.
Vehicle dynamics control (VDC)	(see electronic stability program ESP®)
VDC	(see electronic stability program ESP®)



More often than not, there are Bosch parts under the hood: in 1928, more than 80 percent of all newly launched cars and trucks in Germany were equipped with a Bosch ignition system.

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Published by:
Robert Bosch GmbH
Historical Communications
(C/CCH)
Postfach 30 02 20
D-70442 Stuttgart

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Fax +49 711 811-44504

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