Innovation Days Connected Drive meets Efficient Dynamics.

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Introduction.

Under the term Connected Drive, the BMW Group already unites a unique portfolio of innovative features that enhance comfort, raise infotainment to new levels and significantly boost safety in BMW Group vehicles. Whether it is the latest traffic updates, Advanced Emergency Call, Surround View, email and internet access, or hooking up mobile phones and audio players – thanks to BMW ConnectedDrive and MINI Connected features, your car can be your personal concierge, guardian angel or entertainer, as the situation demands.

In future, Connected Drive will be extending this portfolio with numerous new features arising from the link-up between driver, vehicle and surroundings. On the information and entertainment front, for example, connecting with web servers is opening up fresh possibilities, while mobile devices mean that vehicle functions can be used virtually anywhere, and application-based programming ensures the car's functions are as up-to-date and extendible as possible.

In terms of safety, Connected Drive innovations significantly widen the driver's scope of action and reaction, so that in critical and poor-visibility situations on the motorway, in heavy city traffic or when parking, the BMW Group driver assistance systems help avoid hazardous situations and accidents, or mitigate their consequences.

The scenario becomes even more interesting when the developers link up the Connected Drive features with other vehicle functions, such as Efficient Dynamics technologies. Indeed, Connected Drive information and sensor data perfectly complement the fuel-saving measures of Efficient Dynamics. The upshot is that the car can recognise "green" routes, get to know the driver, his driving style and the traffic environment, and consequently "look into the future" to some degree. This holds out the prospect of the car being optimally prepared for driving situations ahead.

Good prospects.

The sheer number of highlights presented here from the current state of research and development demonstrates just how intensively the BMW

Group is working in the multifaceted field of vehicle networking and the potential it sees within this area. The projects outlined below offer a glimpse of the next logical steps as well as the automotive future from the BMW Group perspective.

1. Infotainment, navigation and personalisation – getting to your destination in comfort and in the know.

When it comes to infotainment in particular, the boundaries between “at home” and “on the road” are gradually dissolving. The car is being transformed into a hub within the overall network of information, entertainment and comfort features. BMW Group engineers continue to pursue their goal of turning the car into an integral component of the customer’s (digital) way of life – and never before have the possibilities been as far-reaching as today.

1.1 The car key of the future.

These days, your average car key can generally unlock and lock a vehicle as well as start the engine. Some car keys are able to store vehicle-related data, such as mileage, fuel level, battery charge level or service data, though this information can only be read by the appropriate appliance at a specialist garage. Beyond this, the keys of BMW Group vehicles are also used for customisation purposes. Favourite radio stations and settings such as one-touch indicator flashing can be allocated to individual drivers via the car key. The BMW Group believes that the car key of the future will allow personal access to a new mobility experience and offer a significantly wider range of features. It will permit the simple and convenient use of future services along the travel chain and in everyday use. A BMW Group research prototype demonstrates the kind of possibilities this would open up: these days the key is already able to store tickets for public transport (KeyTicketing) as well as vehicle information (KeyInfo); it can be used to make payments (KeyPayment) and opens not just cars but hotel rooms as well (KeyAccess).

Near Field Communication (NFC) as an interface for intuitive interaction.

Here the essential prerequisite is to extend the key's electronics by a communications interface with related intelligence. To this end, BMW Group specialists have added an NFC (Near Field Communication) interface and a security controller to a current BMW car key as a basis for interaction with contactless payment, ticketing and access systems.

NFC is a wireless communications technology that is based on RFID (radio-frequency identification) and allows intuitive usage scenarios at short ranges of under ten centimetres. It involves briefly holding two NFC-enabled devices close together to activate the relevant response. The maximum data transfer rate is currently 424 kbit/s. NFC transfer technology is already widely used today, for example in contactless payment systems by credit card companies. E-ticketing systems, where travel or admission tickets are stored on contactless media, are also gaining in popularity. In some countries NFC technology is being used for personal identification in passports and ID

cards; Germany plans to introduce such an interface for identity cards in autumn 2010.

Experts at the BMW Group have further developed the technology and integrated scenarios like these in a car key. BMW Group car keys already meet very high safety and reliability standards; they are far more secure than mobile phones, for example, since the many communications channels on a mobile – such as GSM, Bluetooth and WiFi – as well as the danger of inadvertently installing faulty software (emails with attachments, reloadable applications etc.) present a frequent risk factor. In the case of the car key, the BMW Group uses appropriate security modules and devices to determine who may access the data in the key and when, thus ensuring that the channels are suitably protected.

"A key is the perfect medium for storing sensitive data. And if you should lose it, all functions can be disabled by a single phone call."

Thomas Kratz, Development Access and Authentication Systems

Added functions through connectivity.
The NFC interface in the research prototype already allows for a range of new functions. For example, the driver can purchase a train ticket (KeyTicketing), call up the latest vehicle data for display on a mobile device (KeyInfo), make a contactless payment (KeyPayment), and even open hotel room doors (KeyAccess).

KeyTicketing – paperless tickets, please.
If the navigation system warns of congestion in the town centre or the driver wishes to make a particular journey by rail, he can use KeyTicketing to purchase the relevant ticket for use on local public transport or a train service from the comfort of his car and have it stored on his key. Using the iDrive Controller, he can select the destination and confirm the purchase of the requested ticket. As an alternative to this form of booking via the display and iDrive, the driver will in future also have the option of requesting the BMW ConnectedDrive call centre to search for the most suitable connection. Following confirmation by the customer, the relevant ticket is then booked, e.g. from the servers of Deutsche Bahn, paid for and sent to the car via the existing BMW Online connection. The car automatically transfers the ticket to the customer's key via the available UHF (ultra high frequency)

interface, which is also used for remote vehicle locking and unlocking. The customer can now proceed straight from the car to the train without having to buy a ticket from a machine or print out an e-ticket.

"Unwelcome waiting periods, lack of small change or complicated pricing systems will no longer be a problem in future."

Dr. Jörg Preißinger, Research RFID Technologies, BMW Group Research and Technology

Once on the train, all the passenger needs to do is hold the car key to the conductor's data terminal for the booked ticket to be read. Today this kind of handheld unit is already able to validate e-tickets stored on mobile devices, for example. But the electronic train ticket is just one example taken from the broad spectrum of KeyTicketing applications; in principle, entry tickets for all kinds of events with NFC-based access can be stored on the smart car key.

KeyInfo – all vehicle data at a glance while on the move.

The idea behind KeyInfo is to grant the driver access to important vehicle information even when he is not in the car, by means of a mobile device with an NFC interface. The data currently obtainable includes the open or closed state of the vehicle, mileage, fuel level, battery charge level (for electric vehicles), latest alert messages, service data, GPS location of the vehicle and stored tickets. This allows the driver to double-check whether the car is locked or see when the next service is due. A proposed CarFinder would be able to read the password-protected GPS position data and guide the driver back to the car if he is having difficulty finding the parking space. The charge level for an electric vehicle, moreover, tells you whether the range is sufficient for a detour via the park or lake. The possibilities are numerous, as this set-up basically allows for the display of any kind of vehicle data and conditions while on the move.

"If I'm unsure whether I locked the car, which carriage my reserved seat is in, where my car is parked or how full the tank is – KeyInfo has all the answers."

Dr. Jörg Preißinger, Research RFID Technologies, BMW Group Research and Technology

The user's mobile device merely acts as a display unit, while the sensitive data remains on the key. The requirement for using KeyInfo is an NFC-enabled device with the BMW application installed. Data is automatically transferred from car to key at certain points, for example when the driver exits the car. Password protection for access to the relevant data is already in place.

KeyPayment – paying with the car key.

The car key of the future will also serve as a contactless credit card. Thanks to a steadily growing infrastructure, this is already possible at many contactless payment terminals around the world. Since the car key – unlike a conventional credit card – is always there during a car journey, the customer's ability to pay when travelling is ensured.

"Hold your key to the terminal and the payment is made – quickly, conveniently and simply, thanks to KeyPayment."

Thomas Kratz, Development Access and Authentication Systems

Following the pattern of contactless credit cards, micropayments of sums up to approx. 25 euros can be made quickly and simply. Again, all you have to do is hold the key to the terminal once. Larger sums can also be paid, but these require additional authorisation by the customer in the form of a signature or PIN, as when paying by ordinary credit card. Integrating the credit card function into the car key opens up further options for using services and applications from the car. These might range from new insurance and financial services to acquiring new vehicle software, all the way to drive-through payments allowing the customer to pay for a fuel bill, parking ticket or road toll from inside the car. Even paying at drive-in restaurants would be another conceivable option based on this concept.

KeyAccess – a key that unlocks many doors.

"After a long journey, you arrive at your hotel and bypass reception as you head straight for your room – thanks to KeyAccess I'm already given my room key while I'm in the car."

Dr. Jörg Preißinger, Research RFID Technologies, BMW Group Research and Technology

Based on the infrastructure described (KeyTicketing, KeyPayment), today a hotel room can be booked from the car and electronic access

authorisation stored on the car key. Hotel room doors equipped with the appropriate technology can already be opened by car key. Instead of the contactless key card handed out by the hotel, you simply hold your key against the door lock. Future applications might also include the car key replacing the conventional house key or other access systems such as card readers. Likewise, the key could store access authorisation to the workplace and thus dispense with the ubiquitous company ID card.

The key vision.

The possibilities extend beyond the four scenarios described, however. In future, via an interface at home the key could also enable personalised access to the BMW ConnectedDrive internet platform and thus allow numerous functions to be configured for even better and convenient control – without the need to enter login names, passwords or PINs. In this way, the intelligent car key would also open virtual doors. Vehicle settings and content compiled at the computer, such as a carefully plotted holiday route, are automatically uploaded to the car the next time it is used, the key serving personalisation, authorisation or even data storage purposes.

On a holiday trip, the smart car key of the future could do more than open hotel rooms: if, as well as booking an e-ticket, you also need a hire car to continue your journey, the smart key could also store the necessary authorisation to open and start the hire car – dispensing with the need to pick up the key for the hire car at an office. If the car key has stored authorisation for use of the hire car, KeyInfo can also display the car's location on a mobile phone to enable it to be found easily. Personalised settings and functions from one's own car would also be available in the hire car. And, needless to say, similar solutions would also be conceivable for company vehicle fleets. It isn't even necessary to develop all these solutions for the BMW key of the future since such functions are already partly available and partly in the offing; the "key" factor is that they could all be "opened up" using just one key.

"Our vision is that, in future, the key will not only mean access to the car but, inside and outside the car, will become as it were the 'key' to many functions. I would then be able to set out while checking for just one thing: Have I got my BMW key on me?"

Thomas Kratz, Development Access and Authentication Systems, BMW Group

1.2 My BMW Remote.

BMW remote functions allow individual operations to be controlled from outside the car, such as locking and unlocking doors or adjusting the climate control. Currently, the driver can ring up the BMW ConnectedDrive call centre to have remote functions carried out. The services are made available once the driver has provided his BMW ConnectedDrive login name, password and memorable information for authorisation. With My BMW Remote, the BMW Group developers are now transferring these remote functions to a smartphone application so that the user can access them directly from a mobile phone.

"With My BMW Remote, the customer has access to all BMW remote functions anywhere, any time."

Daniel Koitzsch, Development BMW ConnectedDrive

Following download and installation, the user need only register the application once – for the initialisation process – by entering his BMW ConnectedDrive login name and password and providing his memorable information. From then on he can use the services as often as desired without having to sign in repeatedly. Usage is reliably protected by the mandatory input of a self-selected PIN whenever the application is started.

And more functions.

In addition to locking and unlocking the car, the driver can also use My BMW Remote to access the climate control inside the car and create the desired temperature using a time setting. As the driver won't always know whether the car is parked in the sun or the shade, the vehicle itself decides – on the basis of the outdoor temperature measurement – whether it needs cooling via the ventilation system or, if it features auxiliary heating, needs warming up. Beyond this, the driver also has the option of being visually and audibly alerted to the car's location by means of the "Flashlight" and "Blowhorn" functions. If the vehicle is out of sight and hearing, the Vehicle Finder comes into play: this function can locate the car within a range of up to 1,500 metres, a static map showing the driver the way. However, the Vehicle

Finder will only work if the car's ignition is switched off to prevent it from being used as a tracking device. The Local Search function rounds off BMW's extended range of remote options available from My BMW Remote. It allows the driver to use the Google Local Search interface to look for specific Points of Interest (POIs), have them displayed on a map and then transferred to the car. Within the navigation system, the POIs can be directly entered as destinations.

In future, vehicle data such as fuel and oil levels or the next service appointment will be available through My BMW Remote. Information on the outside and inside temperature and on whether the windows, soft-top or sliding roof are open or closed can then be viewed from a distance. As standard, the display shows the vehicle status after last being locked. The user can retrieve the latest status at any time by actively requesting that this information be sent.

A similar range of functions is planned for electric vehicles. In addition to the remote functions already implemented, services specially designed for electric cars will be developed in the future. Here the focus is on user-friendly and practical transfer of precise information such as the current battery charge state, remaining range and remaining time for a full charge if the vehicle is hooked up to a charging station. The remote functions will also help the driver when looking for a nearby charging station. The features specifically designed for electric vehicles have been implemented in the BMW Concept ActiveE concept car.

"With My BMW Remote the customer has access to his car data and functions – simply, securely and practically anywhere."

Daniel Koitzsch, Development BMW ConnectedDrive

1.3 Seamless Media Access.

A strong trend towards digitisation in the home can be observed today. Where only recently shelves were weighed down with CDs, videotapes or vinyl records, now you may well find an entertainment server allowing easy access to the media – such as music, audio books and videos – stored on it. The Seamless Media Access research project by BMW ConnectedDrive will in future make virtually the entire contents of an entertainment system available on demand in the car. With Seamless Media Access, entertainment functions and content so far accessible only on the home computer will find their way into the car. The aim of the BMW Group developers was to recreate the comfort and convenience the customer is familiar with from home inside the car by means of Seamless Media Access: personal settings such as playlists or information on the most recently played content are automatically synchronised between car and home. This means that content will be available on the relevant device – including the car – ready to be resumed from where you left off. In all, Seamless Media Access offers three specific functionalities: aggregated search, intelligent play history and a browsing function.

Seek and you shall find – the search function.

The first function of the Seamless Media Access system is "Media search in my entertainment server". This allows the driver to search the media library for specific content from the car. This search function also works even if the car is not directly connected to the server, i.e. when it is offline. As soon as the driver enters the first letter of the search term, the display shows an aggregated hit list covering the library's entire contents. Arranged according to medium (music, audio book, video), all library contents starting with the specified letter are displayed. The driver can also see from the results list whether the content shown is already on the car's hard disk or needs to be downloaded. By aggregating the contents in this way, this convenient feature delivers particularly fast results when searching for media content.

Seamless transition thanks to intelligent play history.

A further comfort feature of Seamless Media Access is the option of seamless playback of content when switching from the home to the car or vice-versa. There's no need to remember which chapter of the audio book or which album track you have just been listening to: after proceeding from the living room to the car you can view the play history of the home entertainment server on the display and choose between resuming listening from the point at which you left off or going back to the start.

Browsing the media library.

At times the driver may not be sure what he would like to listen to or can't recall the name of the track he is looking for: this is when the third function of Seamless Media Access comes into its own, allowing him to browse through the server's media library, choosing files and downloading the selection from among the music, audio book, video and playlist categories. Like the media search facility, this feature is also available offline; to download files, however, the car must be online.

The optimal means of transferring the requested data to the car is currently being explored. But in principle one can say that for large data files, such as audio books or videos, it makes sense to use a broadband connection for the transfer, be it WLAN or, in future, also LTE. Smaller files, meanwhile, can be sent to the car via UMTS. One scenario might be for the car to link up to the local area network when parked outside the house (if the customer has WLAN installed in the home) and transfer the selected files itself, or for the user to actively add files to the hard disk from the home computer. That way, the selection of videos for the next holiday trip would be ready for the entertainment of rear-seat passengers, as would the specially compiled playlist for the front passengers.

Infrastructure scenarios.

For the implementation of Seamless Media Access, there are two possible technical solutions. The first sees the user's home server being directly linked to the car. But based on the researchers' assessment, the second, provider-based solution is preferable. To cite just one reason by way of example: a provider is always online, whereas the home server might not be permanently activated for various reasons. The provider-based solution is simpler, safer and more stable: all the tracks in the user's media library are

already in the correct format on the server of a cloud provider, and any files the music provider does not have can simply be uploaded from home to your personal area with the provider. That way all the user's own media would be available in the car, and even content that doesn't yet belong to the user can be made accessible.

"With Seamless Media Access we are taking a further step towards making the customer's latest personal entertainment available at all times. In future the customer will always expect an up-to-date 'window' on his data in the car as well."

Dr. Michael Weber, Head of Development Personal Entertainment

1.4 Mood-based playlist.

Connecting the car to the World Wide Web opens up entirely new possibilities for personalised music enjoyment. For several years, BMW Group researchers and developers have been investigating this potential under the banner of “personal radio”. BMW Group specialists are even exploring the possibility of tying the car in with the content of major music providers to create the largest possible music collection within the car. With a choice of several million music tracks, this would open up an extremely broad and deep range of music to be enjoyed in the car. But how will the driver find the music he likes quickly and simply among this huge diversity? That is precisely the question at the heart of the “Mood-based playlist” research project being pursued by BMW Group engineers, a feature that allows rapid and intuitive access to music that matches the driver’s preference at any given time.

Music sets the mood – or vice-versa.

Music is highly emotional and strongly bound up with different moods. On the one hand it can evoke a particular mood in the listener, while on the other a certain mood or situation demands the appropriate music. Above all when driving, the right kind of music can significantly aid the driving experience and even enhance it. That is why the driver’s choice of music is frequently a very conscious one.

At some stage, however, the driver’s musical knowledge or collection runs dry – he has already selected and listened to all the artists, albums and tracks he knows. With the Mood-based playlist the driver is given access to music he may not have come across, but which precisely matches his tastes and preferences. Solely on the basis of a selected mood, the playlist presents a preselected compilation of music which the driver can narrow down by choosing further parameters such as genre or time period. “Mood”, in its conceptual diversity, is a highly appropriate parameter for a selection of music, since a mood is not in the first instance genre-specific but allows for a large cross-section of different musical styles.

"With the Mood-based playlist, we generate a personal music programme for the driver out on the road, taken from a catalogue of millions of tracks – quickly, simply and without cumbersome searching."

Thomas Helbig, Project Manager Mood-based playlist, BMW Group Research and Technology

As the mood takes you.

To begin with the driver makes a basic choice and specifies a mood as a guide for the selection of music. In the research prototype, the user chooses from a matrix covering the four extremes "angry", "peaceful", "celebrating" and "hopeless". Depending on the selection, intermediate moods can then also be defined. The closer the driver's choice is to one of the extremes, the clearer the selection and preliminary sifting of the music. But even experimenting with intermediate positions can be a very attractive proposition for discovering new music and generating varied mixes.

The user has two options for further defining the choice of music in tandem with his mood. On the one hand, the selected mood can be combined with specific genres so that the music is derived exclusively from these. Conversely, particular genres can be explicitly excluded. The second option is to specify a particular year to limit the choice of music to that period.

With the mood-based music programme feature, the driver can thus create a suitable playlist for the car quickly, intuitively, with very little input – and with minimal distraction from the driving task at hand. It is also an opportunity to discover more of the kind of music he likes. From the vast store of music an individual could never hope to plumb, this feature introduces selections tailored to the user's tastes.

"With a choice of several million tracks, there's bound to be something you don't know but like. Mood-based music programmes are the simplest and fastest way to discover such pieces."

Thomas Helbig, Project Manager Mood-based playlist, BMW Group Research and Technology

How the music gets into the car.

The information on the music selection is subsequently sent from the car to the BMW ConnectedDrive server, and from there to the music provider

that has processed and managed the music database accordingly. Based on the specification profile, the provider then prepares a music selection which in turn is transferred to the car ready for the driver to play.

The basis as well as reference for the mood-based selection of music in the research prototype is the Gracenote Music Mood Analysis technology. This combines the insight of expert musicologists with digital signal processing analysis and machine learning technology. It is providing rich, descriptive profiles of characteristics such as mood and tempo for each music recording in the world. These attributes are also directly incorporated into its Playlist solutions, enabling music fans to now create their own high-precision musical mood atmospheres with just the touch of a button.

Play more like this.

The possibilities of combining the mood-based music selection with other functions are particularly attractive. By selecting a mood the driver firstly discovers new music that matches his taste, and by using the "Play more like this" function he can have more music of a similar kind played in the car. A further development might be to link the system with contextual information from the "Intelligent learning navigation" system (see Chapter 3.3) or the calendar. Drawing on acquired knowledge, the navigation system will know, for example, whether the driver is on holiday or on the commute to work. Based on this and other data such as time of day and current position or route, the car gets to know the driving patterns and which music the driver prefers on which routes, enabling it to generate appropriate playlists automatically.

"In future I'll be able to get into the car and find my personal entertainment programme with the 'right' music for the appropriate driving situation, as well as further information and entertainment content. Whether it's a relaxed drive in the country, fast motorway driving or chilled sounds for rush-hour traffic – the perfect backdrop for my driving experience is always there."

Thomas Helbig, Project Manager Mood-based Playlist, BMW Group Research and Technology

1.5 iPod Out.

With the iPod Out feature, BMW Group engineers are offering BMW and MINI drivers the prospect of new and wider-ranging options for easy and intuitive Apple iPhone and iPod use in the car. New-generation automotive integration of mobile Apple devices means the audio player and its latest features can be used with Apple's own interface shown on the dashboard display, while operation is via the car's controls. The display shows the simple, familiar environment to which users are accustomed from their iPhone and iPod. The Apple iPod Out function requires the iOS 4.1 operating system on the iPhone 3G, iPhone 3GS, iPhone 4 or iPod touch (second and third generation).

"With iPod Out, drivers can experience their music through the Apple user interface on the car's display, accessing it and controlling playback with the car's own controls."

Dr. Michael Weber, Head of Development Personal Entertainment

All features – always up to date.

iPod Out also gives the user direct access to other iPod functions such as Genius, for example. This feature draws on the user's music catalogue to create mixes of compatible tracks. It is in such extended features that the real appeal of iPod Out lies: since the software for the various functions is on the user's device, these can be quickly and easily extended, adapted or optimised via updates without the need to adjust the car's own systems. As soon as the Apple device is docked in the car after updating on a home computer, the new functions are up and running in the car as well.

"Changes implemented by the developers in the morning are already available to the customer in the afternoon via the new update. Never before have we been able to provide our customers with new functions in the car so quickly."

Stephan Durach, Head of Technology Office Palo Alto

The new interface technology developed by the BMW Group thus ensures the long-term in-car use of current and future iPod Out features of the iPhone and iPod, creating a new milestone in the automotive integration of consumer electronics. The use of audio players in Apple devices is just the start; at the same time, it opens the door for the world of Apple and its apps to enter the car. In theory, the future could see further Apple functions and applications find their way into the cockpit courtesy of iPod Out.

BMW Group leads the way.

This new interface technology was developed in a close international collaboration between the BMW Research and Development Centre in Munich and the BMW Group Technology Office in Palo Alto, Silicon Valley, California. In 2004, the BMW Group was the first car manufacturer in the world to enable the iPod to be integrated into the audio system of its vehicles; when the iPhone was launched in 2007, it was likewise ready with an exclusive technology for connecting it to the infotainment system of its cars. With iPod Out, the BMW Group once again takes the lead in integrating the iPhone and iPod into its vehicles' infotainment systems.

1.6 Micropause apps.

The use of micropauses arises from a simple idea: to provide the driver with enjoyable or helpful applications – so-called micropause apps – whenever the car is at a standstill, even for a brief moment. The content of these apps is potentially very diverse, ranging for example from simple news headlines to videos or games.

"With micropause apps we want to give the driver some joy through other channels during stationary periods when driving pleasure is on hold. It means that these waiting times can be put to meaningful use."

Dr. Marc Bechler, Project Manager Micropause Use, BMW Group Research and Technology

The first stage of this research project concerns the scenario of waiting at traffic lights. The idea is to put the stationary red light phase to meaningful use by streaming a variety of content into the car. The prerequisite is that the vehicle knows how long the lights will stay red. The researchers are exploring several approaches. One possible solution is demonstrated by the first prototype, where active communication between the traffic lights and the vehicle allows the lights to send information to the car. Other possible waiting scenarios, such as at level crossings or in traffic jams, are also being considered. Here the experts are currently investigating how the waiting times can be reliably determined in such situations.

Let me entertain you.

At the research stage it works like this: as you approach an appropriately equipped traffic light, the vehicle receives information on the current traffic light phase. As soon as the car comes to a halt at a red light, it checks the remaining waiting period and automatically launches appropriate micropause apps. The researchers even have ideas for meaningful micropauses designed for waiting times as short as ten seconds.

In the research vehicle, the content is displayed via a freely programmable instrument cluster, since this is in the driver's immediate field of vision. The Head-Up Display could equally be used for this purpose or a

combination of Head-Up Display and the central dashboard monitor. Developers are still exploring the optimum location in which to display the various micropause apps.

While the content is being played, a small background countdown indicates the seconds remaining before the lights change. Five seconds before the lights turn green, the micropause app is faded out so that the driver can get ready to drive off again in good time.

Micropause use responds flexibly to the available time window and launches a variety of applications. If the car is stationary only briefly, one or more news items might be shown, for example. For longer waiting times, tie-in video clips could be played. As already demonstrated in the "Personal Video" project, a brief news roundup might be an option, such as the 100-second "Rundschau News" package from the Bayerischer Rundfunk channel. This could also be split between two or three traffic light stops as part of the micropause function.

The future: individual use of micropauses.

The driver can actively contribute to the use of micropauses at any time and also select which micropause apps are to be displayed. If, for example, a news item comes up that the driver does not wish to see, he can simply click forward to the next item using the iDrive Controller. A link-up to the multifunction buttons or steering wheel paddles would also be feasible, allowing control of the micropause apps when at a standstill. Also in the planning is the customisation of apps: the driver could make a preliminary selection and define his preferences at home – for example via the BMW ConnectedDrive portal – in order to experience particular micropause apps at certain times and in certain places. That might mean primarily news bulletins in the morning, and in the evening perhaps short film trailers or new Facebook photos posted by friends. The researchers are also exploring the possibility of including interactive applications such as Pacman or Flipper.

"We want to enable each driver to use the time spent in the car in the way he or she wants – even if stops at the lights for just 15 seconds. If the micropause apps get the driver looking forward to the next red light, then we will have made another contribution to genuine driving pleasure."

Dr. Marc Bechler, Project Manager Micropause Use, BMW Group Research and Technology

1.7 Outlook functionality in the car.

As well as endeavouring to maximise their customers' enjoyment while on the road, the developers at the BMW Group are also keenly focused on enabling them to travel with maximum efficiency – not just in terms of fuel consumption. The idea is for the customer to have the option of making the most efficient use possible of time spent in the car.

Thanks to integral email functionality, BMW customers are for the first time being offered convenient and easy access to their exchange mail server – directly from the car. Even while the car is moving they can access their email account's inbox, contacts and calendar. Here the BMW Group is primarily offering key accounts, customers with vehicle fleets and field staff a premium solution that does away with dependency on a single mobile device. It also dispenses with complex configurations of email accounts on the electronic device, while battery life is no longer an issue either thanks to this integrated solution. The vehicle has direct access to the mail exchange server, from which the work computer would also download emails.

"The moment the driver gets into the car, he is logged on. This solution ensures that you really do have your email account with you at all times and can use it."

Sven Kurzeder, Navigation and ConnectedDrive

The only requirement is to have the BMW ConnectedDrive SIM card in the vehicle, which enables access to the mail exchange server at UMTS speed (where available).

"You've got mail."
Depending on the driving situation, the driver can choose from many of the Outlook features, such as seeing incoming mail in the centre display and reading individual messages in the detailed view, or having them read out. Messages can be deleted or marked as read, appointments can be confirmed or cancelled, and notes made.

Thanks to this range of functions, BMW customers can already keep an eye on their emails on the way to work and have the option of organising their day from the car. They can link important emails up to tasks, delete unimportant emails or manage their diary. To ensure there is no distraction in the interests of road safety, the email function is restricted when the car is moving, the driver only being permitted access to the inbox display and being informed of incoming emails. Thanks to the permanent connection with the server, the driver knows in real time when new emails come in – as when using a laptop or PC. When the car is stationary, the entire range of functions can be used. In the rear of the car, needless to say, all functions are freely usable while on the move.

Intelligent linking of functions.

The future could also see the email function being linked to other features of the infotainment set-up, such as the navigation system, for example. Transferring addresses from the contacts list to the navigation system and planning routes around upcoming appointments are just two of the many possibilities. Moreover, if information on the destination and time of arrival is available, appointments could even be postponed or cancelled from the car if the calculated arrival time turns out to be later than the scheduled start of a meeting, for example. In such a case, a prepared email or text message could be sent to the participants stating the estimated time of arrival. Even taking part in a teleconference using the integrated Bluetooth phone would be an option. To that end, the relevant numbers would be taken from emails, the appointments calendar or contacts list and dialled.

1.8 Message Dictation.

The BMW Group has many years of experience in the field of voice control for vehicle functions. After the introduction of full word destination entry in 2006, 2009 saw a further milestone in the fast and accurate selection of navigation destinations: the BMW Group became the world's first carmaker to offer a system that could understand a complete address, including city, street and number, "in one go". With this single voice command, the BMW Group once again raised the bar. Another unique feature was the selection of music tracks on the internal hard disk by voice control, introduced for the first time that same year. In 2010 this was extended to external music players as well.

The aim behind voice control has always been the convenient, fast and, above all, safe operation of ever more complex infotainment functions, particularly in the area of navigation, entertainment and telephony/communications.

Free text voice recognition in the car.
Communicating by email or text message, whether for private or business purposes, is increasingly being used as a means of private or business communication. Such messages can be displayed and read out in the car. Using a mobile phone for this purpose is a dangerous distraction for the driver and in many countries is against the law while driving. Thanks to the Message Dictation function, the BMW Group developers are for the first time enabling the driver to dictate free text in the car and thus "write" short messages – simply by speaking. It means that brief emails or text messages can be easily composed by voice without having to take your hands off the wheel or your eyes off the road. As with comparable desktop applications, punctuation and commands such as "new paragraph" also have to be spoken while dictating, should you place value on a grammatically correct and easily readable results.

"Message dictation is the logical next step following on from voice output of text messages in the car. At the same time, this is the first move towards flexible and powerful speech processing inside and outside the vehicle by linking the car to back-end systems within the BMW ConnectedDrive framework. If you like, we are now introducing hands-free operation for emails or text messages into the car."

Dr. Christian Süß, Development Voice Processing Systems

The actual speech recognition takes place on a server outside the vehicle as you are speaking, since free text recognition benefits in the first instance from the size of the back-end vocabulary (millions of familiar words). In the car, the recognised text is then displayed or read out. When composing text, the driver naturally also has simple, voice-based editing options at his disposal to ensure the comfortable and, above all, safe creation of emails and text messages.

Prospects for free text dictation.

In future, it will be possible to use the dictated text in other applications as well, e.g. when entering search queries on the internet or when browsing extremely extensive music libraries or POI collections on the web. The plan is for free text dictation to function wherever letters have previously been entered in the iDrive "speller". Here, too, the BMW Group is setting the benchmark for intuitive, comfortable and safe operation of vehicle functions.

1.9 iDrive Controller with integrated touch control.

On laptops they are commonplace, yet in the car they are few and far between – touchpads, or surfaces that are sensitive to fingertip touch. As part of a development project, the engineers at the BMW Group are for the first time integrating a touchpad into the iDrive Controller, the central control unit of the iDrive system. The aim is to make certain operating functions more intuitive, faster and easier to carry out by means of touch control.

"With this integrated touch control, we want to allow the customer fast and simple inputs and thus offer significant added value."

Hermann Künzner, Head of Design Displays and Controls

The great advantage of the touch control placed in the iDrive Controller lies in its high integration capability. Mounted directly in the central control unit, it allows for even more intuitive operation – without direct eye contact. The controls for entering, selecting and confirming are sited close together, enabling a seamless transition when switching between voice input, touchpad and rotary knob operation. Depending on preference and situation, the driver has the option of making and confirming selections – or, if he finds it easier, quickly switching between the deliberately redundant control options. As the integral touchpad barely takes up more installation space than the iDrive Controller used so far, it will be relatively easy to install into future vehicles. Before that stage, the technology still needs to be honed and tested in various applications. Asian character recognition, for example, is highly complex. The BMW Group specialists are working intensively to provide solutions that will meet customer requirements.

Character recognition at a fingerstroke.

When it comes to writing in particular, an integral touchpad can facilitate and speed up the input process. To date, the desired letter is selected via the "speller" – a circular arrangement of letters in the display – using the rotary knob and confirmed by pressing it. This allows the driver to enter names or phone numbers. With the integral touchpad, it is now also possible to write letters on the surface of the rotary knob with your finger. The touch-

sensitive surface recognises the letter and the speller immediately jumps to it. All the driver has to do is confirm it.

This is a major boon for the Chinese market in particular, where several thousand characters make text input far more complicated than when dealing with the Latin alphabet. The iDrive Controller with integral touchpad allows characters to be selected and confirmed quickly and simply: as Chinese characters begin with a certain stroke sequence, the driver can radically limit the selection of characters just by entering the first stroke. By adding further character features the range is further refined. BMW Group specialists are still working with their Chinese colleagues to determine exactly what form of implementation is best suited for the Chinese market. But one thing is clear: even with differing handwriting, the character in question will be recognised. In future, this function will extend to all other language options as well.

Map navigation.

A further touch control application is to be able to move freely within a navigation map on the display. If there is a traffic jam looming, the driver can use the touchpad to move to this area on the map and look at the alternative route recommendation. There is also the option of selecting Points of Interest (POIs) embedded in the map by touch control and have details flagged up by pressing the rotary knob to confirm. There are also plans to allow waypoints on the map to be changed and thus routes to be individually adapted or planned using the display and touchpad.

The future of touch control.

As before, the development framework includes enabling internet navigation with a mouse pointer that can be controlled via the touchpad. Character input will trigger the display of a list, i.e. as soon as the driver enters the initial letter, the system automatically jumps to all entries beginning with that letter in the relevant application. This includes the address book, music library, navigation system, Seamless Media Access (see Chapter 1.3) or even connected electronic devices. The driver can then either select and confirm an entry by using the rotary knob or enter more letters to refine the search further before selecting the required entry.

"Touch control offers many possible applications and we have equally many ideas. But it is important to us that, if in doubt, the focus should be on fewer functions that have been fully thought through and are designed in a practical and reliable way."

Hermann Künzner, Head of Design Displays and Controls

1.10 microNavigation.

Modern navigation systems provide accurate, failsafe navigation to any desired destination. But if that destination happens to be, say, a multistorey car park, the driver may still be left wondering how to find the entrance – and how to get from there to a specific location within the car park as quickly as possible. Unfortunately, detailed information about large, enclosed destination areas is not – or not yet – available in today's vehicles. To address this need, the specialists at BMW Group Research and Technology are currently working on a "microNavigation" research project, which they hope will be able to plug this gap sometime in the near future.

Detailed map display in complex destination areas.
With the microNavigation research project, BMW Group experts are developing a completely new dimension in navigation, using a BMW 3 Series as a prototype. The system allows complex enclosed areas that are not covered by road maps, or are only partially covered, to be visualised in a detailed, large-scale map display. Before getting out of the vehicle, the driver would already be able to see how to get to a specific point within the destination area. His mobile device would then direct him the last part of the way on foot to the end destination – and, of course, navigate him back again to his vehicle when he wanted to return.

"The realistic visualisation of a building like a complex multistorey car park by means of a microNavigation map in the Central Information Display of the research prototype gives the user a clear navigational and informational advantage that goes far beyond the conventional scope of a road navigation solution."

Carsten Isert, Project Manager microNavigation

Specifically, the system works like this: the driver can check out his destination in advance, on his home PC, and find out if a "microMap" is available. If so, he will automatically be offered one. A detailed destination can then be selected within the microMap. The map data plus destination is then automatically transferred to the driver's vehicle, where it is added to

the existing navigation data. Naturally, it will also be possible to download microMaps spontaneously while en route, from the vehicle. By integrating camera information, GPS coordinates and map data, the researchers have also developed a lane-level vehicle positioning system. The driver is navigated to his destination – for example a vacant parking space near to the most convenient lift – with lane-level accuracy. Detailed maps, in combination with vehicle positioning which is accurate down to individual parking space level, assist the driver with orientation and navigation within the car park. After the vehicle has been parked, the data can be transferred to the driver's mobile device, allowing him to be navigated all the way to his destination, even when the last part of the route has to be negotiated on foot, in a complex and unfamiliar destination area.

"microNavigation gives drivers tailor-made navigation during the journey and also at the destination, and thereby significantly increases confidence and convenience."

Robert Hein, Head of Navigation and Data Services of the Future

Years of experience in navigation system development.

The advantage that current BMW navigation systems enjoy both over retrofit solutions and over built-in systems of other car manufacturers is due not least to many years of experience in the field. In 1994, BMW was the first European manufacturer to introduce an integrated navigation system in a production vehicle. This was one of the first steps on the way to a new genre of systems capable of connecting the vehicle with its environment, a concept which today goes by the name BMW ConnectedDrive. To strengthen its lead in this field, the BMW Group is committed to the continuous and systematic improvement of its navigation systems. The focus is on developing innovative supplementary functions to increase efficiency, safety and convenience.

1.11 Urban navigation.

Navigation in urban areas always involves a certain number of unknowns. It is not always easy for the driver and the navigation system to find the quickest route to a destination. Not only is it necessary to take into account real-time local traffic information, for example about which routes are currently worst affected by rush hour traffic, or what roadworks or public events are currently taking place; it also has to be remembered that what might appear at first sight to be a very short route may actually be a very time-consuming one, due to traffic light phasing. With its work on "urban navigation" systems, the BMW Group is therefore developing two functions that will use local "traffic knowledge" to make navigation in large cities faster, easier and, particularly at rush hour, more predictable, namely adaptive navigation and strategic routing.

"The urban navigation functions reflect the BMW Group's leadership in the field of intelligent integrated routing."

Martin Hauschild, Head of Traffic Technology

Adaptive navigation – one route, three arrival times.

In addition to the navigation function per se, existing navigation systems also take into account traffic information and use it to avoid congestion. In large conurbations, however, this strategy is rapidly reaching its limits. Due to the high traffic volumes, the recommended detours quickly become congested as well. It is also often very difficult to predict actual traffic volumes. These two factors make it hard to accurately estimate arrival times. The development engineers are therefore working on a solution – adaptive navigation – which takes into account historic traffic data when calculating arrival times, in order to make ETA predictions more reliable.

Whereas a conventional navigation system only gives one estimated time of arrival (ETA), adaptive navigation offers three: the typical, average ETA, an optimistic ETA based on the driver catching a series of green traffic lights, and a pessimistic ETA that assumes the route will be affected by traffic disruption. A driver setting off for the airport might therefore choose to

plan his journey around the later (worst case) arrival time, whereas for his journey home from work he might assume the earlier time.

"Adaptive navigation offers the driver not only the typical, average ETA but also upper and lower-end estimates for which the statistical probability of an even worse – or even better – outcome is only ten percent."

Tim Lange, Project Manager Urban Navigation

But how does adaptive navigation compute these times? To understand the basic principle, it helps to look at the factors which can cause journey times to vary. In terms of the type of road, although a journey via a winding road with poor sight distance will naturally take longer than one on a straight road with good sight distance, the variation in journey times associated with this factor is only small, since there is little variation in traffic flow on these roads. By contrast, factors which do cause a big variation in journey times are unforeseeable events such as traffic jams due to roadworks or accidents. Some types of road show a higher occurrence of such incidents than others, and thus a higher variation range. Based on a detailed historic analysis of traffic data, a variation range can be calculated for any given road. It is also possible to calculate a variation range for the quality and reliability of real-time traffic information issued by traffic information services, based on an analysis of the relevant data. The adaptive navigation system is the first system to take these variations into account in its ETA predictions, helping to make journey times, particularly in town, much more predictable and more transparent.

"The big uncertainty factor here for drivers is the wide variation in journey times. With adaptive navigation, we can do something to reduce this uncertainty for the driver, because adaptive navigation can tell me what to be prepared for on any given route."

Tim Lange, Project Manager Urban Navigation

Strategic routing – navigation using local authority information.
Nobody has a better inside knowledge of traffic data and events in a given city than the city authorities themselves. It is therefore an obvious step to actively incorporate this knowledge into the navigation system's route planning and navigation functions. With strategic routing, the BMW Group is engaged in an exclusive project with a number of towns and cities to make traffic management data and information about temporary

disruptions such as roadworks or special events accessible to navigation systems and to take this into account in route planning.

"If we know where and when longer traffic light phases can be expected, what roads are currently overstretched, whether special events are taking place which will involve road closures, or whether roadworks are scheduled, we can use this information to provide drivers with the optimal route."

Tim Lange, Project Manager Urban Navigation

A digital road map alone is often unable to show which route is likely to be the quickest way of getting to a destination. To compute the fastest and most efficient route, it is necessary to supplement this data with local knowledge. Local authorities have a fund of such knowledge at their disposal, in the form of planning data and information about active traffic management measures which may temporarily affect traffic and traffic flows. Alternative routes supplied by conventional navigation systems in some cases use roads which have only a limited traffic capacity. The result is then collectively induced congestion. The local authorities, on the other hand, have first-hand knowledge of which routes are most suitable for use as detours. Information about local authorities' active traffic management measures or traffic planning schemes is incorporated by the strategic routing system into the navigation system and used in calculating the route. Strategic routing provides clear added value in the form of significantly more predictable journey times since traffic is always free-flowing.

"Local authorities know in advance when and where congestion could occur. We put this knowledge to good use. Rather than simply reacting when the congestion has already developed, we help to prevent it from occurring in the first place."

Martin Hauschild, Head of Traffic Technology

But it is not only BMW Group customers who stand to benefit from strategic routing. There is currently a lack of transparency about local authorities' traffic management strategies. For example, compliance with temporary signage is less than ten percent. As a result, such measures are then ineffective, and congestion still occurs. By integrating such data into the navigation system, this strategic information could be circulated more quickly, and to

more road users, which would significantly help to improve the success of these measures.

1.12 Mobility Assistant.

As already indicated, ensuring quick and trouble-free mobility around town can be something of a challenge. People on the move often face the following questions: What can be done to ensure a punctual arrival even when the navigation system indicates congestion? Will a parking space be available on arrival? Where is the nearest recharging point for an electric vehicle? Will Park+Ride get the driver to his destination more quickly, or more conveniently? Answers to all these questions will in future be available from the BMW Group's Mobility Assistant, which is currently undergoing testing in Berlin as an iPhone application. This service will allow individually customised navigation, using different modes of transport. When a destination is entered, the Mobility Assistant will show various possible ways of getting there – whether by car, by local public transport or by a combination of the two. Depending on the details entered, the users will be presented with a range of options for reaching the desired destination conveniently, quickly, or using a preferred form of transport.

"The Mobility Assistant is a first step towards making intermodal transport a reality, thereby extending mobility beyond the driver's own vehicle to various other modes of transport. In this way the BMW Group will be able to support mobility which is both sustainable and geared to the needs of the individual user."

Dr. Markus Mailer, Head of Traffic Management

Only the best way will do.

The key function of this application is to generate personal "itineraries". The user enters his starting point and destination, and his preference for a particular mode of transport – the "routing modes" comprise "bus&rail", "car" or "Park+Ride". The starting point and destination can include the user's current location, any address or a public transport stop. As soon as the user has confirmed his choices, the application presents various suggestions as to how to reach the destination.

"The Mobility Assistant offers the user a very high degree of individual customisation when compiling a route. It provides a choice of routing mode and a choice of waypoints such as Park+Ride car parks. It also provides extensive information – for both the outward and the return journey."

Dr. Markus Mailer, Head of Traffic Management

In the "connections" view, the user can also see immediately which modes of transport will be used for which sections of the various routes, along with the total number of changes, and the time of the latest possible return journey. Naturally the duration of each option is also shown. Connections can be checked out in more depth by choosing to "show details", which will display journey routes, pedestrian routes and map information. For example, this view shows up-to-the-minute information about current parking availability at Park+Ride car parks, details of fees and whether electric vehicle recharging points are available. A special function in the map view allows the user to explicitly display the various mobility-related points of interest (POIs), such as charging stations, car parks and Park+Ride facilities, so that he can plan his route accordingly. Needless to say, it is also possible to modify the details of the routes displayed. As soon as the change is entered, the Mobility Assistant calculates the new route using the changed parameters. A further special feature is a location-based search function which allows the user to display Park+Ride facilities, car parks, public transport stops or recharging stations within a given area.

The Mobility Assistant is a highly flexible route planning tool. It can respond situationally and adaptively and is therefore equally suitable both for advance journey planning or for making spontaneous route changes. For example, in the event of an unforeseen incident on the chosen route, the parameters can simply be changed and the user will instantly receive an alternative suggestion. The system therefore offers the driver a safety net in the case of congestion and road closures, since he can request an alternative way of getting to his destination on time – even when the problems only come to light while en route.

Intermodal mobility.

The BMW Group sees the Mobility Assistant as a potential future interface with other modes of transport. Currently, the application is undergoing pilot testing, which is being supported by the Federal

Environment Ministry. Selected MINI E customers in the Berlin area are “test-driving” the Mobility Assistant and will supply detailed feedback to the developers at the end of the test. A hotline is also available to help them if they run into difficulties using the application. This first trial will allow customer requirements to be integrated even more efficiently into the Mobility Assistant. The customer feedback received will flow directly into the ongoing development of this application. In other words, the MINI E customers are actively participating in the design and optimisation of the Mobility Assistant.

2. Driver assistance systems of the future – a guardian angel on board.

Thanks to advances in the field of active and passive vehicle safety, the number of road deaths continues to decline. In Germany the figure fell by a further 7.3 percent between 2008 and 2009. Every accident, however, is one too many. Which is why smart safety systems remain an important development focus for the BMW Group.

2.1 Active PDC.

With Active PDC (Active Park Distance Control), the information and warning system Park Distance Control is making the transition to active intervention. Active PDC, the new, extended version of this well-established parking aid, offers even greater protection from parking bumps and scrapes. Active PDC uses a three-stage intervention strategy – based on speed limitation, appropriate adaptive braking and braking to a complete stop – for safe and convenient parking particularly in poor-visibility parking and manoeuvring situations, thereby preventing the risk of annoying dents or scratches on the vehicle.

"Unlike the garage parker, which can steer the vehicle or apply the accelerator when negotiating the ramp into a double garage, the Active PDC system's functionality comprises signal feedback and deceleration. The tasks of acceleration and steering must be performed by the driver, who remains in charge of the vehicle at all times."

Christian Reuter, Project Manager Active PDC

Parking with Active PDC.

On commencing the parking manoeuvre with Active PDC, the driver first of all receives the familiar visual and auditory feedback regarding the remaining clearance in front of and behind the vehicle. For improved detection of the vehicle's surroundings, the four ultrasound sensors at the front and rear of the vehicle are assisted by the laterally positioned sensors of the Park Assist system as featured in the new BMW 5 Series. During the parking manoeuvre, Active PDC limits the speed of the vehicle to 5 km/h. When an obstacle appears in the predetermined sensing range, the system smoothly reduces the speed of the vehicle down to 1 km/h as the gap decreases. If there is an acute risk of collision because the vehicle is continuing to move despite the PDC system giving a continuous warning tone, the next and final stage is abrupt braking of the vehicle to a complete stop. This provides a further, tactile warning about the imminent collision, while at the same time preventing it. Braking operations in response to obstacles in the driving path also take into account the vehicle's direction of travel and the

steering angle. The system also primes the brake system in advance, in order to further reduce response times. By braking or applying the accelerator, the driver can override or reinforce the function at any time, without deactivating it.

"Particularly when reversing out of a parking space and applying a large amount of steering lock, the front of the vehicle will swing out a long way – while the driver's attention is focused mainly on the rear of the vehicle. In this situation, Active PDC helps monitor the area at the front of the vehicle, allowing the driver to focus on the rear."

Christian Reuter, Project Manager Active PDC

In the research prototype, the warning braking range is currently identical with the red range on the PDC display. But the plan is to reduce the braking range in the course of further development of the system. Eventually, the warning braking really will occur only at the very last moment.

2.2 Remote Controlled Parking.

While the Park Assist system in the new BMW 5 Series helps drivers during parallel parking, Remote Controlled Parking goes a step further, performing an entire parking manoeuvre – in this case forward perpendicular or garage parking – single-handedly. The driver does not even have to be sitting inside the vehicle. The Remote Controlled Parking function, also known as the "garage parker", was first presented by the BMW Group in 2006, and the development engineers have been improving and refining it ever since. The new prototype of this system, which is capable of parking in any garage, even an unfamiliar one, without the aid of a reflector, demonstrates the progress made in developing near-production, automated driving functions.

A driver planning to park in a narrow garage or other confined parking space using Remote Controlled Parking gets out of the vehicle and activates the automatic parking manoeuvre using the vehicle key. From this point on the garage parker takes control of the acceleration, braking and steering functions and manoeuvres the vehicle autonomously into the narrow garage – or out of it again. This spares the driver any awkward gymnastics or the risk of damage to the doors when getting into or out of the car in confined garages.

The parking manoeuvre is activated by pressing a specific sequence of buttons within a set time limit. The driver must remain in the immediate vicinity of the vehicle throughout. Activation of the system simultaneously locks the vehicle, switches on the parking aid and the dipped headlamps and folds in the exterior mirrors. The latter operation also serves as confirmation to the driver that the vehicle is ready to park. If the driver then presses and continues to hold the key button, this gives the signal:

"Over to you, RPC."

Unlike the previous prototype, featuring a camera and reflector, the current prototype uses the vehicle's existing sensor systems. Guided by the six ultrasound sensors of the Park Distance Control and Park Assist systems, the vehicle slowly moves forward into the garage at a speed of approximately 2 km/h, aligning itself centrally between and parallel to the walls on either

side. Any necessary steering corrections to achieve this positioning are performed by the power steering system motor. The garage parker's control unit also controls the engine Auto Start-Stop function, the automatic transmission's gear selector, and the brake system.

If an obstruction is identified, the sensors order an automatic stop and the hazard warning lights come on to show the driver that the operation has had to be aborted. If, on the other hand, there is nothing in the vehicle's way, the system completes the parking manoeuvre, braking to a standstill and changing to selector position "P", so that the vehicle is left properly secured. To activate the exit manoeuvre, the driver presses the same sequence of buttons used when parking. The vehicle will then autonomously back out of the garage or parking space. Again, the sensors monitor the area around the vehicle for any obstacles and again the driver must be standing close enough to the garage to be able to follow the entire operation.

"The challenge when developing the garage parker was the need to take into account so many different scenarios. The vehicle must be able to find its way just as easily when entering a garage where the walls are lined by shelves or piles of wood as when entering a smooth-walled double garage or underground garage."

Patrick Matters, Project Manager Remote Controlled Parking

Safety first.

Safety considerations are paramount with this prototype. Throughout the parking manoeuvre, whether entering or leaving the garage, the last button in the sequence must remain held. If the button is released, the car stops immediately. If, after leaving the garage, the driver's door is not opened within a given time limit, the system automatically shuts off the engine and locks the vehicle again. There is also a restriction on the distance which the vehicle is "permitted" to travel autonomously: this is limited to a few metres, depending on the length of the vehicle (seven metres maximum in the case of the BMW 5 Series prototype). Before the garage parker can go into production, however, it will first be necessary to clarify the legal situation regarding autonomous vehicle operation. In many countries it is illegal to start the engine from outside the vehicle or to move the vehicle if the driver is not sitting at the wheel.

2.3 Proactive pedestrian protection systems.

The best protection against an accident that carmakers can offer is active safety. Fewer than two percent of accidents occur due to technical problems such as punctures. The overwhelming majority are due to human error. Hence the importance of offering effective strategies that assist with the driving task and avert potential accidents at the earliest possible stage.

In many countries the number of fatal accidents has been falling for years – despite more vehicles being on the road more often and for longer periods. This is due partly to passive safety (e.g. seatbelts, airbags), but also and above all to active safety systems (chassis control, driver assistance systems). In all of this, of course, special attention must be devoted to protecting the most vulnerable road users – pedestrians.

Since accidents involving pedestrians frequently occur at night or in the early morning or evening, in 2008 the BMW Group added a pedestrian recognition function with warning to the BMW Night Vision system. A second frequent accident scenario involves daytime encounters between cars and pedestrians in heavy urban traffic. For this highly complex risk scenario as well, the BMW Group is developing a proactive pedestrian protection system designed to minimise injury or ideally to prevent an accident altogether.

"On out-of-town roads at night, single pedestrians usually move in a straight line along the side of the road, so the BMW Night Vision system can detect them easily. In a daytime urban situation, however, a detection system has to be able to cope with much more dynamic pedestrian behaviour. We have therefore developed distinct system designs to address these different types of scenario as efficiently as possible"

Christian Gruber, Head of Integral and Active Safety Concepts

2.3.1 Camera-based pedestrian protection.

The BMW Group's advanced development project "Proactive pedestrian protection" is geared particularly to preventing – or mitigating the consequences of – potential collisions with pedestrians in an urban setting.

"A priority in this work is to develop a function which as far as possible covers the complete range of speeds in urban driving. This is why we are designing the system for speeds of up to 60 km/h."

Alexandra Vogt, Project Manager Camera-based Pedestrian Protection

The system identifies a potential pedestrian accident, warns the driver at an early stage and, if there is nothing the driver can do to prevent a collision, initiates emergency braking in order to reduce the vehicle's kinetic energy as much as possible. Bearing in mind that if a vehicle collides with an obstacle at 40 rather than 60 km/h kinetic energy is reduced by more than 50 percent, it is clear that a reduction in speed of even just a few km/h will significantly reduce the severity of injury in the event of a collision between a car and a pedestrian.

How it works.

In the research prototype, pedestrians are detected using a camera. This camera can also be used for other driver assistance functions such as traffic sign recognition, collision warning and lane departure warning. The attractiveness of this concept in cost terms facilitates faster penetration, particularly in the lower market segments. In parallel with such image recognition systems, research is also being carried out into the use of other sensor concepts and sensor combinations.

The camera-based pedestrian protection system is based on a detection and warning algorithm which detects potential pedestrian accidents using a sequence of camera images in combination with vehicle-related data. If the system assesses a situation as critical, a two-stage warning strategy is initiated. First comes the acute warning stage, which as with the BMW Night Vision system warns the driver of potential risks by means of visual and auditory signals. At this point in time the pedestrian will still be far enough

away from the vehicle for the driver to be able to avoid a collision unaided, by taking evasive action or by braking. In parallel with this warning, the braking system is primed so that it will be able to deliver more braking power more quickly. As well as warning the driver, these measures also help him to react more effectively. If it is no longer possible for the driver to react in such a way as to avoid an accident, the system moves to stage two: automatic braking. This braking function can also be reinforced by the driver, thereby further increasing the deceleration and further reducing the energy of the vehicle.

At any time, the driver can not only reinforce the system's intervention, he can also override and cancel the automatic emergency braking intervention by steering or accelerating.

The biggest challenge when developing a system like this is the highly dynamic nature of pedestrian movement. It is extremely difficult to predict accurately how a pedestrian will behave. For maximum effectiveness, the system must decide to act at a point in time when the pedestrian still has the possibility to withdraw from the danger area. By the same token the actual automatic emergency braking itself must take place as late as possible, in order to prevent unnecessary activation. Despite the short duration of the emergency braking – no more than 600 milliseconds at most – this function can nevertheless achieve an appreciable reduction in the speed of the vehicle at the moment of impact, which in some cases can have a life-saving effect. The driver warning stage, designed to increase his attentiveness, begins considerably earlier. This gives the driver the opportunity to avoid a collision with a pedestrian through his own braking or evasive actions, as appropriate in the particular situation.

Continuous development.

Active safety is not a new topic: research and development of active safety systems has been systematically conducted by the BMW Group for many years. Systems range from purely warning systems (BMW Night Vision with pedestrian recognition), preparatory systems (Adaptive Brake Assistant) and supportive systems (Dynamic Brake Control) to systems which actively intervene in the driving task (Dynamic Stability Control, or collision warning with braking function). This work is an important focus of development, geared to continuously improving safety. Whereas previous systems only provided a warning, the radar-assisted collision warning with braking

function for the new BMW 5 Series goes further, with a three-stage warning and intervention strategy. The system first provides a purely visual warning, following this up with an acute visual and auditory warning while simultaneously priming the brake system. Finally, automatic braking is activated. But at the same time as more intervention functions are being developed, so too the range of scenarios that these systems can address is also increasing. While the collision warning system with braking function mainly addresses potential collisions with other vehicles at higher vehicle speeds, the proactive pedestrian protection system extends the applications of active braking to a further scenario: pedestrians in an urban environment. BMW Night Vision, meanwhile, provides proactive pedestrian protection in out-of-town, night-time scenarios. And in future, transponder-based systems such as AMULETT/Ko-TAG will significantly advance the frontiers of active pedestrian systems further still – for example improving their performance in situations where pedestrians are concealed from view.

2.3.2 AMULETT.

In parallel with conventional pedestrian protection measures, whose focus is on reducing injury risks in a collision, the BMW Group is also carrying out intensive development work on proactive systems designed to prevent contact between a vehicle and a pedestrian in the first place. The highly sensitive sensor technology used in these systems can accurately calculate the likelihood of impact. As well as camera-based proactive pedestrian protection systems, the BMW Group is also researching transponder-based systems, under the AMULETT and Ko-TAG projects.

AMULETT – wireless technology for increased road safety.
The AMULETT research project ("Active mobile accident avoidance and mitigation of accident effects through cooperative data acquisition and tracking technology") has demonstrated a way in which "car-to-X" communication can be used to improve pedestrian safety. The vehicle communicates with a wireless transponder worn or carried by the pedestrian or cyclist.

AMULETT works as follows: a query signal is transmitted by the vehicle, which the transponder then replies to with an identification signal. The vehicle evaluates this reply, from which it is able to calculate the distance between the vehicle and the transponder, along with the angle of incidence of the signal. It can also identify the type of road user. The electromagnetic waves emitted by the transponder when it replies to the query signal are evaluated by a 2.4 GHz multi-aerial system fitted behind the front windscreen of the test vehicle. A signal-processing unit determines the angle of incidence and identity of the signal. Also, based on the time lapse between transmission of the query signal by the vehicle and receipt of the transponder's reply, the system calculates the distance between the vehicle and the pedestrian on the echo time principle. This location-sensing system has a range of well over 100 metres in an unobstructed environment and at least 20 metres if the pedestrian is concealed. Thus even without a direct line of sight, the driver is

informed at an early stage if, say, a pedestrian hidden behind a parked vehicle is close to the road and moving quickly towards it. The driver can then react to the situation in a timely manner.

If, based on the information it receives, the system detects a potential collision situation, the driver is first given a visual warning – via the Head-Up Display as well as the central information display. If he fails to react, or does not react fast enough, the warnings escalate right through to automatic emergency braking, as a last-resort means of preventing a collision. At all times the driver has the option of overriding the emergency braking manoeuvre and remaining in full charge of the vehicle. If the driver intervenes – for example by taking evasive steering action – the brake is automatically released, in order not to restrict the driver's freedom of decision.

Ko-TAG – the next logical stage.

Under the joint project Ko-TAG, the BMW Group is systematically developing the findings of the AMULETT project a stage further as part of the research initiative "Ko-FAS – Cooperative Vehicle Safety" (for more information, visit www.ko-fas.de). The aim of this work, which is being carried out by the BMW Group and 18 partners, including a number of well-known vehicle manufacturers, suppliers and universities, along with research establishments from throughout Germany, is to significantly improve road safety and thereby substantially reduce the number of accidents and road deaths.

In this connection, Ko-TAG is focusing particularly on further optimisation of the AMULETT cooperative sensory system. This will comprise development of a protocol to support system functionality in complex scenarios, along with further miniaturisation and industrialisation of the transponder. Current standards used in the area of vehicle-to-vehicle communication are an important basis for this work. Whereas at the start of the AMULETT project the transponder was still roughly the size of a school bag, the revised version is currently only size of a small cigar box. In future, the transponders will shrink further still, and may soon even fit into a walking stick or inside a small compartment in a school bag.

In addition to pedestrian protection, the Ko-TAG project is also researching the use of such transponders for car-to-car applications. Equipping vehicles with the transponder technology would provide a way of

preventing accidents based on a combination of car-to-car data transmission and location-sensing. Also under the Ko-TAG project, the engineers are exploring a wide range of special situations, in order to ensure that the vehicle only takes action if there is a real collision risk.

Although the data transmitted by the transponder is completely anonymous, the BMW Group is very concerned to ensure that a transponder cannot in any way be identified with or linked to its carrier. The transponder code is therefore regularly changed on the "rolling code" principle. Precautions have also been taken to ensure that the system cannot be used outside this vehicle application, in order to prevent possible abuse. In this way user anonymity is ensured at all times, and data protection laws are met, yet without compromising the predictive capabilities of the sensor data.

Research on pedestrian protection within the BMW Group.
Under the Ko-TAG project, the BMW Group researchers are not restricting their focus just to the technical system itself but, in order to ensure relevance to real-world accidents, are also carrying out detailed analysis of documented pedestrian accidents. With a knowledge of typical real-world accident chronology and typical pedestrian movement patterns, it is possible to improve the system's intervention thresholds and in this way to maximise its effectiveness in everyday road traffic.

Before the transponder-based pedestrian protection system can go into production, the BMW Group engineers must not only carry out further research on the system itself but also need to address a number of collateral issues. For example, the transponder cannot work without a reliable power supply. Also, reliable and interference-free data transmission requires a dedicated wireless frequency. Currently, however, no frequencies are available, and even in future it is unlikely that any frequencies will be freed up for this type of safety function. Also, at the present time a transponder can only protect individuals who actually wear or carry it. One stated project objective is therefore to find other ways of integrating the transponder – for example in mobile phones – which would allow this technology to be deployed as widely as possible, achieving a high level of penetration as quickly as possible. It would also be possible to equip particularly vulnerable road users with a special solution, for example in the case of schoolchildren transponders could be integrated in their school bag or, in

the case of joggers, in their running shoes. The BMW Group development engineers are already working flat out on a variety of possible solutions, because in the long term they see transponder-based pedestrian protection as a very simple and above all effective accident prevention measure.

2.4 Active Hazard Braking.

"Braking even a tenth of a second earlier before an unexpected obstacle can mean an accident is avoided."

Dr. Peter Zahn, Project Manager Active Hazard Braking

In many cases, fractions of a second can decide whether a collision can be avoided through emergency braking. Active Hazard Braking, a research project conducted by BMW Group Research and Technology into the avoidance of rear-end collisions, aims to make maximum use of this minimal timeframe. The existing proximity warning system can detect accidents before they happen, alert the driver in good time, preload the brakes and, in the new BMW 5 Series, activate the brakes as well. But Active Hazard Braking goes further, initiating an autonomous braking manoeuvre, if required. At relative speeds of 80-130 km/h, the research prototype can even use braking to avoid an accident, rather than merely limit its consequences. The system can also detect stationary vehicles. Work is continuing on motorcycle recognition.

Precise and real-time interpretation of traffic situations provides the basis for the successful avoidance of rear-end collisions. Only once the overall situation regarding the driver and vehicle is clear can the hazard braking system initiate the correct braking strategy. This places extremely high demands on the car's sensors, which have to piece together an overall picture using individual sources of data, and determine on that basis whether there is an actual danger of collision or if the driver is merely preparing to overtake another vehicle, for example.

Sensor data fusion allows a complete picture to be created.
To ensure that situations are recorded as accurately as possible, the sensors not only record the distance and speed to the vehicle in front, they also determine overlapping, acceleration differences and the time in hand in relation to all relevant vehicles within the detection range. They monitor the entire area around the car, including the crash barriers and any constructions lining the road to check whether an evasive manoeuvre

would be an alternative course of action. In the current prototype, laser scanners and radar sensors pick up vehicles and obstacles up to approx. 160 metres in front of the car and up to 20 metres on either side. Additional radar sensors monitor the area up to approx. 150 metres behind the car. This allows the engineers to examine and compare the use of various sensor technologies. Vehicle data, such as the car's steering angle, and driver inputs – e.g. activation of indicators – are also included in the calculations for the driving situation assessment, while information from lane recognition and driver alertness systems can add further detail to the interpretation of driving situations and be incorporated into the reaction strategy.

"High-resolution sensors and powerful algorithms allow us to ensure that the system in no way impairs the driver or takes decisions out of his hands in non-critical instances, but only brakes – as required and in order to avoid a collision – in situations where a rear-end impact is likely."

Dr. Peter Zahn

Adapting to each situation – the various warning options.

In order to address the wide variety of traffic scenarios as effectively as possible, BMW Group Research and Technology specialists are working on situation-oriented strategies to ensure rapid and correctly judged responses. If a critical situation is foreseeable, the car first alerts the driver to the hazardous situation ahead of the latest possible braking opportunity. The warning signal – flashed up on the Head-Up Display but also delivered in audible and tactile form – first gives the driver the chance to take action himself. Only if he does not react and it is no longer possible to execute an effective evasive manoeuvre does Active Hazard Braking intervene to slow the vehicle automatically and, ideally, avoid a collision. The degree of stopping power is graded as the situation demands to the point of emergency braking. This anticipatory strategy gives Active Hazard Braking capability far beyond that of the emergency braking systems currently available.

With Active Hazard Braking, too, the driver remains responsible for the vehicle and can override the technology at any time. If the driver unmistakably presses the accelerator or swerves around an obstacle, the hazard braking manoeuvre is cancelled immediately.

Looking ahead.

The research engineers are currently working on incorporating the distance to the vehicle behind the car into the activation strategy of Active Hazard Braking. The aim here is to reduce the risk of rear-end collisions caused by the car braking rapidly and the vehicle travelling behind it failing to take the appropriate braking or evasive action in time. For example, if Active Hazard Braking detects that there is still sufficient room ahead for braking it can tailor the braking strategy in such a way that the car brakes earlier but less heavily. This means that the vehicle behind is given suitable warning of the car slowing, rather than being surprised by sudden emergency braking, giving him more time to react in the most effective way.

2.5 Lateral Collision Avoidance.

We have now reached the stage where it is hard to imagine the BMW Group building a premium vehicle without driver assistance systems. They monitor the area in front of the car, to the sides and to the rear, and in so doing help to improve road safety and avoid accidents. On multi-lane roads, in particular, a situation often occurs where vehicles draw too close alongside one another – as a result of one of the drivers avoiding an obstacle, perhaps, or maybe because they are not paying attention. In order to avoid side-on collisions, BMW Group Research and Technology engineers are developing a new driver assistance system that goes by the name of Lateral Collision Avoidance (LCA).

"LCA warns me if another vehicle is coming too close to the side of my car, or if I myself am getting too close to another vehicle."

Thorsten Tronnier, Project Manager LCA, BMW Group Research and Technology

The principle: sensors monitor the sides of the vehicle.
In the spring of 2010 – 25 years after it was first set up – BMW Group Research and Technology presented the Narrow Passage Assistant, a driver assistance system which helps the driver to follow the optimum central line along roads narrowed by roadworks, for example. Lateral Collision Avoidance is a further development of this system.

It works on all roads with at least two lanes and uses powerful ultrasonic sensors positioned at the front and rear of the vehicle flanks to monitor the sides of the car. The sensors monitor an area on either side of the car measuring anything up to four metres, depending on the car's speed. In the current research prototype the side area monitoring system works when the car is travelling at up to 130 km/h, and so covers the side areas of the car up to the recommended speed on German motorways. The researchers are working on further extending the speed band within which the system will

function. Lateral Collision Avoidance is the optimum extension of the Lane Change Warning System (which monitors the driver's blind spot), as it is triggered when vehicles are travelling directly alongside one another.

The warning concept.

The development of the side collision avoidance system includes investigation of the various warning concepts and how they work most effectively. The display and warning systems are deployed in several stages. If another vehicle enters a predefined area around the car, the driver is first alerted by a symbol in the Head-Up Display. The symbol changes appearance according to how close the other vehicle comes to the car, allowing the driver to assess the situation as effectively as possible on either side of the car without taking his eyes off the road ahead. If the other vehicle closes to within a critical distance, the alert symbol becomes a warning, accompanied by a slight steering impulse. If the driver follows this tactile recommendation of action, the potential collision will be avoided. If space is getting tight on both sides of the car, the steering impulse points the driver towards the middle of the bottleneck.

"The strength of the steering impulse can be compared with driving over a rutted road and can be overridden by the driver at any time. This is a fundamental principle of our driver assistance systems, as the driver always has responsibility for his vehicle."

Thorsten Tronnier

If the driver goes with the steering impulse, the car immediately moves away from the danger. However, the driver always retains full decision-making power over the car's responses and can decide for himself whether he follows the recommended action or overrides the system and continues along his current line. In tests, researchers have established that this form of feedback to the driver is immediately and intuitively understandable, as it follows another basic principle of the BMW Group driver assistance philosophy: feedback is primarily delivered to the driver at the point where action is recommended.

"It was important to us that the steering impulse could be felt by the driver, but did not present a distraction and, above all, could be overridden at any time. However, the car uses this tactile feedback through the steering wheel to indicate clearly what kind of action is recommended. The driver then knows intuitively what the correct course of action is. And it is here that he gains those extra tenths of a second which could prevent an accident."

Thorsten Tronnier

Side-on collision avoidance is more than purely a safety feature; it also increases comfort levels. By displaying the distance to objects to the left and right of the car on the Head-Up Display, this system provides the driver with the information he needs – directly within his field of view – on the available space around the car at all times. This allows him to choose the best line on the road and handle critical situations with much greater assurance and safety.

2.6 Traffic Jam and Queuing Assistant.

Active Cruise Control with Stop & Go function (ACC Stop & Go) not only maintains the desired distance to the vehicle in front, it also brakes the car's speed in heavy traffic down to a standstill. But wouldn't it be useful if the car could also actively control the steering, especially in more mundane situations such as traffic jams and queues? BMW Group Research and Technology experts working as part of the "Traffic Jam and Queuing Assistant" research project are focusing on giving the car the ability to steer itself in order to help drivers stay in their lane. The intervention of the Traffic Jam and Queuing Assistant makes life easier for the driver in comparatively tedious situations – from 0 km/h right through to 130 km/h.

A car that can think and steer.

The experts at BMW Group Research and Technology have extended the reach of ACC Stop & Go to include a "lateral guidance" function – the Traffic Jam and Queuing Assistant. Taking the vehicle in front of them as a reference point, drivers can use the system to determine the distance between them and their own top speed – in the same way as with Active Cruise Control. The difference is that the car can now also actively control the steering. Further development of the camera technology already in use today enables the car to anticipate the path of the road ahead on the basis of the road markings and automatically carry out minor corrections in its line. However, there are limits to what the video-based sensors can do. Automated driving is not yet possible (or desirable) through corners of a certain tightness, as drivers should not be relinquishing the task of driving the car; technology should merely help them fulfil this task. For this reason, every time the research vehicle comes to a halt, the Traffic Jam and Queuing Assistant requires the driver to reconfirm "longitudinal guidance", i.e. resumption of the journey with the system switched on. The system is only active when the driver has his hands on the steering wheel. Equally, though, he can deactivate this steering assistance by starting to change lane, either through a clear steering movement or by switching on the indicator.

"Our aim is to assist drivers in tricky driving situations, but without taking the responsibility for driving the car out of their hands."

Dr .Thomas Schaller, joint head of the Traffic Jam and Queuing Assistant project with Dr. Nico Kämpchen

The Traffic Jam and Queuing Assistant complements the proximity control function of ACC by actively introducing steering inputs to correct the car's line. These interventions can be clearly felt through the steering wheel, which is why the driver has to keep his hands on the wheel at all times in order to use the Traffic Jam and Queuing Assistant. If his hands come away from the wheel, the system is automatically deactivated and the driver is given a clear alert. The function can only be reactivated once the driver has his hands back on the wheel. This safety mechanism is designed to ensure that the driver is not tempted to drive with no hands, but is ready to take action at any time.

If a corner is too tight or the system reaches its limits due to insufficient road markings, the Traffic Jam and Queuing Assistant prompts the driver to take over full driving duties once again and switches itself off. The status of the system and this driver alert are flashed up within the driver's direct field of view both in the instrument cluster and on the Head-Up Display.

A highly automated view of the future.

Although the Traffic Jam and Queuing Assistant is still at the research project stage as things stand, it is allowing the engineers to build up important real-world experience on the technology's lateral guidance capability and to gradually explore its limits. The research is certainly heading in a clear direction. In the future, vehicles capable of a high level of automated driving in traffic tailbacks, in particular, would be a very attractive proposition. Up to certain speeds, this would allow the driver to work on emails or call up multimedia applications, for example. Heterogeneous and redundant sensors – i.e. the simultaneous use of radar, camera and laser scanners – could link up with extremely accurate digital maps to transform this idea into a reality.

"Technically, we are already very close to realising this vision, as systems such as the BMW TrackTrainer and Emergency Stop Assistant show. However, many issues surrounding the technology still need to be clarified, and we're looking into these with our prototypes."

Dr. Nico Kämpchen, joint head of the Traffic Jam and Queuing Assistant project with Thomas Schaller

2.7 Emergency Stop Assistant.

A car is travelling in the outside lane of a busy motorway when the driver suffers a heart attack and can no longer control his vehicle. The car therefore becomes an incalculable hazard for his fellow road users. As part of the "SmartSenior – Intelligent Services for Senior Citizens" research project, BMW Group Research and Technology engineers are developing the Emergency Stop Assistant to combat these types of scenarios. Emergency Stop Assistant is an assistance system that activates an autonomous driving mode when it detects that the driver has a serious medical problem, and carries out a controlled emergency stop. In simple terms, the car switches on the hazard warning lights and manoeuvres carefully – taking into account the traffic around it – to the outer edge of the road, before drawing to a standstill. At the same time, an emergency call is sent out containing the data required to initiate the necessary medical and traffic-related assistance measures. This enables the provision of effective emergency care tailored to the situation at hand. While project partners Siemens and Berlin's Charité University Clinic are working on the development of technologies aimed at establishing the driver's vital data, BMW Group Research and Technology is responsible for the functional implementation of the automated driving function.

"In the first stage of development we deliberately narrowed down the variety of complex driving situations and developed the Emergency Stop Assistant prototype initially for use on motorways and other similar stretches of road."

Dr. Peter Waldmann, Project Manager Emergency Stop Assistant, BMW Group Research and Technology

So far it has only been possible to experience the Emergency Stop Assistant in a simulation, but now the assistance system can also be tried out in a research prototype. In the test vehicle a heart attack can be "simulated" at the touch of a button on the steering wheel. The technology then takes over, the Emergency Stop Assistant keeping an eye on other road users as it automatically steers the vehicle – over several lanes, if necessary – onto

the hard shoulder and brings it to a standstill.

Highly automated driving to increase road safety.

The special characteristic of the Emergency Stop Assistant developed by BMW Group Research and Technology is that it not only assists the driver but – in a new development – takes over full control of the vehicle. As it can be assumed that the driver is no longer able to drive the car when the Emergency Stop Assistant is activated, the system has to safely carry out all longitudinal and lateral guidance tasks. This means keeping the car within its lane and maintaining a safe distance to the vehicle in front, before eventually moving onto the hard shoulder – changing lane several times, if required – and braking to a halt.

"The key information for the Emergency Stop Assistant is: Where am I and what are other vehicles on the road doing? To answer that question the car has to know where it is within its lane down to the last centimetre, but at the same time what other vehicles are doing. Only then can the system respond as required."

Dr. Peter Waldmann

In addition to clarification of the legal parameters, the development of new algorithms to record and interpret the area around the vehicle in relation to its current position is of key importance. Secure pinpointing of the vehicle within its lane and, above all, the reliable recognition of all vehicles and objects in its immediate area provide the basis for working out clear action strategies for the vehicle. This is achieved by bringing together various redundant sensor technologies, such as LIDAR, radar and camera recording on all sides of the vehicle. Redundant certainly does not mean superfluous here, but rather that the vehicle uses at least two different measuring principles in each direction to clearly establish its position. In this way, the BMW Group Research and Technology development engineers can ensure that automatic lane changes do not result in collisions.

Access to digital maps and positioning data from the highly accurate GPS system not only enable the research prototype to remain aware at all times of which lane it is currently in, but also provide it with precise information on the course of the road, how many lanes there are on this section of motorway and whether there is a hard shoulder available. This data is then processed

further and used as a basis to decide on actions which do not place nearby road users in danger.

The responses required to pull the vehicle gradually to a standstill in an emergency build on technology found in driver assistance systems already available in series-produced models, such as the Lane Change Warning system and Active Cruise Control with Stop & Go function. However, the technological challenges presented by highly automated driving mean that these systems have to be extended and adapted. Algorithms use the data from sensors to calculate the vehicle's next responses and the possible effects of these on vehicles in the vicinity. For example, the Emergency Stop Assistant pulls back from initiating a lane change if the manoeuvre would impede another driver. Only when it is possible to change lanes without creating danger does the vehicle move into the new lane. Once it has changed lanes, it continues to follow the road until a further change of lanes is possible. When it has reached the hard shoulder the vehicle then draws to a standstill.

"Our aim is to ensure that the vehicle moves onto the hard shoulder in a controlled fashion, rather than just as fast as possible. Even if the whole road is clear, the vehicle would still move onto the hard shoulder gradually so as to avoid dangerous or unpredictable manoeuvres."

Dr. Peter Waldmann

Looking ahead.

With the first development stage of the Emergency Stop Assistant to be fitted in a vehicle, BMW Group Research and Technology is debuting a safety feature which uses automated driving to avoid accidents. At the same time, the experts are demonstrating the possibilities that already exist as far as automated driving manoeuvres are concerned. There are, though, still one or two legal issues that need to be cleared up before the Emergency Stop Assistant can be registered for the road. Despite this, BMW Group Research and Technology is standing by automated driving as a possible way of avoiding accidents. Indeed, the development engineers are already working on extending the system. This opens up the possibility that vehicles of the

future could actively seek out spaces to change lanes and also contribute to improving safety for other road users in other contexts, such as by implementing adaptive stopping strategies on urban or country roads.

3. Connected Drive for Efficient Dynamics – improved efficiency and dynamics through integration.

Connected Drive links the vehicle and its occupants intelligently with the outside world. This networking approach offers BMW Group customers increased levels of safety, comfort and infotainment – through driver assistance systems, navigation system options and personalised entertainment. The example of intelligent sensors or data from the navigation system linking up with the measures used by Efficient Dynamics to reduce fuel consumption provides further evidence of the added value possible through networking. Functions of this kind point the way to a new dimension in Efficient Dynamics with improvements in fuel consumption of up to 15 percent.

3.1 Green Driving Assistant.

Among the selection criteria that the current generation of navigation systems gives drivers to help them choose a route is the expected journey time of each option and the distance to the destination. With the Green Driving Assistant, the BMW Group offers drivers a tool that also tells them their fuel consumption over each route and helps them to select one which would burn less fuel.

Quick, short or ECO – route planning with the Green Driving Assistant.

When planning their route ahead of a journey, drivers can compare suggested routes to determine which offers the shortest travelling time or the lowest fuel consumption. To help them decide, the Green Driving Assistant adds expected fuel savings to the familiar criteria of time of arrival and distance making it easy to decide whether a possible saving of fuel makes a slightly longer journey time worthwhile.

"The Green Driving Assistant gives me an objective way of selecting which route I follow and whether I wish to make use of the potential for saving fuel. In this way I can make a conscious decision to take quarter of an hour longer on the "green" route, for example, but save one litre of fuel in the process."

Johannes von Grundherr, Project Manager Green Driving Assistant

Tailored to the situation and versatile – journeys with the Green Driving Assistant.

The Green Driving Assistant offers options while driving to ensure that drivers reach their destination even more efficiently and comfortably. The technology informs the driver straightaway if it registers that the vehicle has insufficient fuel in the tank to reach the desired destination with the current driving style and route. The system shows whether, by activating the ECO mode (see Chapter 3.2) or choosing another route, the consumption could be optimized in order to reach the destination without stopping to top up – and enduring the delay that this involves.

If the driver wants to continue with the same driving style, the Filling Station Assistant subfunction of the Green Driving Assistant allows the timing of a refuelling stop to be planned carefully into the route. When choosing which fuel station to stop at, the system takes into account whether the driver prefers a particular fuel company – because he holds a customer loyalty card, for example – or fuel, and how great a detour would be involved. Once the driver has decided on his preferred filling station, it is entered into the navigation system as an intermediate stop and the route calculation is adapted accordingly.

The Green Driving Assistant never stops learning.

A journey or driving profile learned by the navigation system serves as the basis for its calculation of the distance, arrival time and potential fuel savings involved. Here, the BMW Group engineers have developed an algorithm which learns the typical fuel consumption. A learning phase of approx. 500 km is all that is required to produce an adapted, vehicle- and driver-specific value which can be used by the Green Driving Assistant each time the driver is planning a new route.

3.2 ECO mode – even more efficient driving at the touch of a button.

Giving a car a sportier or more comfort-focused character at the touch of a button is nothing new nowadays. But now the ECO mode adds another facet to this capability, enabling owners to drive more efficiently. The aim here is to develop a driving style that is both relaxed and optimises fuel economy. An integral approach combining drive configuration, display concept and interior comfort offers the customer Sheer Driving Pleasure with the option of reducing fuel economy at the same time: savings of well over ten percent are possible. In combination with the Proactive Driving Assistant and active coasting, the potential rises to as much as 15 percent.

"The ECO mode supports a calm, relaxed, forward-thinking driving style. The result is the best possible fuel efficiency for any particular driver. It's ideal for coasting along and has the effect of reducing the number of fuel stops."

Silvia Patricia Ghella-Schröder, Head of Energy Management

Drive configuration.

When the driver activates the ECO setting using the switch on the centre console, the output available from the engine remains the same, but its performance characteristics change. The accelerator mapping and the gear change characteristics of the automatic gearbox (or the gear shift indicator settings in cars with a manual gearbox) are adapted in order to support a more efficient driving mode.

The car works in ECO mode at up to approx. 70 percent of maximum accelerator movement. Above this, the accelerator allows the output of the normal driving mode to be accessed. This enables considerably lower fuel consumption to be achieved while still allowing the driver to deal assuredly with situations such as a busy motorway slip road or an overtaking manoeuvre.

3.2.1 Display concept.

The first things the driver notices when he switches to ECO mode are changes to the displays in the instrument cluster. These ECO displays help and motivate the driver to drive more efficiently. An accelerator recommendation is displayed in place of the current fuel consumption. An area highlighted in blue symbolises the efficient accelerator positions. If the driver moves out the blue area, the increasing accelerator pedal angle marks a transition to maximum performance. The accelerator mapping has been adjusted to enable this transition to be understood intuitively and found at any time. The driver also has the option of setting a personal ECO top speed of between 90 and 130 km/h. An "ECO tip" appearing in the central display alerts him if he exceeds this speed. The familiar gear shift indicator is also integrated into the ECO tip concept.

The ECO mode enables the driver to save fuel and increase range, as shown in a new "Bonus Range Display". In this way the driver is given direct feedback about his success in saving fuel and is "rewarded" with bonus kilometres. The longer the driver continues economically in ECO mode, the higher the number of bonus kilometres will be. This could be described as the driver's "kilometre cushion".

"The ECO displays show me – right in front of my eyes – how efficiently I'm driving. I can decide how I want to drive based on the situation at hand, and I can see what effect this has on range."

Christian Popp, Displays EfficientDynamics

The driver can also consult the central display for a historical record of fuel consumption. He can see which mode he has been driving in and how high or low his average fuel consumption is. The "Experience Technology" monitor – which can be displayed as and when desired – gives visual expression to the BMW EfficientDynamics measures currently in action: from the Auto Start-Stop function at traffic lights or Brake Energy Regeneration when decelerating to active coasting (see Chapter 3.2.2). The active systems are highlighted in an abstracted vehicle diagram, while the accompanying

text provides more detailed information on the status and effect of each function. In this way, the customer can find out which systems are activated and when for better knowledge and understanding of the technology.

Using a mobile terminal, different driving parameters can be recorded and the efficiency of a journey can also be analysed away from the car. An example of such an application is the concept of an iPhone App called MINIMALISM Analyser that is based on MINI Connected. In a game-like format, this provides customers with feedback about how efficiently they are accelerating, how carefully they are braking in advance and how well they are changing gear. The MINIMALISM Analyser edits the data in a simple and informative way. Once at the destination, this application enables the journey to be analysed, provides tips for reducing fuel consumption and enables the user to compare his performance in a Community Ranking.

3.2.2 Active coasting and the proactive driving assistant.

ECO mode also gives the driver the benefits of the “active coasting” and “proactive driving assistant” functions, which enable an even more efficient driving style.

Proactive driving assistant.

In the ECO mode, the “proactive driving assistant” is also active. This helps the driver to anticipate future driving situations and make optimum use of the car’s kinetic energy. The car recognises speed limits, tight bends and turnings and calculates the exact moment when the driver should take his foot off the accelerator and let the car roll or glide. The vehicle uses data from the navigation system to identify the appropriate situation and the indicator appears in the instrument cluster and in the Head-up Display directly in the driver’s line of vision. The proactive driving assistant considers the braking required, based on current data from the car and data on the course of the road and also takes into account whether the car is fitted with the gliding in neutral function (see below). The proactive driving assistant encourages the driver to let the car glide at the right times and in so doing save fuel without impeding vehicles following behind. Added to which, in the future it is likely to use current traffic and road data from the intelligent learning navigation system (see chapter 3.3), in order to optimise its prediction.

“If I can see the future, I can obviously prepare better for upcoming situations. Predictive ability therefore gives a new dimension to intelligent energy management, which we have introduced in all our vehicles in the form of BMW EfficientDynamics.”

Norman Wiebking, Project Manager, Proactive Energy Management

Active coasting over the road.

“Active coasting” is an innovative function for automatic vehicles, which the BMW Group is making available for the first time exclusively with the ECO mode. The principle involved is extremely simple: if the driver takes his foot off the accelerator, the gearbox automatically cuts the drive connection between the engine and gearbox. The only forces now braking the vehicle

are rolling resistance and drag. With an appropriately predictive driving mode this eliminates frictional losses in the drive train and saves fuel. When the driver gives the brakes a light touch, the clutch engages again automatically and the car coasts, continuing to slow under what is known as the “engine brake”. When the driver releases the brakes again, the car continues to coast down to lower speeds and Brake Energy Regeneration continues to save fuel. Renewed acceleration followed by the driver taking his foot off the gas – as before – allows the car to glide along again. Needless to say, all control and stability systems remain active when the car is coasting.

“Here we’re using only the kinetic energy already built up in the car. It’s fascinating to see how far a vehicle rolls when you let it do just that. And this is exactly what we’re focusing on here."

Geert Schmitz, Head of Energy Concepts

Although the engine still uses fuel at active coasting, fuel consumption is very low, at just 0.5 to 1 litre per hour. Active coasting uses less fuel than simply using engine braking because it avoids frictional losses and – when used with a predictive driving technique – can be maintained over longer distances. The vehicle rolls much further when it is coasting than when slowing under the engine brake.

“It’s simple maths. Without the prediction function, I might drive at a constant speed up to a speed-restricted section of road and only take my foot off the gas and brake shortly before the speed-restriction starts. With prediction, I can coast in neutral to optimum effect using a small amount of fuel. I would only have to be coasting for two seconds for my fuel consumption to be lower than if I was using engine braking.”

Victor Kühn, Project Manager Active coasting

The active coasting function generates potential fuel savings of between two per cent (in average customer use without prediction) and ten percent. To achieve this value, the driver has to be thinking way ahead at all times. Here, the Proactive Driving Assistant can play a major role.

Scope for adjustment.

The scope of ECO mode can be personalised beyond the pre-set configurations. The ECO mode functions “ECO maximum speed” and “coasting in neutral” can be switched on and off individually. The driver continues to have the option of selecting a special efficiency programme governing interior comfort, which consists of a separate climate control programme and the special management of systems using electric power.

The future: proactive energy management and a proactive operating strategy.

The proactive energy management helps the car to think with and in advance of its driver. Information available in the car, such as from the navigation system, is used to predict the upcoming traffic situations such as traffic jams, hills, speed limits or zones with traffic-calming measures. The operating strategy can adjust itself and respond optimally to these boundary conditions. As an alternative, this information from the proactive system is a further important way of optimising one other way of controlling fuel consumption: driving style. That is why the BMW Group is working on driver assistance systems that support the driver proactively with information, e.g. for a braking situation at a speed limit on the road ahead. To this end, BMW Group is collaborating with the German Federal Ministry for Education and Research (BMBF) and partners from the German automotive industry on research into proactive energy management within the scope of the research project “Energy-Efficient Driving EFA2014”.

If a driver, for example, wants to move from a trunk road to a motorway, proactive thermal management can lower the coolant temperature in advance in order to provide more power. During urban trips, on the other hand, the temperature is raised as no high loads are expected that require special cooling. The result: less internal friction in the engine and greater efficiency.

If a hybrid vehicle, for example, is approaching a downhill section of road, the on-board computer is notified accordingly. This triggers the disconnection of the generator in advance and transfers the charging of the battery to the engine braking while travelling downhill. If a traffic-calmed zone is detected, the battery is primed in advance for maximum electrical drive.

3.3 Intelligent learning navigation.

Nowadays, navigation systems are extremely popular among drivers as a reliable means of route guidance. However, drivers have always had to tell the system where they needed to go. Now, though, BMW Group Research and Technology is using artificial intelligence to teach the pathfinders how to learn, opening up totally new potential when it comes to plotting a route. In the future, navigation systems will be able to use these skills to predict the destination of a journey without the driver having to enter it beforehand, to give warnings of traffic jams and to reduce fuel consumption.

Learning how to predict.

The BMW 3 Series converted by the BMW Group research engineers into a prototype can predict with a high level of probability where a journey is heading and which route has been chosen – without the driver inputting the information in advance. As part of the "self-teaching route predictor" project, the BMW Group Research and Technology experts are working on enabling vehicles not only to react to the driver's commands but also to be proactive. In that way a vehicle will be able to prepare itself for future events. The upshot is increased convenience, improved dynamics and enhanced fuel economy.

To make the required predictions, the navigation system first has to get to know the driver and his regular routes. A secure profile is created for each driver in which past journey history is recorded. This will include not only destinations, short cuts and rat runs used en route, but also information such as the time of day and seat occupancy.

"If it's a Monday morning, my car decides that my workplace will be my likeliest destination. If my child is also on board, the navigation system will plan for a detour past the school. Or if it's a Saturday morning, my personal route planner decides that I'm most likely off to do some sport."

Robert Hein, Head of Navigation and Data Services of the Future

The research engineers' system has already earned a reputation for the reliability of its forecasting. While at the start of the project it was on the

right track in only 30 percent of cases, its success rate has now risen to around 80 percent.

More comfort, better dynamics, greater efficiency.

All this information helps to make the driver's life considerably easier. Early warnings of
congestion, rapid selection of the most likely – as opposed to the most recent or pre-stored – destination, and cross-checking of predictions against the personal calendar function in the driver's smartphone are just the first of many possible ideas.

Things really start to get interesting when the learning navigation system is linked up to in-car systems, such as the proactive energy management of BMW EfficientDynamics (see Chapter 3.2.2). For example, Brake Energy Regeneration presently only operates when the engine is on overrun, for example when descending a hill. But with proactive navigation, regenerative braking can start saving fuel well before the downhill section, as the system knows that at that point on the route the battery will be recharged. And if the driver plays his part too – for example, by making use of information about a currently hidden speed limit that's coming up 500 metres ahead, and reducing his speed gradually rather than hitting the brakes suddenly – then proactive energy management on future vehicles could achieve fuel savings of between five and ten percent.

"With this concept of integrating intelligent learning navigation systems into our vehicles we will be able to further refine and systematically introduce our BMW EfficientDynamics strategy."

Robert Hein, Head of Navigation and Data Services of the Future

The developers are hard at work on other potential features too. For hybrid drive vehicles in particular, information about approaching 30 km/h zones, for example, and where they start and finish can prove very useful, allowing the battery charge to be managed as required and utilised to optimum effect. The BMW Research and Technology prototype is also equipped with the road sign recognition camera already used on the BMW 7 Series. This camera can "teach" the navigation system about any speed limits it may be unaware of. Another potential application would be to use the vehicle's sensing systems to inform the intelligent navigation system about the

radius of upcoming corners, or about road topography. Everything that the navigation system learns can be fed into the operating strategy.

The ability to learn and share.

"The magic word for the future is integration. An integrated navigation system can share information it has learned with other vehicles and therefore also benefit from their knowledge. That offers huge potential."

Robert Hein

Much of the data absorbed by the intelligent navigation system is useful not only for individual drivers, but for all navigation system users. This includes information on road characteristics, i.e. inclines, the radius of corners and speed restrictions. This data is cross-checked with the digital map database, helping to systematically improve the database at the same time. Information on traffic flow and fuel consumption can also be learned and shared with other vehicles.

The navigation system can use the information it has learned to suggest routes to the driver that might be particularly fast or use less fuel. This intelligent predictive ability would also benefit from the information learned by all other vehicles on the road. In this way, the predictions for the road ahead become more precise, possible errors in the maps are corrected and forecasts for the traffic situation ahead are improved. All of which allows the vehicle's proactive energy management systems to work even more precisely and efficiently.

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