BMW GROUP
Corporate Communications

THE NEXT 100 YEARS

Rolls-Royce Motor Cars Limited

Press release
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BMW Group opening of Unterschleißheim campus

Contents

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Introduction. On 11 April 2018, the BMW Group is celebrating the official opening of the Autonomous Driving Campus, which marks a major step forward for the systematic development of highly and fully automated driving at the BMW Group.

Over the course of recent years, the BMW Group has demonstrated the basic essentials needed for highly automated, fully automated and ultimately autonomous driving at various events.

As long ago as 2006, a BMW 3 Series was lapping the Hockenheim race circuit by itself and the BMW Group has been road-testing automated prototypes on the A9 motorway between Munich and Nuremberg since 2011.

In 2014, an automated prototype from the BMW Group drifted its way around the Las Vegas Speedway for the first time, proving that even driving at the limits of performance is within the realms of possibility.

Following its acquisition of a stake in HERE in 2014 and its collaborations with Intel, Mobileye (since 2016) and other partners, the BMW Group has given the go-ahead for developing the BMW iNext for series production.

Due in 2021, the BMW iNext will be the first ever vehicle from the BMW Group to offer safe Level 3 functionality when driving on motorways (a detailed explanation of Levels 1 to 5 and the differences between them can be found in the appendix at the end of this text).

The BMW Group is working together with its partners on a scalable technology platform for putting stable and safe highly / fully automated driving into practice, and their activities will now be based at the new BMW Group Autonomous Driving Campus.

Major development milestones to date:

2006: The first self-driving Track Trainer (a BMW 3 Series) laps the Hockenheim race circuit on the racing line.

Since 2011: Highly automated test cars in action on the A9 motorway in Germany.

2014 CES: Drift Assistant demonstrates perfect vehicle control even when driving at the limits of performance.

2015 CES: 360° collision prevention and Remote Valet Parking Assistant presented in the BMW i3.

2016 CES: Automated Gesture Control Parking in the BMW i3.

2017 CES: Level 4 demonstration drive with a BMW 5 Series Sedan – highly automated, connected and personalised.

2017: A test fleet made up of 40 highly and fully automated BMW 7 Series test vehicles commences operations in Germany, the USA and Israel.

2018: Official opening of the BMW Group Autonomous Driving Campus in Unterschleißheim near Munich.

15 months ago, the decision was taken to amalgamate all working resources involved with driver assistance and highly / fully automated driving at a single location.

The planning process for and conversion of an existing property in Unterschleißheim near Munich to create the BMW Group Autonomous Driving Campus was completed in record time. The new campus offers 23,000 square metres of office space with room for 1,800 employees, while the areas for

vehicles have a maximum capacity of 500 vehicles.

When searching for an appropriate location, the site's excellent infrastructure, its proximity to the Research and Innovation Centre, and nearby links to the motorway network tipped the balance in its favour.

New spaces – new working method. The BMW Group is of the view that the requisite technological leaps in the fields of driver assistance and highly / fully automated driving can only be made by using methods of agile development as a key success factor.

Agile development methods such as the Large Scale Scrum (LeSS) approach help to make the complexity of the challenge far more manageable. The new working method – which involves assigning subtasks to as many as 80 feature teams – in turn calls for suitable work spaces, which have been specially created for this purpose at the new campus.

The organisational structures and the role of managers have both been carefully aligned to the new method of working – values such as trust and transparency have to be practised if work on a software code that is shared by everybody is to be organised successfully.

The data-driven development cycle.
For the data-driven development cycle, a wealth of reality-based data must first be collated via the **system of sensors** fitted in the vehicles. The types of sensor and their positioning in the development vehicles match the target set-up, as part of a focus on the entire vehicle from the outset. Lidar, radar, camera and ultrasound technologies combine together to create a picture of the vehicle's immediate surroundings and wider environment. Ultimately, a total of

several dozen sensors will go to work in vehicles to give them their perceptive powers.

The vast quantities of data produced in this process then undergo intelligent preparation and provisioning. During a working day, a test vehicle with highly automated driving sensors collects around 16 terabytes of data, while a test vehicle fitted with sensor technology for fully automated driving amasses some 40 terabytes. Data preparation and provisioning takes place in the **Data Centre** that is located about two kilometres (1.25 miles) from the Autonomous Driving Campus.

Commensurate levels of computing power ensure this data is quickly made accessible for training neural networks and refining algorithms.

This clearly illustrates how autonomous driving and associated online services will push back today's boundaries in terms of storage infrastructure and computing power.

After putting together its **test fleet** of 40 vehicles in 2017, the BMW Group now gathers sensor and vehicle data in all manner of different traffic situations. This data is needed for validation, simulation and machine learning algorithms. The test fleet will grow in size from 40 to 80 vehicles in 2018 and will be deployed in Germany, the USA, Israel and China.

By 2021, over 200 petabytes will have been processed in the Data Centre. The network infrastructure for data transfer (2 x 100 Gbps) is many times faster than the current data line capacities.

The Data Centre's infrastructure forms the basis for analysing all conceivable driving situations in order to guarantee subsequent safe operation on public

roads. There are approx. 100,000 CPU cores to help with the evaluation of the data (in a machine learning process) and the simulation of traffic scenarios.

The simulation. Through simulation scenarios that occur too infrequently in real life can be mapped as completely as possible. This is done by importing the test vehicle's current level of functionality into a virtual vehicle in a virtual world.

Only **artificial intelligence** makes autonomous driving possible. It became apparent at an early stage that autonomous driving cannot be achieved using rule-based approaches alone. Instead, adaptive machines are what is needed to turn the vision of autonomous driving into reality.

It is only with the help of artificial intelligence that the system in the vehicle can derive an intelligent interpretation of a given situation and an ideal driving strategy can be determined.

Artificial intelligence is a sub-discipline of information technology that involves using computer programs to tackle the sort of problems that humans would have to apply their intelligence to solve. Artificial intelligence is a key technology for numerous aspects of present-day and future mobility.

It has a wide variety of applications at the BMW Group. Production processes are optimised with the help of artificial intelligence, for instance, and bespoke customer interaction developed using natural language.

Another field of application is the creation of high-precision roadmaps with dynamic contents, such as temporary obstructions or current traffic levels. The BMW Group is already active in all of these areas and is working hard on fusing them into a worthwhile and extremely enjoyable overall user experience.

Artificial intelligence is increasingly enabling computers to come up with solutions to highly complex tasks that would have been quite unthinkable just a few years ago. The software developers at the BMW Group have played a substantial role in this progress and are able to experience the new technology directly in the product.

The PADS. The sensor data is pre-processed in the sensors before being outputted at speeds of several Gbit/s and relayed to the environment model, which is computed in the PAD.

The PAD control units act as a central “brain” for calculating the driving task. The incoming data received by the PAD includes all sensor data as well as the data from the back-end’s high-precision map.

This data is used to compute the environment model, driving strategy and trajectory. The trajectory is in turn transferred to the vehicle’s “Motion Control”. The Motion Control governs the car’s drive system, brakes and steering. Safety and the smoothness of the vehicle’s motion are the priorities here.

The PAD control units also boast supreme computing performance together with maximum security. It is the size and performance capabilities of the PAD control units that produce tangible distinctions between Levels 2 to 5. Industrial manufacturing of the PADs represents one of the major challenges along the road to highly and fully automated driving.

The Level 5 showcase at the official opening of the BMW Group Autonomous Driving Campus: The Autonomous Driving showcase presented by the BMW Group as part of the campus's official opening takes a look ahead at the functionality of and interaction with Level 4 and Level 5 vehicles.

A BMW 7 Series gives an impressive demonstration of how fully automated driving technology can transform the future face of personal mobility. In the showcase, a BMW 7 Series sets off with nobody aboard having been summoned by its owner to pick them up via a smartphone app.

The vehicle can be sent to a selected pickup point, with the smartphone used for access authorisation once it arrives there. Another authentication option illustrated as part of the showcase is the prototype exterior display, which even greets the passenger being picked up by name.

This display makes it possible to unlock the car doors by touch control, as an alternative to using the smartphone app. As it will no longer be necessary for any of the occupants to be directly involved in the task of driving (in the Level 5 scenario), a Rear Seat Entertainment System of prototype design is used to commence the journey.

The destination address is transferred to the vehicle beforehand via the smartphone app. The driver's seat remains empty. Thanks to the safety mechanisms that have been implemented, the journey can only begin once all occupants have fastened their seat belts.

As no further intervention is required throughout the fully automated journey, the vehicle's passengers can spend their time on board as they please or explore the Entertainment System, which can also be used to initiate stops en route. It is

also possible to control vehicle functions, as illustrated by the following functions: the horn, headlight flasher and locking / unlocking of doors. Once the destination has been reached, the passenger locks the car from the exterior display, after which it parks itself automatically.

The "Schwabinger Tor" testing ground: The BMW Group is working hard to tackle one of the biggest challenges facing all motorists: parking. BMW Parking Services will be integrated into all BMW models, while a smartphone app will also allow them to be used in any other vehicle.

BMW Parking Services have all aspects of parking covered: quickly finding a free spot on the street or in a multi-storey car park, booking a parking space easily and paying for it without cash, and finally fully automated and driverless parking (Valet Parking Service) in a multi-storey car park or shopping centre car park.

BMW sees a fully automated / driverless Valet Parking Service as having great potential, and is therefore working towards offering this particular service to the widest possible spectrum of customers.

Creating a comprehensive and widely available product offering for our customers requires a standardised interface for wireless communication between parking zones/car parks and the vehicle. Under the umbrella of the German Association of the Automotive Industry (VDA), BMW is working together with other OEMs, parking zone operators and suppliers to establish an ISO standard for this purpose.

Appendix

The roadmap to autonomous driving – from Level 0 to Level 5.

Level 0 describes a car that moves without any form of assistance functions. The responsibility for the task of driving lies entirely with the driver at all times.

Level 1:

This refers to the first ever assistance systems aiding safe and comfortable driving, with functions such as cruise control, which keeps the vehicle moving at a set speed.

Level 2 (today):

Driver assistance systems provide a preliminary stage of automated driving. The driver is responsible for the task of driving at all times.

Level 3 (starting in 2021 with BMW iNext):

Once Level 3 is reached, it will be possible for the driver and vehicle to share responsibility for controlling the vehicle. During highly automated driving in traffic that is moving in the same direction and is segregated from oncoming traffic, drivers will be able to perform secondary activities on in-vehicle media for longer periods of time or simply relax (eyes off). They must, however, still be in a position to take over the task of driving again within a reasonable amount of time (a few seconds) when prompted by the system.

Level 4 (starting in 2021 with technical provisos, BMW iNext):
Fully automated driving in urban traffic and – in a version with extended functionality – in traffic that is moving in the same direction and is segregated from oncoming traffic. The driver can sleep during long-distance journeys if necessary. The key difference compared to Level 3: the timespan for taking over control again is far longer (mind off).

Level 5 (developments in parallel to Level 3 and 4, expected to be possible post-2021 in the form of pilot projects):
Autonomous driving. Passengers sit in the vehicle without any involvement in the task of driving; no driving licence is required (driver off). Assuming the vehicle is fitted with pedals and a steering wheel, the driver may take over control if they wish, but will not be obliged to do so at any time.

If you have any questions, please contact:

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The BMW Group
With its four brands BMW, MINI, Rolls-Royce and BMW Motorrad, the BMW Group is the world's leading premium manufacturer of automobiles and motorcycles and also provides premium financial and mobility services. The BMW Group production network comprises 30 production and assembly facilities in 14 countries; the company has a global sales network in more than 140 countries.
In 2017, the BMW Group sold over 2,463,500 passenger vehicles and more than 164,000 motorcycles worldwide. The profit before tax in the financial year 2017 was € 10.655 billion on revenues amounting to € 98.678 billion. As of 31 December 2017, the BMW Group had a workforce of 129,932 employees.

The success of the BMW Group has always been based on long-term thinking and responsible action. The company has therefore established ecological and social sustainability throughout the value chain, comprehensive product responsibility and a clear commitment to conserving resources as an integral part of its strategy.

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