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1. Z stands for the Future: “BMW Technik GmbH” and its Projects.

When BMW founded “BMW Technik GmbH” 15 years ago, it was the result of a venturous idea: the idea of installing an innovative remote office, a type of think-tank, physically separated from all other development groups. The plan was to have selected engineers, technicians and designers from BMW who, for a specific time, would have all imaginable freedom to realize their best creative concepts, even by themselves.

It was one of the most fruitful ideas in the history of BMW.

Less than five minutes away by car from the corporate headquarters, a concentrated high-technology company was established which has long become a role model for the world. The think-tank is neither a design office nor a research laboratory, rather it is manned by specialists from various fields of research and development who find ideal surroundings for the typical BMW environment consisting of innovation, design and engineering. The team is comprised of about one hundred employees under the mantle of the “Technik GmbH” who are in continuous dialogue with their BMW Corporation colleagues, primarily with those in the research and engineering center (FIZ). Not only ideas, concepts and designs are exchanged, many specialists already have their FIZ developments in production, which originally emerged from the “BMW Technik GmbH”. In a very individual structure the team’s organization is project-orientated, flexible and detached from the current product selection at any given time. This small idea factory has its own design department and model construction, development department for packaging, body, engine, technical physics, computation, propulsion and frame, electric and electronics, as well as its own prototype construction. In addition to this, they have practically every conceivable piece of equipment including their own engine testing station – and the world’s first acoustic wind tunnel.

The World's First Acoustic Wind Tunnel for Cars.

Every BMW product must go through this 141 foot long and 49 foot high aero-acoustic wind tunnel before it reaches the market. The result is a higher degree of internal noise comfort thanks to minimizing the wind noise. Not only cars and motorcycles are buffeted by the stormy conditions in the tunnel with wind speeds up to 152 mph from its 2,000 kW works. Motorcycle helmets are also a target – and sometimes even skiers: BMW is a sponsor of the Austrian national ski team and takes its role as an active advisor very seriously. Even an historical phenomena was resolved in the acoustic wind tunnel: the reason for the infamous whistling which announced the rapid approach of the legendary 502 sedan from the 1950s, was finally traced to the grille, of all things, which today still possesses the typical design of the BMW brand – the BMW "kidney".
Generally the "Technik GmbH" orients its activities around technology or components. Besides the contract jobs that are managed by the development department, it can also select its own subject matter.

It ideally selects projects which require a high degree of innovation which means that tasks can be tackled which are technically motivating but may be risky. As a result, there is no obligation for every project ever started to be put into production. Many technical ideas simply can't be realized and are not pursued further.

The Z1: Product of a very specific work ethic.

BMW Corporation's first contract for the "Technik GmbH" had absolutely nothing concrete to do with the development of an automobile. This aim was adopted by the engineers themselves: The "ZT" team, so called by BMW internally, entered the scene with the task of inventing innovative partial aspects of automobile construction and they immediately overwhelmed everybody with an entire bundle of ideas which were then implemented in the concept of the Z1.

This approach is characteristic of this very specific work ethic and at the same time is proof of the power of creative freedom: viewed soberly, the Roadster Z1 was a pilot project for use of new con-struction materials, for a different style of vehicle design and for the reduction of development times. The work started in the second half of 1985 – three years later the first production version of the Z1 rolled out of the Munich factory. All tolled, 8,000 units were produced – today it has become a legend.

The body of the Z1 is its unique feature. Its skeleton is a monocoque style of chassis with a bonded synthetic base. The outer shell of the body is composed of elastic resilient plastic. Particularly notable characteristics are the sinkable doors which can be lowered using a sophisticated electromechanical system and the high side skirt which contribute significantly to a new level of passenger protection for a car of this type. The Z1's cart-like road handling provides an added measure of fun when driving. The Z1 was also the debut of the so-called central point guided, spherical, double suspension arm, which became well known as the Z-axle in the BMW 3 Series.

The E1: The first pure bred electric car.

Naturally most of what happens behind the unimposing brick walls of the "Technik GmbH" is strictly confidential. Therefore there are large gaping arithmetic and time lapses between the serially numbered Z projects which reach the public's eye. As a result, the next event which caused talk about the "Technik GmbH" was actually called the Z11 which then became known as E1. This was how this creative group realised their task of creating a pure bred electric automobile. Their main aim was to create a car that was typical of BMW with regard to originality, performance and functionality, but overall it should operate exclusively on electricity. The E1 was the star of the Frankfurt International Automobile Exhibition in 1991. And everyone who was able to drive it agreed on the unexpected performance and viability for daily use. Shortly thereafter, a somewhat larger American variation, the E2, based on the E1, was developed as part of a study. Some variations of this contained combustion motors.

One and a half years later in the spring of 1993, at the Geneva Salon, the "Technik GmbH" engineers and designers once again made the headlines. They surprised the experts with an automobile design which had never before existed: the fully functional prototype of an automobile which combined the benefits of a large comfortable sedan with the dimensions of a compact car. The appearance of the Z13 was a consequence of the statistic that on the average, even large cars are usually occupied by fewer than 2 persons. It was short with a sporty design and constructed as a single-seater with the steering wheel in the middle. Different than a racing monoposto, there is still room for two more passengers, one to the right and one to the left, seated halfway behind the driver's seat.

The C1: Two wheeler with car-like safety.

Once again, a different concept embodied the Z14 which came onto the market this spring as the C1. The “Technik GmbH” initiated an entirely new vehicle category, the C1, which combined the advantages of a motorized two-wheeler with numerous safety elements of an automobile. The C1’s safety concept allows driving without a helmet and protective clothing. This is possible because of a safety cell with shoulder bar and exchangeable deformation elements, safety belt, a special seat and headrest. In the event of an accident, a crash deformation element above the front wheel and the BMW telelever minimize the consequences. With its roof and windshield, the safety cell offers additional protection from the elements. It is driven by a 125 cc, 15 hp water-cooled four cycle engine with a three-way catalytic converter. Anyone who wishes, can even order the C1 with antilock braking (ABS).

Bike 2000: Driving Machines for the Demanding.

BMW brought out their third generation of a series of high-tech bicycles, the BMW Q6.S mountain bike and the Q5.T touring bike as driving machines for the demanding cyclist. The formation, new design and the revolutionary technology were clearly influenced by the “Technik GmbH” engineers. Thus the foldable aluminium frame has front wheel mountings using BMW’s telelever principle. The front wheel mounting and suspension/cushioning adopted from BMW motorcycles and the folding system, which is typical of BMW bicycles, provide the bikes with a unique position in this market segment and emphasise the goal, i.e. to provide mobility with quality.

The Z18: The curtain goes up for the secret all-terrain roadster.

For its 15th anniversary the “Technik GmbH” once again airs a secret and reveals a further spectacular concept car that awakens feelings of envy; the Z18. The idea: one of the most successful motorcycles of the nineties was the Enduro – a mixture of a street and a dirt bike. Why shouldn’t a variation of this theme be carried over into the automobile world? Thus the Z18 came the into being, which combines the roadster drive with the robustness and high seat position of an all-terrain vehicle. It is not by chance that the world’s first – and only – all-terrain roadster with its smooth surfaces and well defined lines, resembles a boat. The main feature of the interior is the central positioning of the instruments which have been reduced to a minimum. The variable concept allows the Z18 to be used as a two-seater, a two-seater pickup or a 2+2 with trunk space. The prototype which was constructed in 1995 had a drive-train like the X5 with the 4.4 liter V8 and four wheel drive in a steel

profiled frame structure and a plastic outer shell. Its 3,439 pound basic weight and the axle articulation of 3.91 made a husky and equally agile four wheel Enduro out of the 14 foot long runabout car in spite of its 114-inch wheelbase.

The Just 4/2: Car which is as fun to drive as a motorcycle.

It is easy for the Z18 to sneak incognito through the Bavarian forest roads because the “Technik GmbH” presented the public with yet another eye catcher for its tenth anniversary. The Z21 which was christened with the expressive stage name, Just 4/2, stood on the BMW booth like a public magnet of the first degree at the Tokyo Motor Show in 1995. Just as the name says, (just four two) it is a motorcycle on four wheels: a two-seater with open wheels, without a roof or windscreen. It is suitably driven by the four cylinder engine from the BMW K 1100 as a rear engine with 100 hp, which catapults the 1212 pound runabout to a speed of 62 mph in about six seconds. The instruments tell the driver the most important things but not more. This has nothing to do with thriftiness as no safety equipment is missing from the Just 4/2. It also has side-impact protection and driver and passenger airbags are included, of course. And then there are a multitude of new ideas such as a trunk which can be carried like a suitcase and is, therefore, a trunk and suitcase in one. There are also accessories for the driver and passenger which are as chic as they are practical with everything from a weatherproof outfit to a helmet – everything matching the Just 4/2.

As different as the projects were over the 15 years of the “Technik GmbH” – the lightweight construction theme has become a common thread throughout the “ZT” projects. This started with the Z1 with its monocoque, and continued through the Z13, E1 and C1 with their aluminium space-frames and on to the 5 Series of the E34 generation which the Technology Corporation equipped with a full aluminium construction and an aluminium rear axle. These were adopted by the current 5 Series, almost unchanged.

For its 15th anniversary the “Technik GmbH” is presenting the Z22. Even for this one there will be repercussions. There is also sure to be an equally interesting successor.

2. The Z22:
The super-light Mechatronic Car.

“BMW Technik GmbH” presents the Z22, the lightest and most advanced mechatronic car which has ever been presented to the public. Mechatronic is the generic term for “mechanical system with electronic control” and together with lightweight construction will revolutionize automobile technology in the years to come.

In both of these key technologies the Z22 sets a new standard with its 70 innovations and 61 patent applications: “steer-by-wire” and “brake-by-wire” in the Z22 have completely replaced mechanical steering and hydraulic brakes; the electronics concept is without comparison in its efficiency and versatility. An innovative horizontally divided body which separates into functional frames and cells solves the conflicting goal of comfort and that of lightweight construction by using a new carbon-fiber technology which is nearly ready for production. By having this the Z22 has a fuel consumption of only six liters per 100 km during normal running conditions, however the driving performance, comfort and interior space fit into the category of the 528i sport wagon with automatic transmission, but with even greater safety.

Although it was projected to be just a feasibility study, this flagship of technology is a full-blooded and ready-to-drive car that requires no more time to get used to than does a conventional car. However, in spite of this, you can still expect a comparatively effortless and relaxed driving experience with a multitude of new possibilities.

Project goal: Automobile technology for the years after 2005.
The Z22 is the most demanding car project of the “Technik GmbH” and simultaneously is the most comprehensive flagship of technology that has ever emerged from BMW. The goals of the project which began in 1995 were visionary, however still in touch with reality: it was supposed to be a car with the pick-up and elasticity of today’s 528i sport wagon, with an automatic transmission, speeds up to 112 mph and fuel consumption of only 6 liters per 100 km. To make it even more of a challenge: the car had to offer at least the comfort of the 5 Series sport wagon, be able to be manufactured in units of 100 per day, fulfill economy, environmental, energy balance and recycling requirements as

well as meet the newest safety standards. All of this was supposed to be ready for implementation in production projects as of 2005. And finally within these specifications it was still supposed to be a typical BMW.

These goals required an all-inclusive approach made up of new car packaging, technologies, construction methods and materials. An innovative and special car concept with a four-cylinder engine, mounted transversely in front of the rear axle, came into being. Thereby it was possible to relocate the heater/air-conditioner in the interior in front of the front wall, where an electronic air conditioning compressor with stop-and-go operation provides cooling as needed. Simultaneously due to the space that was gained, a new approach to the interior design and instrument panel was developed. Thus the slightly raised seat position is more convenient when entering, provides a better view and better passenger protection. In total the Z22 combines the wheelbase of a 7 Series with the turning radius of a 5 Series. It is as short as a 3 Series and has the space of a 5 Series.

Key Technology Lightweight Construction:
Innovative Body Concept.

The consumption and driving performance prerequisites could only be fulfilled by a car whose weight is under 2,425 pounds. Thus the Z22 weighs as much as a modern compact car and about 33 percent less than a 528i sport wagon. This was made possible particularly through an innovative body concept which divided up the construction horizontally into functional frames and cells. This was for many reasons: the division allowed the correct usage of such basically different body construction materials such as aluminium and high performance fiber-reinforced materials. Compared to steel, the weight of the building components can be reduced by up to 50 percent. At the same time the position of the passenger cell in the vibration nodes of the function owner provides good insulation from sound through the structure. Resulting from this, it was possible to integrate the chassis into the aluminium functional frame without an insulating axle carrier which combines consistent lightweight construction with predominantly ideal kinematic and elasto-kinematic characteristics. By using by-wire technology in its entirety it was also possible to detach the mechanical components from the interior. This partitioning also has production technology advantages: the manufacturing time was seriously under that of a 5 Series sport wagon.

A striking example of using fiber-reinforced material is the side panel which is made out of one piece of carbon-fiber-reinforced plastic (CFK).

This component which stretches from the A-pillar over the entire length of the car is composed of a high-performance reinforced material with 50 percent of its volume being fiber and weighs only 42 pounds. A comparable sheet metal part would weigh about twice as much. In addition there is the dimensional stability of this new material with its length differential of less than 0.15 inches. From the tip of the side panel to the B-pillar, the side panel is manufactured by using a sandwich construction and by means of this a hollow profile. The entire frame was made “in one shot”, to quote plastics terminology, and then hardened in less than 20 minutes. Furthermore the floor group, roof, tailgate and parts of the doors are made out of CFK. The Z22’s body is made up of a total of 20 components, today’s norm is over 80.

The biggest challenge in using fiber-reinforced structures is clearly in automating the production processes for a limited series. Therefore it was intentional that six various procedures on various components were implemented to expose the strengths and weaknesses of the processes.

The frame concept also subscribes to this philosophy and contains very light components but still can be produced in the expected number of units. Titanium LCD springs, magnesium rims and fiber-reinforced steering rods resulted in 50 percent lighter axles as compared to the 5 Series.

Key Technology Mechatronic: Electronic Steering and Braking.
The electronic throttle control regulator, introduced as the “E-Gas” with the BMW 750i, has long since passed production testing: replacing a mechanical connection with an electronic one and using an electromechanical actuator doesn’t result in any disadvantages in reliability and safety; however it does have significant advantages for comfort, reaction speed and reaction quality.

The Z22 opens up a new chapter in “by-wire” technology: steering as well as braking are now only initiated electronically. The driver continues to use both the steering wheel and brake pedal, which have no changes to their basic function, but they can make full use of the benefits of the new technology based on advanced capabilities and characteristics. By doing away with mechanical components such as the steering column and parts of the foot pedal mechanism, the passengers passive safety and comfort are increased. By not having a steering column, the foot pedal mechanism can be displaced lengthways by 2.4 inches, which results in even better adjustments to the seat position. The power supply

required for all electrical systems including the by-wire features is provided by the crankshaft starter generator (KSG) with a five kilowatt capacity as well as by additional buffer batteries. A hybrid power network provides power levels of
14 volts, 42 volts and 200 volts.

The Electromechanical Steering:
More comfortable in the city, more secure on the motorway.
Conventional mechanical steering has a fixed gear ratio which, even though it becomes more progressive with each turn of the wheel, always transmits the driver's steering commands the same way. That forces a compromise which applies to all speeds and driving situations: the conflicting goals of agility, stability and comfort.

This imposition is removed by the electromechanical steering: the benefit of steer-by-wire is that the car's driver can maneuver more comfortably and safely:

- When parking, the steering wheel resistance is translated in an increasing progression; the wheels reach the full lock position without your having to cross your hands over the steering wheel.

- For city and country road traffic the steering translation is more direct than a conventional steering system which means the car reacts with more agility.

- With increasing speed the translation becomes more indirect, quick driving maneuvers such as swerving in front of an obstacle can be safely controlled with intuitive steering wheel motion.

- Driving on the highway on straight stretches is easier with the improved stability – independent of the load.

- Irregularities on the driving surface, for example because of sewer lids or cobblestones, are directly suppressed by the front wheels as well as by the steering wheel.

- Only the steering forces which are important for each driving situation are reported back to the driver through the steering wheel.

- The steering wheel returns to its original position without overrunning and it adapts to the speed.

To achieve these functions the electromechanical steering is made up of the steering wheel module, steering drive module, controller and the battery module. The steering wheel module registers the driver's demands and returns a feeling to the driver of steering that is typical for a BMW. The steering wheel is connected to a brushless DC motor with integrated drive electronics which creates the return torque. The steering wheel angle is limited to 160 degrees, at full lock the turning radius is less than 36 feet. The maximal transverse acceleration of about 1g can be reached at any speed.

Angle sensors measure the steering angle and torque sensors register the steering wheel torque. The steering drive module translates the driver's demands into steering motion in the front wheels and determines the return force from the wheel/road contact. Two DC motors drive the cogwheel in the steering drive with a gearbox. The controller uses the measurement data from the steering wheel and the steering drive module to establish the controlling signals for the electronic drive. Simultaneously the controller monitors all system components and warns the driver if there is a fault. The battery module assures a connection to the Z22's onboard power network on one hand and on the other, in case the onboard network fails, it provides an emergency supply by means of its own buffer battery.

Safety was the top priority during the steer-by-wire development. Even if there is a fault – according to the prerequisites of the Z22 project – the ability to steer must be maintained independent of the type or location of the fault. Based on these requirements a redundant system was created. A set of sensors is assigned to every piece of steering equipment and every piece of steering equipment and every controller independently calculates a control signal for each of the three actuators. For each actuator, fault-tolerant monitoring systems, called "voters", decide according to plausibility which control signal will be used. Each actuator is monitored by each controller. The driver's warning is also redundant and follows the dead man's principle: if the system no longer produces the permanent function signals then the warning is activated. The achieved redundancy is nevertheless purely for test operation because the legal requirements have currently not been defined.

The goal of the development was the safe realization of electro-mechanical steering. For this purpose the engineers did a lot of underlying development of safe drives and sensors, of safe power supplies and safe software. Over 5000 miles are behind the

electromechanical steering so far. There have been no accidents yet, only a lot of fun driving.

The Electromechanical Brake: Safer and more comfortable.
Already in today's production cars, electronics have an active hand in brake systems. The stability system–DSC–functions by individually braking specific wheels and the DBC controls the build-up of brake pressure by computer as needed. Only when transferring power to the brake pads do conventional automobiles follow the traditional methods of hydraulics.

The "BMW Technik GmbH" engineers have taken the next logical step with the Z22 by developing an electromechanical brake. This means that not only the complicated hydraulic system with its power brakes is no longer necessary but all functions such as ABS, CBC, DSC and DBC are exclusively contained in the central controller. The advantage is not only in the integration but also the driver can make better use of all current functions and new ones as well:

- Potentially shorten the braking and stopping distance.
- Brake pedal with the same pedal force independent of car load or lower pad friction due to thermal stress.
- Automatic parking brake works on all 4 wheels.
- Automatic braking when stopped, e.g. hill starts or red light.
- Comfortable braking with smooth stop.
- During ABS control no retroactive transfer to brake pedal, quiet operation.
- No crash-induced pedal intrusion.
- Comfortable implementation of autonomous braking interventions.
- Easily adjustable pedal module.

Furthermore brake-by-wire provides dynamic distribution of the brake force, thus when braking in a curve more force is applied to the brakes on the wheels on the outside of the curve. There is also a greater use of the rear wheels when braking in a straight line and there is a reversal of

the distribution of the braking force when driving forwards and in reverse. In all, the electromechanical brakes offer the optimum between braking distance and braking stability.

The driver feels practically no changes to the Z22's brake pedal – except the conveniences. However instead of the hydraulic pressure, he moves his foot against the force of a pedal simulator which has freely selectable characteristics. It electronically captures the driver's braking signals with sensors, analyzes them and passes them on to a central unit. There they are processed with additional external signals from the driving conditions and perhaps from braking requirements from additional control systems. The central control continually calculates the optimal application pressure individually for each wheel while taking driving stability and brake characteristics into consideration and then it forwards them to the wheel electronics. Now, instead of the conventional brake shoes, electromechanical actuators press the brake pads against the discs. The actuators are mainly made up of permanent-magnet motors with a subsequently connected drive for converting the torque and rpm, and with a spindle to create the translational motion. The application pressure which occurs can reach many tons.

The actuators used in the Z22 underwent ongoing development in the meantime. As a result the high dynamics of conventional brake systems has been achieved. The parking brake was realized by a braking device integrated into the actuator. It is controlled by a manually operated electronic push button.

Just as was the case for steer-by-wire, fundamentals had to be developed for safe drives and sensors, for safe power supplies and safe software. In addition an ingenious fault-tolerant system structure only shuts off individual defective actuators if the worst happens, and still provides safe emergency operation. Just as with the electromechanical steering, the electromechanical brake system has already successfully passed many thousand trial miles – without any particular incidences.

Key Technology Ergonomics: Electronics and operator concepts pointing the way to the future.

The Z22 has a powerful and versatile electronics concept like no other car ever presented, which makes a series of additional solutions possible for the first time. 46 controllers or components exchange their information over two interconnected optical data-bus systems. To increase the EMC security and to transfer large volumes of data, the body's CAN-Bus as well as the audio and communications bus contain

a total of 427 feet of optical fiber with a 100 megabit/s throughput. The Z22's power network is independent of the data network. The data and power networks form the basis for the motor control, transmission control, steer-by-wire and brake-by-wire as well as for a series of new functions and further innovations. For example these include:

- Fingerprint instead of key: today's key will be replaced by a biometric system. Entry and authorisation to drive result from a fingerprint so that the driver doesn't have to take any extras for his drive. In the same way, all doors are equipped with electromechanical locks.

- Intelligent light technology: The curve light and also the intersection light are turned on and controlled depending on signals from the car. The flat construction tail lights weighing 1.7 kilograms are constructed using optical fiber technology for the white reversing lights and LED technology for the remaining tail light functions. The interior lighting consistently contains fiber-optic rods and cables.

- Cameras instead of mirrors: Today's two exterior mirrors and the interior rear-view mirror have been replaced by cameras. By using image processing, a single panoramic image is created out of the three individual images and is shown on an 8x3 display in the place of the interior rear-view mirror. This totally eliminates the blind spot.

- Heads up display: All primary information for the driver such as speed, driving level, warning lights and level indicators or navigational information are projected onto the windscreen on a heads up display – the Z22 no longer has conventional com-bination instruments. The focal point has been selected such that the driver has a virtual image about 7.5 feet in front of him.

The Z22 uses this technology as a key element to create an interface between the driver and the car which supports the driver in the most optimal way without diverting attention away from driving duties. This is a philosophy which is followed by the entire display and operator concept. That way the Z22 only has a center monitor in addition to the rear view mirror monitor and heads up display. The specially shaped multifunction steering wheel and a central operator control element in place of today's gearshift, known as the Man-Machine-Interface (MMI), is all that is needed for the entire operation. BMW has already presented the MMI technology in the Z9 at the Frankfurt Auto Show (IAA) in 1999 and a further variation is just about ready for production.

By using the assigned push buttons on the multifunctional steering wheel, the driver can change gears with the STEPTRONIC, use the cruise control and horn as well as set the foot pedals and heads up display. The central MMI is composed of a six-position rotary switch and a keypad. To start the engine, the driver has to place his finger on the rotary switch which uses the fingerprint – as did the door – to determine if he is authorized to drive. Afterwards he can use the rotary switch to start the engine and select the program for the CVT drive. The keypad behind the rotary switch contains keys for the parking brake, four-way flashers with an integrated emergency call function. volume control, central locking, window controls as well as child-proofing the doors and windows.

The innovative heart of the multifunctional steering wheel and the MMI is the navigator, a roller between two keys – by using these three elements, all additional functions in the Z22 can be controlled by a dialogue with the center monitor. By using the roller and the keys, the functions are selected or set. Press the roller to alternate between selecting a function and setting a parameter. The navigator connects the driver and passenger with the multiple options in the audio system, air conditioning, communications and navigation. Furthermore, as an alternative, the most important functions can be voice-controlled.

Overall, this innovative operator concept has already proven to be a total success: in a series of tests, testers were able to complete their set tasks without a long learning phase. They rated the operator and display concept very positively in spite of the multitude of known and new possibilities. The reason: the system is natural and intuitive to operate. Pure ergonomics.

3. Key Technology Mechatronic:
BMW presents the first steer-by-wire steering for production use.

BMW develops the first mechatronic steering for production use: the steer-by-wire system made with active electric/hydraulic power-steering and electronic overlap steering. This has set new standards in safety, agility and comfort. The system with its development name, Active Front Steering (AFS), evens out yawing motion for example when braking on road surfaces where the right side and left side of the car are on different textured surfaces by optimal counter-steering and stabilising the car without the driver even noticing. In practice more braking force can be transferred and therefore the braking distance can be reduced by up to ten percent. Basically AFS can intervene for more stability with slight corrections to the steering angle of the front wheels much earlier than the DSC stability system which works through the brakes and it is an ideal enhancement to DSC. Thanks to the innovative steering, the car clearly reacts with more agility and precision when driving in a sporty way. In city traffic and when parking, steering is reduced to effortless steering commands.

Today AFS is the step leading to the future of pure steer-by-wire which has already been implemented by “BMW Technik GmbH”. However this can not yet be approved according to today’s regulations. The development of Active Front Steering is so far advanced that BMW will offer such a system in one of the next model generations.

Greatest safety through mechanical basic steering.
The core of Active Front Steering is known as overlay steering. In the partitioned steering column there is an integrated planetary gear. In this planetary gear an electric motor intervenes with a self-inhibiting spiral drive and if needed, creates an additional – or reduced – front wheel steering angle. Another component is regulated power steering.
A regulator provides the control for steering wheel torque and front wheel steering angle and adapts them to the driving situation. This produces ergonomic as well as driving dynamics advantages.

Because of the permanent mechanical connection of both steering column parts by cogwheels, this gear concept guarantees that you can still manually steer even if a fault is caused by simply turning the motor

off. AFS then fulfills the highest safety requirements much easier than other systems without permanent mechanical steering.

Advantages and Capabilities of Active Front Steering.
This is how Active Front Steering already offers the definite capabilities and advantages of a fully electronic steer-by-wire:

- When parking, the steering wheel resistance is translated in an increasing progression, the wheels reach their full lock position without the driver having to reach over the steering wheel. The steering torque is comfortably low.

- For city and country road traffic the steering translation is more direct than a conventional steering system which means the car reacts with more agility.

- With increasing speed the translation becomes more indirect and is more like the usual standard when driving on the highway. Simultaneously the steering inertia level is set to hinder unintentional steering movements.

- Quick driving maneuvers such as swerving in front of an obstacle are done more spontaneously and can be safely controlled with intuitive steering wheel motion. In critical situations the driving dynamics regulator improves the stability so that in most cases a DSC intervention isn't necessary.

- For a µ-split brake (the right and left sides are on different road textures) the forward motion and driving stability are additionally improved.

AFS resolves the conflict that every conventional power steering has. Today's mechanical steering has a fixed gear-ratio which is progressive with increasing turns of the wheel, but the driver's steering commands are always transmitted in the same way. That forces a compromise which applies to all speeds and driving situations: the conflicting goals of agility, stability and comfort. By stepping over to steer-by-wire the driver can maneuver the car much more comfortably and safely under normal situations.

4. Key Technology Lightweight Construction:
BMW develops the first reinforced carbon-fiber and lightweight metal technology for production cars.

BMW is developing a totally new technology under full steam with which the entire passenger cell in production cars can be manufactured out of carbon-fiber-reinforced plastic (CFK). Even this year the first test units will be finished and can prove their exemplary passive safety. Through this, BMW assumes the leading role in developing a significantly lighter car which in addition is safer, more comfortable and sporty. In the next few years the development of processes and manufacturing technology for the construction of production cars should be completed and production compatible tool created. Afterwards there is technically nothing standing in the way of production.

Carbon-fiber-reinforced plastic in the body structure offers the greatest potential to reduce a car's weight according to the state of modern technology. The highly durable material weighs up to 50 % less that sheet steel and up to 30 % less than aluminium profile. Less car weight also means lower fuel consumption. Today carbon-fiber is only used in constructing automobiles for racing. For example the monocoque of the BMW team's Formula 1 racing car is made out of this material.

BMW has already presented the Z22, a technology flagship whose entire side panel is made of CFK. The decisive manufacturing and process technology necessary for series production is being developed in the Landshut innovation and technology center (LITZ). This technology center in the BMW group's factory in Landshut is made up of the branches, LITZ Plastics and LITZ Lightweight Metals which each develop and test processes to manufacture weight-optimised automobile components. The LITZ is the center of the entire lightweight construction strategy which BMW is pursuing for designing future car generations .

The low density of plastics, which ranges from 25 percent to one percent as compared to steel, makes it predestined to be used for lightweight car construction. Another BMW test case currently under construction will be 30 percent lighter than an equivalent production model and at the same time it will be made out of fewer components. This means further simplifications such as time and cost savings in

series production. Other examples are technologies for manufacturing plastic surfaces in cockpits and door coverings. With the same or an improved surface quality, a weight reduction of up to 35 % is possible.

The greatest chances for the future are being awarded by all the experts in the automobile industry to thermo-plastics and duro-plastics. In the future they will decisively influence the state of automobile technology. BMW's focus is on technically further developing fiber-reinforced materials to be able to repeatedly manufacture high quality innovative lightweight construction products under production conditions. Extremely lightweight construction solutions can be achieved by using reinforcing fibers such as glass, carbon or even aramid in the form of roving, laying and fabrics. The LITZ plastics branch is viewed as one of the world's leading centers.

Lightweight metal technologies open new savings potential.
BMW also made great progress by combining lightweight metals to save weight and simultaneously improve component characteristics. That way they were able to reduce the weight of the coupe door by 16.5 pounds simply by using aluminium and magnesium. Both lightweight metals are used in such a way that the door still completely fulfills all crash requirements. Furthermore all aluminium and magnesium parts can be manufactured in serial production.

Even in the engine technology field, using a combination of various lightweight metals promises major savings. Similar to the developmental step from a cast metal crankcase with an aluminium cylinder head to an all aluminium engine, there is a significant potential to reduce weight by changing to a magnesium crankcase with an aluminium cylinder head.

The developers are quite optimistic about the first concrete results, however this doesn't solve the well known corrosion problem in the coolant area. Engine developers and process technicians are hot on the trail of this problem. With just a straight six cylinder engine, this new technology saves between 11 and 15 pounds per engine as compared to today's production equivalent.

BMW's own developments in process and manufacturing technology open further potential for reducing the fuel consumption of future cars. With this new technology BMW is continuing its strategy to only use materials whose characteristics are optimally suited. This means for the body as well as the drive and frame. This future direction of manufacturing technology will be developed in the LITZ Lightweight

Metals branch that was opened only eight months ago. Just like LITZ Plastics, LITZ Lightweight Metals researches and tests processes and procedures to manufacture weight optimised automobile components. LITZ Plastics has already developed body structure parts, door reinforcements and integral axles out of aluminium as well as door and body parts out of magnesium. A front panel for the 3 Series convertible, which in conventional steel construction is made by welding together twelve individual parts, can be manufactured as a single cast aluminium component with better static characteristics. Furthermore the possibilities of combining highly durable plastics with lightweight metals is being researched. The development includes a very light and resilient brake disc made of a carbon-fiber friction ring with a steel insert which is bonded to an aluminium casing by friction welding. Friction welding of different materials is an innovative development which BMW already uses in the manufacturing of universal shafts in series production.

Development helper:
One of the world's largest pressure-casting machines.

The focal point of the manufacturing technology development at LITZ Lightweight Metals is the possibility of opening up new innovative application areas of pressure-casting technology. At the heart of LITZ Lightweight Metals is one of the world's largest pressure-casting machines. With its compression of 4,400 tons and weight of 290 tons, it is quite literally the heaviest instrument for lightweight metal development. The hot lightweight metal, with a temperature of up to 1300 ◦ F, is injected into the machine at speed of 230 feet per second – about 155 mph – or it is pressed in with pressure up to 14,500 psi.

This pressure-casting process is the only casting process that provides the ability to manufacture components which have a large surface area and a thickness of less than two millimeters – indispensable for major weight reduction. The surface area which the machine provides is 9.1 feet by 9.1 feet, which is enough for entire doors or gates. The pressure-casting process is still distinguished by its high productivity, high retention of dimensions and that it can be fully automated.

Furthermore, the re-equipped warehouse space gives the LITZ Lightweight Metals developers the possibility of trying out innovative technologies such as using water-jets to cut cast components or producing a small series of parts to gain additional process know-how. A computer tomograph is available in Landshut so that faults can be recognized without destroying the part and that the dimensions can be checked.