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International Motor Show (IAA) 2015 **Bosch overtakes the automotive market** Sales in automation and connectivity in the billions

September 15, 2015

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- ▶ Mobility solutions: growth in weaker market environment
- ▶ Groundbreaking development in battery technology for electric vehicles
- ▶ Assistance systems: sales expected to reach one billion euros by 2016
- ▶ Services: Bosch is connecting cars beyond the hood

Frankfurt/Stuttgart, Germany – The Bosch Group’s mobility business is growing considerably faster than the global automotive market. “Bosch is assuming a leading role in the transformation that is about to sweep through the automotive sector. Automation, electrification, and connectivity – Bosch is already enjoying success in all three areas,” said Dr. Volkmar Denner, chairman of the board of management of Robert Bosch GmbH, at the International Motor Show (IAA) in Frankfurt. The Mobility Solutions business sector is expecting sales growth in 2015 of around ten percent, or five percent after adjusting for exchange-rate effects¹. In the same time period, global vehicle production will only increase marginally. One reason for Bosch’s success is efficient combustion technology. This year, the supplier of technology and services will sell 15 percent more gasoline direct injection systems and ten percent more high-pressure diesel injection systems. Sales of ESP systems will also grow once again by a quarter. “Our innovative strength in all the mobility growth trends is helping us attract new customer groups and tap business opportunities beyond the automotive industry,” Denner said.

Mobility solutions: new customers, new services

Whether for private or commercial vehicles, multimodal transportation offerings, fleet management, or smart transportation infrastructure, Bosch brings together vehicle technology, the data cloud, and services to offer complete mobility solutions. In the future, the customers for these solutions will include new market players such as Tesla, Google, two-wheeler manufacturers, and car-sharing pro-

¹ Since February 2015, Bosch Automotive Steering GmbH (formerly ZF Lenksysteme GmbH) has been consolidated as part of the Mobility Solutions business sector.

viders. Bosch is also already working on specific projects with insurers, leasing companies, and other fleet operators.

Breakthrough in battery technology: solid-state cells for electric cars

At this year's IAA, Bosch is presenting solutions and innovations in the growing fields of connectivity, automation, and electrification. Each year, Bosch invests nearly 400 million euros in turning electromobility into a reality. That this is bearing fruit was underscored by Denner, who presented a possible breakthrough innovation in battery technology. Having bought U.S. start-up Seeo Inc. (Hayward, CA), Bosch now possesses essential know-how in the area of innovative solid-state cells. This technology complements the developments the company has already achieved with its Japanese partners GS Yuasa and Mitsubishi Corporation. To date, the aim has been to double energy density and halve its costs by the end of this decade. With the Seeo technology, Bosch sees the potential to increase the energy capacity of lithium-ion cells even further. "Bosch is applying its knowledge and a great deal of financial resources to help electromobility achieve a breakthrough," Denner said.

Automated driving: sales in the billions on the horizon

In particular, the trend toward self-driving cars is already a major sales driver for Bosch. More and more new vehicles feature assistance systems such as lane-keeping support or emergency brake assist. Sales of radar and video sensors will once again double in 2015 for the second year in a row. This high demand means sales of Bosch driver assistance systems will exceed one billion euros as soon as 2016. As Denner explained, "Automated driving will arrive gradually by a process of developing and refining driver assistance systems." The company has some 2,000 engineers working on this alone – a good 700 more than two years ago.

The company has also set itself ambitious goals for connectivity. Bosch technology is making vehicles an active part of the internet, but this development will go beyond cars in the future. Bosch already supports providers of car and bike sharing and operators of trains and buses with software solutions. It is in the services business where Bosch's versatility is particularly advantageous. The supplier of technology and services is in a better position than any other company in the automotive sector to connect mobility with energy, building, and industrial technologies.

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Mobility Solutions is the largest Bosch Group business sector. In 2014, its sales came to 33.3 billion euros, or 68 percent of total group sales. This makes the Bosch Group one of the leading automotive suppliers. The Mobility Solutions business sector combines the group's expertise in three mobility domains – automation, electrification, and connectivity – and offers its customers integrated mobility solutions. Its main areas of activity are injection technology and powertrain peripherals for internal-combustion engines, diverse solutions for powertrain electrification, vehicle safety systems, driver-assistance and automated functions, technology for user-friendly infotainment as well as vehicle-to-vehicle and vehicle-to-infrastructure communication, repair-shop concepts, and technology and services for the automotive aftermarket. Bosch is synonymous with important automotive innovations, such as electronic engine management, the ESP anti-skid system, and common-rail diesel technology.

The Bosch Group is a leading global supplier of technology and services. It employs roughly 360,000 associates worldwide (as per April 1, 2015). The company generated sales of 49 billion euros in 2014. Its operations are divided into four business sectors: Mobility Solutions, Industrial Technology, Consumer Goods, and Energy and Building Technology. The Bosch Group comprises Robert Bosch GmbH and its roughly 440 subsidiary and regional companies in some 60 countries. Including its sales and service partners, Bosch is represented in roughly 150 countries. This worldwide development, manufacturing, and sales network is the foundation for further growth. In 2014, Bosch applied for some 4,600 patents worldwide. The Bosch Group's strategic objective is to create solutions for a connected life. Bosch improves quality of life worldwide with products and services that are innovative and spark enthusiasm. In short, Bosch creates technology that is "Invented for life."*

Additional information is available online at www.bosch.com, www.bosch-press.com, <http://twitter.com/BoschPresse>

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BOSCH

September 15, 2015
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**New systems, new services, new customers:
Bosch mobility solutions**

Presentation by Dr. Volkmar Denner,
chairman of the Bosch board of management,
at the IAA press conference
in Frankfurt on September 15, 2015

Check against delivery.

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Ladies and gentlemen,

The IAA is with us again, and our focus is on the future of the car. This future is something Bosch is delivering, and it is doing so at an ever faster pace. In battery development, we see the potential for a breakthrough soon, as I will show in a few minutes.

In fundamental terms, we are preparing for three major trends: driving is becoming electric, automated, and connected. We are making good progress in all three areas of automotive development. On this subject, Mr. Bulander will be presenting some new solutions at this booth following my remarks on our strategy.

At least in the big cities, the car will link up with other means of transport. Bosch sees this as the basis for services – a business with new customers, also outside the automotive industry. This explains why we decided to rename our Automotive Technology business sector Mobility Solutions. We want to achieve safety, convenience, and efficiency for both the car and the intermodal transport of the future.

2015: Bosch is growing despite stagnating vehicle production

But first, let's take a look at our current business. Our growth course has continued this year as well, despite current developments in China giving us reason to be cautious. All in all, though, the Bosch Group's performance is still at the top end of our growth expectations. The Mobility Solutions business sector is developing especially well. Its sales will likely grow by some ten percent in 2015, and by more than five percent after adjusting for exchange-rate effects. We are growing, while global vehicle production will only increase marginally.

At Bosch, unit sales of important systems have again increased steeply this year: the figure for the ESP electronic stability program is 25 percent, for gasoline direct injection systems 15 percent, and for common-rail diesel

injection systems ten percent. The driver assistance business is growing particularly strongly: unit sales of our radar and video sensors will again double in 2015.

The potential of mobility solutions: new customers, new services

For Bosch, mobility solutions mean new customers with growing business volume:

- There are the new Californian players in the automotive industry – we are supplying both Google and Tesla.
- There are the makers of two-wheelers. We are the European market leader for e-bike systems. Two years ago, we launched MSC motorcycle stability control – the world’s first ESP for motorcycles. And now, we’ve set up our own two-wheeler business unit in Yokohama.
- There are insurance companies and vehicle-leasing companies. We are lowering the operating costs of their fleets by supplying a connectivity control unit that automatically transmits driving and servicing data to a Bosch server for evaluation. Once the data have been processed they can be used to plan servicing appointments more accurately, and thus to keep down times as short as possible. We already have five major orders in this area.
- There are individual drivers, and not just when they visit our Bosch repair shops. For example, our Drivelog Connect mobility portal offers them a real-time analysis of their driving behavior, together with tips on how to save fuel. All they need for this is a smartphone app and an electronic connector for reading out the data from the on-board network.
- And finally, there are the operators of traffic infrastructure. Ultimately, this means that anyone who is traveling from A to B can also be a Bosch customer. With our software solutions, we help make one-click tickets

possible – for car and bike sharing, trains, and buses, for instance in the Stuttgart Services pilot project.

These examples show how much potential our mobility solutions have to offer. The new name for our business is more than an empty shell. For some time now, it has stood for new solutions that go beyond the car and focus on the entire traffic system. Moreover, it is increasingly about services as well. With our mobility services, we are opening up a new and promising area of business.

We also derive new ideas for services from the technological expertise we already have. The best example of this is our active parking lot management system. We install our web-enabled micromechanical sensors in the pavement, where they detect whether a parking space is vacant or not. This results in a real-time parking map that reduces the time spent looking for vacant parking spaces, which after all accounts for 30 percent of urban driving. The first test zones with Bosch sensor technology and software have been set up, and we will go into production before the year is out. This is a solution that helps parking garage operators utilize their capacity better.

In this services business, Bosch also benefits from its diverse industrial expertise. No other company in the automotive industry compares with us when it comes to connecting mobility with energy, building, and industrial technology. We have the broad base that allows us to develop cross-domain services as well – such as when a connected car is about to return to a connected house, or smart home. Opening the garage door, firing up the central heating or the oven – the car gets the first household chores done automatically, shortly before arriving.

The car of the future: progress on all three development paths

For Bosch, connectivity is one of the three paths developments will take toward the car of the future. It underpins the other two development paths – powertrain electrification and automated driving. We are making progress on

all three paths with innovative solutions. And with our profound systems understanding, we are also creating the technological conditions for them.

The car of the future may be electrified, automated, or connected, but more than ever before it will become a computer network on wheels. Data volumes are rising rapidly, not only as vehicles exchange information with their environment, but also within the vehicle itself. The signs are that developments in the electrical and electronic architecture over the next five years will be close to revolutionary: memory capacity will at least quadruple and computing power will triple. Indeed, in some control units, it will increase as much as 20-fold. And the bandwidth for data bus systems will widen exponentially. Our objectives are clear. We want data security on every level, and we want to combine IT intelligence with the reliability of automotive engineering. To develop our mobility solutions, some 40,000 people are working in R&D, and even now, one-third of these associates are software engineers. This means that Bosch is already a software company. The importance of software will continue to grow – and with it, our need for qualified software specialists.

On a more concrete level, what are we doing in these three areas of development? Before Mr. Bulander presents a number of innovations, allow me to briefly outline this work.

- **Powertrain electrification** depends crucially on further advances in battery technology. And it is here that we are taking a great leap forward. Bosch has acquired the U.S. start-up company Seeo Inc. This company has come up with a solid-state battery cell with a lithium anode – a technology that complements our joint development work with Japanese partners. Our assumption up to now has been that we will double batteries' energy density and halve their cost by the end of this decade. Thanks to Seeo's groundbreaking cell technology, we see the potential to achieve even greater gains in energy density. Bosch is using its

knowledge and considerable financial resources to achieve a breakthrough for electromobility.

However, it is also clear that well into the next decade, the relationship of combustion engines and electric motors will not be so much one of either-or as one of both-and. Without the diesel and its outstanding fuel economy, the EU's ambitious climate-protection targets for 2021 cannot realistically be achieved. Indeed, by then, we will have improved its efficiency by a further 15 percent. A higher share of diesel also means less carbon dioxide – this is a formula we must not ignore, also in the context of the present debate about air quality in large cities. It is also worth noting here that the diesel has long since become a kind of vacuum cleaner, cleaning the air of particulate matter. Moreover, more diesel does not by any means have to mean more nitrogen oxides. Bosch has the technology to bring diesel nitrogen oxide emissions to an extremely low level, even in real driving conditions. And indeed, it is our development goal to comply with current standards not only at the test bench, but also on the roads.

- **Automated driving** will arrive as a result of progress in driver assistance systems. For work on these systems alone, we employ some 2,000 engineers – a good 700 more than two years ago. By 2018, we want to have achieved fully automated parking. It will then be enough to drop off the car outside a parking garage. From there, the car will find a vacant space on its own. By 2020, the Bosch highway pilot will be ready for production – an electronic chauffeur that the vehicle can use to drive autonomously on freeways. We are already driving our test vehicles on U.S. and German freeways, and in the U.S. we are the first automotive supplier to have driven an automated prototype exit to exit on freeways. In collaboration with TomTom, we are developing the extremely accurate maps needed for highly automated driving.

- But it is only when **driving becomes connected** that the car will also be able to see ahead – further than any sensor, and with much more up-to-date information than any map. It will even be able to see around bends, as it were. Traffic jams, accidents, and construction sites – with dynamic information such as this, we can enhance the electronic horizon. This will make automated driving even safer, and hybrid vehicles will always know when it's time to convert braking energy into electricity, thus extending their range. The car of the future will drive best when it is connected. It will also know when it needs to be serviced, thinking ahead far better than a warning lamp indicating possible faults. Even now, we are making remote, web-based diagnosis of our diesel injectors possible.

Summing up, Bosch is in a technologically strong position with its mobility solutions. This strength will allow us to shape the transition in the automotive industry. But what are the major innovations we are presenting here at the IAA? That is a question Mr. Bulander is well placed to answer, so I will now hand over to him.



Electromobility

Bosch has groundbreaking battery technology for electric vehicles

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- ▶ Acquisition in California: Seeo Inc. to be part of Bosch
- ▶ Pure lithium anodes: an innovative leap in cell construction
- ▶ More than twice the range possible with solid-state cells

Hayward/Stuttgart – Bosch is debuting a new battery technology for electric cars that could be production-ready in as little as five years. “Bosch is using its knowledge and considerable financial resources to achieve a breakthrough for electromobility,” said Dr. Volkmar Denner, the chairman of the board of management of Robert Bosch GmbH. The acquisition of the U.S. start-up Seeo Inc. (Hayward, CA near the Silicon Valley) will help make this possible. In addition to its own development in the area of battery technology, Bosch now has crucial know-how in innovative solid-state cells for lithium batteries as well as exclusive patents. “Solid-state cells could be a breakthrough technology,” Denner said. “Disruptive start-up technology is meeting the broad systems knowledge and financial resources of a multinational company.” Up to now, the declared industry target has been to double batteries’ energy density and halve their costs by the end of this decade. With the new solid-state cells, Bosch sees the potential to more than double energy density by 2020, and at the same time reduce the costs considerably further. A comparable electric car that has a driving range today of 150 kilometers would be able to travel more than 300 kilometers without recharging – and at a lower cost.

Strategic expansion of existing battery research

The acquisition of Seeo Inc. fits seamlessly into Bosch’s electromobility strategy. Bosch already offers a wide range of components for electromobility, from motors and power electronics to batteries. So far, Bosch has realized 30 production projects related to electromobility. At the same time, engineers are working on further refining the technology, and in doing so, making electromobility a more practical proposition. After all, by 2025, the company forecasts that roughly 15 percent of all new cars built worldwide to have at least a hybrid powertrain. In Eu-

rope, more than a third of all new cars will be electrically powered – the majority as plug-in hybrids. To this end, in 2014 Bosch joined GS Yuasa and Mitsubishi Corporation in establishing the joint venture Lithium Energy and Power GmbH & Co. KG, whose objective is to develop a more powerful generation of lithium-ion batteries. Seeo Inc.'s technology complements the work done thus far with Bosch's Japanese partners. The result will be a combination of groundbreaking start-up technology with Bosch's systems and technology know-how, GS Yuasa's cell competence, and Mitsubishi Corporation's broad industrial base.

Bosch has first samples

For years, automakers and suppliers have been trying to create more powerful batteries. Cells are an important building block – the battery of an electric car consists of numerous interconnected cells. Cells are thus a substantial part of the value-added. The performance of an energy storage device can be improved with various methods. For example, in cell chemistry, the material that the positive and negative poles (cathode and anode) are made of plays a major role. In current lithium-ion batteries, one of the reasons energy capacity is limited is because the anode consists to a large degree of graphite. Using solid-state technology, Bosch can manufacture the anode out of pure lithium, which considerably increases storage capacity. In addition, the new cells function without ionic liquid, which means they are not flammable. "The pure lithium anode represents a huge innovative leap in battery cell construction," Denner said. Thanks to its acquisition of Seeo Inc., Bosch now possesses the first sample cells which have the potential to meet the high standards of the automotive industry where durability and safety are concerned.

Press photos: 1-BBM-21511-e, 1-BBM-21559, 1-BBM-21560

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network is the foundation for further growth. In 2014, Bosch applied for some 4,600 patents worldwide. The Bosch Group's strategic objective is to create solutions for a connected life. Bosch improves quality of life worldwide with products and services that are innovative and spark enthusiasm. In short, Bosch creates technology that is "Invented for life."

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IAA technology in a nutshell
The Bosch innovations on show at the IAA 2015
Electrification, automation, and connectivity
for the mobility of the future

September 15, 2015

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- ▶ Raising pressure in diesel and gasoline engines
- ▶ Connected powertrain: reduced emissions and fuel consumption
- ▶ Electrification: affordable hybrids, increased range thanks to smart thermal management
- ▶ Assistance systems: help with collision avoidance, making turns, and in heavy traffic
- ▶ More safety, efficiency, and convenience for drivers: Bosch solutions for displays and connectivity

Frankfurt/Stuttgart, Germany – For decades, Bosch has stood for progress in automotive manufacturing. It will be presenting its solutions for the electrified, automated, and connected car of the future at the 66th International Motor Show (IAA) in Frankfurt am Main. You can find Bosch at booth A03 in hall 8.

Raising pressure in diesel and gasoline engines

Diesel injection: Bosch is increasing the fuel pressure in diesel engines to 2,700 bar. Increased injection pressure is key to reducing an engine's nitrogen oxide and particulate emissions. The higher the pressure, the more finely the fuel is atomized and the better it mixes with the air in the cylinder. This means that the fuel burns as cleanly and as completely as possible.

Digital rate shaping: This new diesel technology significantly reduces emissions, fuel consumption, and combustion noise all at the same time. Unlike the system of pilot and main injection used up to now, the injection process is divided up into many tiny injections of fuel. The result is a gentle combustion process, with extremely short intervals between the individual injections of fuel.

Gasoline direct injection: Bosch is increasing the fuel pressure in gasoline engines to 350 bar. The result is improved fuel atomization, more efficient mix preparation, reduced film formation on the cylinder walls, and shorter injection times. Compared with a 200-bar system, these measures significantly cut particulate emissions. The advantages of the 350-bar system come to the fore at moments of high load and dynamic engine operation – in other words, during intense acceleration or at high speeds.

Turbocharging: An engine's air system plays a significant part in ensuring that the engine complies with rigorous emissions standards. By tuning the combination of turbocharging, exhaust-gas recirculation, and the relevant control unit functions, it is possible to attain a further significant reduction in basic engine emissions (including nitrogen oxides) in real driving situations. It is also possible to cut fuel consumption by a further 2 to 3 percent in the European driving cycle.

Variable turbine geometry: Bosch Mahle Turbo Systems (BMTS) has developed a new generation of variable turbine geometry in exhaust-gas turbochargers, based on a principle that can be more widely employed in gasoline engines in the future. The key breakthrough is that the turbochargers are less prone to deformation at higher temperatures and are capable of withstanding sustained temperatures of 900 degrees Celsius – BMTS is even working on demonstrators that can cope with up to 980 degrees Celsius. Engines fitted with this new technology deliver more performance or are more fuel efficient. The same holds true for diesels, in which a reduced guide-vane gap further enhances the efficiency of the variable turbine.

Connected powertrain: reduced emissions and consumption

Connected particulate filters: Thanks to connectivity, Bosch can regulate the regeneration of the particulate filter via the electronic horizon – that is to say, on the basis of data about the route ahead. This might involve the filter regenerating itself while on the freeway, for instance, so that it is fully functional when the vehicle hits city traffic.

Predictive powertrain: The electronic horizon offers an in-depth look at the route ahead. For example, the navigation software knows that a downtown area or traffic-calmed zone is coming up just a few kilometers down the road. The vehicle will then charge its battery in preparation, so that it can pass through the area in full-electric, zero-emissions mode. In the future, these navigation data will be supplemented with current traffic updates from the internet, so that the vehicle also knows where to expect congestion or mobile construction sites.

Active gas pedal: The Bosch active gas pedal helps save fuel, providing a gentle haptic signal to show the driver the most fuel-efficient pedal position.

Consequently, the technology helps to achieve fuel savings of up to 7 percent. And if the vehicle has an assistance system such as adaptive cruise control, the pedal becomes a warning indicator: coupled with the navigation system or a camera that recognizes road signs, the innovative Bosch gas pedal gives drivers a haptic warning signal if, for example, they are approaching a dangerous bend at too high a speed.

Electrification: increased range thanks to consistent system optimization

Lithium-ion technology: If electric cars are to become even more widespread over the coming years, they must become significantly cheaper. Battery technology will play a key role here: by 2020, Bosch expects batteries to provide twice the energy density, but at half the present cost at most. To research the next generation of lithium-ion batteries, Bosch has joined forces with GS Yuasa and Mitsubishi Corporation in the Lithium Energy and Power joint venture.

Battery cells: In addition, Bosch is acquiring the U.S. start-up company Seeo, Inc. (Hayward, CA). With the purchase, Bosch now possesses essential know-how in the area of innovative solid-state cells. This technology complements the developments the company has already achieved with its Japanese partners GS Yuasa and Mitsubishi Corporation. To date, the aim has been to double energy density and halve its costs by the end of this decade. With the Seeo technology, Bosch sees the potential to increase the energy capacity of lithium-ion cells even further.

Battery system: Bosch is using multiple approaches to drive forward the development of high-performance batteries. As part of the battery system, innovative Bosch battery management monitors and controls the cells in the system as a whole. Intelligent battery management can increase a car's range by up to 10 percent.

Thermal management for electric vehicles: A larger battery is not the only way of extending the range of an electric vehicle. After all, the air-conditioning and heating can also significantly reduce range. Bosch now offers a smart thermal management system. Because it works much more efficiently than previous versions, it can extend range by up to 25 percent. A system of controllable pumps and valves collects cold and heat at source – in the power electronics, for example. The heat can then be used for things such as heating the passenger compartment. Such an integrated system of thermal management reduces the heating system's wintertime power requirement by up to 60 percent.

48-volt hybrid: At the IAA 2015, Bosch will be presenting the second generation of its 48-volt hybrid. This modified entry-level electrification solution reduces fuel consumption by up to 15 percent, as well as providing an additional 150 newton meters of torque. In this second generation, the electric motor is integrated into the transmission. Both the electric motor and the internal-combustion engine are separable via a coupler, which means that they can provide power to the wheels independently. This enables parking in full-electric mode, as well as fully electric driving for short periods, such as in stop-and-go traffic.

On the road to automated driving: help with evasive action, with making turns, and in heavy traffic

Evasive steering support: Evasive steering support helps drivers who need to avoid obstacles. Radar and video sensors detect and measure the obstacle. By deliberately intervening in the steering maneuver, the assistant helps even inexperienced drivers to take evasive action. The assistant helps achieve maximum steer angle 25 percent faster and keeps drivers safe even in extremely complex situations.

Assistant for turning against oncoming traffic: When turning against oncoming traffic, it is easy to miss an oncoming vehicle. This assistant uses two radar sensors at the front of the vehicle to monitor oncoming traffic. If the gap in the traffic is too small to permit a turn, the system prevents the vehicle from moving forward. Alternatively, if a collision with an oncoming vehicle is imminent, the system will stop the turn in time by performing an automatic emergency braking maneuver.

Highway pilot: The highway pilot is a highly automated driving function which takes over complete control of the car on stretches of freeway. Prerequisites for this include sensors that reliably monitor the vehicle's entire surroundings, highly accurate and up-to-date map data, as well as powerful, interconnected control units. Once the vehicle has been driven onto the freeway, the driver can activate the function and lean back. Before the highly automated part of the journey ends, the highway pilot alerts the driver and warns them to prepare to take control of the vehicle again. Bosch is already testing the function with specially equipped vehicles on public roads. Assuming that the necessary changes are made to the legal framework – above all to the Vienna Convention on Road Traffic, UNECE Regulation R 79 – the highway pilot could be production-ready by 2020.

Traffic jam assist: The traffic jam assist system is based on the sensors and functionality of ACC Stop & Go and of the lane-keeping support. Up to a speed of 60 kilometers per hour, the system automatically follows the vehicle ahead in heavy traffic. Not only does the traffic jam assist accelerate and brake, it also

keeps the vehicle in its lane by way of steering interventions. Drivers are relieved of their burden. All they have to do is monitor the system.

Stereo video camera: With only a 12-centimeter distance between the optical axes of its two lenses, the Bosch stereo video camera may well be the smallest system of its kind currently available for automotive applications. It detects pedestrians and things such as traffic signs and clear spaces, and is a single-sensor solution for a range of assistance systems. The solution is a standard feature in the Jaguar XE and the Land Rover Discovery Sport. Both vehicles use the camera for their urban and interurban emergency braking systems (AEB city, AEB interurban). In vehicle demonstrations at New Mobility World, Jaguar, Land Rover, and Bosch are demonstrating further prototype solutions that are possible solely on the basis of the stereo video camera. These include pedestrian protection, a construction zone assistant, and an assistant for calculating overhead clearance.

More intelligent parking: find and report vacant spaces, park safely, or let the car park itself

Active parking lot management: Bosch active parking lot management makes it easier for drivers to find a parking space and helps parking garage operators improve capacity utilization. Sensors installed in the pavement indicate whether or not a space is occupied. The sensors wirelessly relay this information to a server, where the data is incorporated into a real-time map. Drivers can then access this map over their smartphones or the internet, allowing them to pick out an available space and navigate to it.

Smart trailer parking: The smart trailer parking system offers a convenient way for drivers to control their vehicle and trailer from the curbside using a smartphone or tablet computer. This is made possible by interfaces with the electric power steering, the braking system, the engine management system, the automatic transmission, and with a function measuring the angle of articulation. Using an app, drivers can preselect driving direction and speed from the curbside. And they can then use their fingertip to steer and safely park the car and trailer.

Community-based parking: In many residential and inner-city areas, on-street parking spaces are a scarce commodity. Bosch community-based parking makes the search for suitable spaces easier: using the sensors of their parking aid system, cars identify and measure the gaps between parked cars as they drive past them. The information they record is transferred to a digital road map. Using smart information processing, Bosch then corroborates the data to supply a prediction of the parking situation. Vehicles in the vicinity can access the digital

map in real time, allowing drivers to navigate to a suitable spot. Once the size of the available parking spaces has been determined, it is also possible to search for spaces for a specific type of vehicle, such as a compact car or motorhome. The more cars participate in the community-based parking system, the more detailed and up-to-date the map.

Multi-camera system: Four near-range cameras fitted in the vehicle provide drivers with good all-round vision while parking. With an aperture of 190 degrees each, the cameras capture the vehicle's entire surroundings. Thanks to special visualization technology, the display unit provides 3D images that are practically distortion-free. Drivers are also free to choose any perspective they wish, so they can see even small obstacles in the parking area.

Fully automated parking: Automated valet parking is the name of the Bosch function which not only relieves drivers of having to search for a parking place, but also enables the vehicle to park itself. Drivers simply drop off their vehicle at the entrance to a parking garage. Using a smartphone app, they instruct the car to find itself a place to park. They instruct the car to return to the drop-off point in exactly the same way. Fully automated parking will require several things, including an intelligent parking garage infrastructure, on-board vehicle sensors, and connectivity for both. The car and parking garage communicate with each other: sensors in the pavement identify where free parking spaces are located, and transmit this information to the car. Bosch is developing all the necessary components for fully automated parking in house.

More safety, efficiency, and convenience for drivers: Bosch display and connectivity solutions

Display systems: Navigation systems, new vehicle sensors and cameras, and internet connectivity mean a flood of information for drivers. Display systems therefore have to prioritize and present information in a way that allows it to be processed as intuitively as possible. This is where Bosch's freely programmable displays come in. Not only are these solutions no longer mechanical, they also present all the relevant information electronically on a high-resolution display in a way that is flexible and specific to the current situation. The technology can be supplemented with the Bosch Combiner Head-up Display, which shows the most important information directly in the driver's field of view.

Bosch is also showcasing an innovative user interface in which visual and acoustic interaction is supplemented by haptic elements. When drivers are using the touchscreen, they get a haptic response that makes it feel like their finger is running over a button. They then have to press more firmly on the virtual button

to activate it. This reduces driver distraction, as they no longer have to visually check what they are doing.

Connected horizon: Even today, the electronic horizon provides data on inclines and the sharpness of bends to complement navigation data. The connected horizon will build on this by adding current, dynamic data relating to things such as traffic jams, accidents, and mobile construction sites. This solution enables drivers to travel more safely and with an even better picture of the road ahead.

Bosch mySPIN is an appealing smartphone integration solution that smoothly integrates the smartphone into the vehicle, ensuring safe in-car use. This means drivers can continue to use their favorite apps safely and in the usual way, both for iOS and Android smartphones. The apps are pared down to show relevant information only, and displayed and managed via the vehicle display. To ensure minimum disruption and maximum safety, they have been specifically tested for use while driving.

Wrong-way driver warning: In Germany alone, some 2,000 warnings about wrong-way drivers are broadcast each year. In most cases, however, the warning comes too late, since such incidents generally end after an average of 500 meters – in some cases with fatal consequences. Bosch is developing a new cloud-based solution designed to provide a warning within ten seconds or so. As a pure software module, this alert function can also be inexpensively integrated into existing infotainment systems or apps.

Drivelog Connect: Drivelog Connect, provided by the Drivelog mobility portal, is a connectivity solution that is also suitable for older cars. All it requires is a compact wireless module, or “dongle,” and a smartphone app. It can then offers tips on how to drive more economically, present error codes in an easily understandable form, and contact a towing service and garage in the event of a breakdown.

Press photos: 1-BBM-21235, 1-BBM-21240, 1-CC-21083, 1-CC-21164, 1-CC-21167, 1-CM-21209, 1-GS-21523, 1-BBM-21511-e

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Cloud-based wrong-way driver warning **A guardian angel in the data cloud** Bosch solution swiftly identifies danger

September 3, 2015

PI 9017 CC Ks/SL

- ▶ Wrong-way drivers rapidly identified and alerted
- ▶ Simple integration into existing internet connections
- ▶ Bosch offers a variety of connected solutions for more safety, efficiency, and convenience

Frankfurt/Stuttgart – Traffic reports about wrong-way drivers are an all-too-familiar occurrence. Some 2,000 such warnings are broadcast on German radio alone each year. And all too often, these incidents lead to critical situations – including serious accidents. According to statistics, nearly every third of such incidents end – fatally, in the worst case – before the vehicle has traveled just 500 meters. However, it takes several minutes for warnings to be broadcast over the radio, by which time it is too late. Bosch is developing a new solution that alerts drivers much faster. The new Bosch cloud-based wrong-way driver warning is designed to provide a warning within ten seconds or so. “Bosch is developing a guardian angel in the data cloud,” says Dr. Dirk Hoheisel, member of the board of management at Robert Bosch GmbH. As a pure software module, this alert function can also be inexpensively integrated into existing infotainment systems or apps. The supplier of technology and services is planning to start production as early as 2016.

To detect wrong-way driving, the cloud-based function compares the vehicle’s actual movements with the permitted direction of travel. Information about this is stored in a web-based database. If the two sets of information clash, the wrong-way driver is alerted to their error. At the same time, drivers of oncoming vehicles are also warned. The function relies on regular, anonymized reporting of each vehicle’s position to the cloud – a central computer center in which data are stored and analyzed over the internet. The more connected vehicles there are, the denser the invisible safety net and the more comprehensively road users can be warned of wrong-way drivers.

Cost-effective system configuration

This new function will be available as a cloud service from 2016. It can be integrated into existing apps, as well as into automakers' infotainment solutions. In the medium term, the solution could also be integrated into standardized emergency call concepts such as eCall. The wrong-way driver alert requires an unbroken connection to the internet. Either the vehicle already has an appropriate infotainment solution on board, or the driver's smartphone is connected to the vehicle using an integration solution such as Bosch mySPIN. The good thing is that one of these connection options is often already fitted or can be easily retrofitted. There is no need to integrate any additional hardware. That makes the cloud solution as global as it is cost-effective. "We're aiming to achieve quick market acceptance so that the system can realize its life-saving potential to the full as soon as possible," Hoheisel says.

Bosch uses connectivity for new services

Bosch is making the car an active part of the internet. Sensors, for example, collect a multitude of data both within the car and about its surroundings. Bosch then synchronizes these data via the cloud. The Bosch IoT Suite made by the Bosch subsidiary Bosch Software Innovations is the technological foundation for IoT applications. It provides all the functions needed to connect devices, users, companies, and partners on an IoT platform. Last but not least, Bosch offers an increasing number of services based on that platform. For Hoheisel, there is no doubt that connectivity "makes driving even safer, more efficient, and more convenient." To give two automotive examples: using Bosch charging apps, drivers of electric vehicles or plug-in hybrids can use their smartphones to find charge spots with ease and pay for the electricity they use – no matter which of the many providers in Germany operates the facility. Nearly all public and web-enabled charge spots in Germany are already part of this network. Bosch also offers fleet management for fleet operators such as freight forwarding and car rental companies. A Bosch communication module relays vehicle operating data such as mileage, position, and error messages. This data helps optimize operations and service planning.

Press photo: 1-CC-21424

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Safer, more efficient, and more relaxed mobility **Bosch is making the car an active part of the internet**

September 15, 2015

PI 9018 BBM Ks/Na

- ▶ Comprehensive connectivity expertise for the car – and beyond
- ▶ A wide range of solutions for corporate and private customers
- ▶ Connectivity is the key to electrified and automated driving

Frankfurt/Stuttgart, Germany – These days, we could hardly conceive of life without the internet – and soon that will be true of internet in the car as well. “Connectivity is the key to electrified and automated driving – and to lots more besides,” says the Bosch board of management member Dr. Dirk Hoheisel. “Connected vehicles are safer and more efficient, and make life easier.” In the future, online connectivity will mean that drivers have access to information about things such as congestion, accidents, and wrong-way drivers, as well as on where to find free parking spots and charge spots – which they can reserve and pay for straight away. Cars are also turning into multimedia centers as Bosch facilitates continuous access to online music services, social networking sites, and a wide range of smartphone apps.

Like few other suppliers of technology and services worldwide, Bosch is excellently positioned to exploit the possibilities of the internet of things. For example, Bosch is developing connected solutions for smart homes, energy supply, industry – and of course mobility. This lays the groundwork for innovative solutions: in one current test scenario, for instance, the car’s navigation system is used to automatically turn up the heating at home shortly before the vehicle arrives.

Connectivity is the prerequisite for electrification and automation

Bosch expects that as many as 15 percent of all new vehicles will have an electric motor in addition to a combustion engine by 2025. It also expects to see highly automated driving on freeways soon after 2020. Both trends rely heavily on connected solutions. For example, the Bosch Group’s software and systems unit has developed an app that makes it significantly easier to find the charge spots of different providers and pay for the electricity. Up to now, doing this would have required a different customer card for each provider. Now all drivers need is a

smartphone, the app, and a PayPal account. Receiving real-time traffic information also enables a connected electronic horizon function, which tells connected vehicles what to expect around the next few bends. This helps hybrid and electric vehicles make better use of the recuperation function and thus increase their range. In addition, navigation systems can optimize route planning. The information also contributes to vehicle safety. For instance, if several vehicles report an intervention from the ESP system at the same point, the system can refer to the weather data and conclude there is black ice present, warning the drivers following on behind. What's more, information about things such as speed limits, temporary construction sites, or the location of a traffic jam allows automated vehicles to anticipate events and ease off the gas in plenty of time. This makes for a more relaxed and efficient driving experience. For Hoheisel, there is no doubt that "connected cars have the edge."

Using a smartphone or connectivity control unit to access the internet

To connect the car with the internet, Bosch pursues two main approaches. First of all, the driver's smartphone can be used. MySPIN is an integrated solution that allows Android and iOS devices to link up to vehicles' infotainment systems. An array of apps can then be conveniently operated from the vehicle's central display. Second, Bosch offers the connectivity control unit (CCU) as a command center within the vehicle. The CCU receives and transmits information using a wireless module equipped with a SIM card. It can also determine the vehicle's position using GPS if desired. It is available both as original equipment and as a retrofit solution which can be connected up to the vehicle's electrical system via the on-board diagnosis (OBD) interface. The CCU sends vehicle operating data to a cloud server, unlocking a variety of potential services. This is a perfect application for the Bosch IoT Suite software platform provided by the Bosch Software Innovations subsidiary. The Bosch IoT Suite unites devices, users, and companies to make it as easy as possible to offer attractive services – including Bosch services.

Solutions for business customers cut servicing costs and times

Connected fleet management is a service aimed at fleet operators. The solution uses the CCU to securely transmit journey and service data to Bosch servers for analysis. Companies can use the collected data to help plan operations, lease agreements, and service and repair visits with more precision. This cuts operating costs and reduces time out of service. In the future, Bosch will put augmented reality to use in workshops, enabling a sort of X-ray under the hood. When a repair-garage worker takes a tablet computer and holds it under the hood, the tablet's camera image is overlaid with comprehensive additional information and repair instructions for precisely the area being displayed. The mechanic can manipulate the overlaid objects via the touchscreen and call up additional

information. This makes poring through service handbooks a thing of the past. A Bosch server provides all the detailed data online.

Smartphones provide the basis: Drivelog Connect and wrong-way driver alert

Drivelog Connect, provided by the Drivelog mobility portal, is a connectivity solution that is also suitable for older cars. All it requires is a compact wireless module, or “dongle,” and a smartphone app. It can then offer tips on how to drive more economically, present error codes in an easily understandable form, and contact a towing service and garage in the event of a breakdown. And finally, a digital logbook helps company car drivers with their bookkeeping.

In Germany alone, radio stations broadcast some 2,000 warnings about wrong-way drivers on the country’s freeways every year. Nearly a third of such incidents end – fatally, in the worst case – before the vehicle has traveled just 500 meters. However, it takes several minutes for warnings to be broadcast over the radio, by which time it is too late. Bosch is developing a new cloud-based wrong-way driver alert system, which will be able to warn drivers within ten seconds or so. As a pure software module, it can be inexpensively integrated into existing infotainment systems or apps. To detect wrong-way driving, the cloud-based function compares the vehicle’s actual movements with the permitted direction of travel. Information about this is stored in a web-based database. If the two sets of information clash, both the wrong-way driver and oncoming cars are alerted. The function will be available as soon as 2016.

Connected components permit predictive diagnostics

Bosch is increasingly drawing on “Industry 4.0” techniques in developing and manufacturing its products. The goal is to connect each component so that it can seamlessly communicate manufacturing, test, and operating data about itself. This is opening up new possibilities: to take a current example from preventive diagnostics, it is already possible to use a connectivity control unit to gather operating data from a diesel injector throughout its service life and reconstruct its operation online from the cloud. If the data indicate signs of wear or a change in operating conditions, a modified version of the operating map can be automatically released, again online. It is also possible to immediately arrange a service visit and order a replacement part if the customer so desires. These analytical data are also an important source of information for the development of future product generations and for optimizing the manufacturing process.

Press photos: 1-BBM-21513, 1-CC-21424, 1-CM-21209

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Parking smarter **Special-effects technology for safe parking** Bosch multi-camera system

September 10, 2015

PI 9015 CC joe/Na

- ▶ Four near-range cameras capture vehicle's entire surroundings
- ▶ Bosch blends real and virtual worlds in live image
- ▶ Vehicle parks itself with the help of sensor data fusion
- ▶ Automated parking begins in the car but goes much further

Frankfurt/Stuttgart, Germany – Parking a car can be hard work, especially since cars have generally been getting longer and wider over the years, while parking spaces and garages have not. In view of this, it is not surprising that parking is among the activities most likely to be associated with accidents. Help is available, though, in the form of Bosch electronic assistants. The parking aid, for instance, directs drivers into tight parking spaces with acoustic signals. And the park assist even takes control of the steering. “But if you’re parking somewhere where every centimeter counts, it’s usually more useful to see than to hear,” says Dr. Dirk Hoheisel, member of the board of management of Robert Bosch GmbH. At the IAA, therefore, Bosch is showcasing its new multi-camera system, a variant of which features in the new 7 Series BMW. This system gives drivers a clear view of what is happening during parking – all around the vehicle. To realize this, Bosch engineers turned to the kind of 3D visualization technology that is already used in Hollywood blockbusters.

Cameras capture surroundings from every angle

The multi-camera system comprises four tiny near-range cameras. One faces forward, another backward, while the two side cameras are integrated into the exterior rear-view mirrors. With an aperture of 190 degrees each, they capture the vehicle's entire surroundings. The ingenious part is in the display, which blends the real and virtual worlds. Drivers see their vehicle as a true-to-life 3D model complete with detailed design features. Steering actions and the turning of the wheels are also displayed as animated graphics. The car's immediate environment, however, appears in the form of real-time images. Using a touchscreen, for instance, drivers can select almost any perspective imaginable. This lets them

look in front of the hood or behind the trunk, alongside the vehicle or with a bird's-eye view from above. Whenever the driver selects a new perspective, the camera optically swings around the car to the new vantage point. Meanwhile, there is plenty of computing power on hand to continue showing the vehicle's surroundings with real-time imagery.

The biggest challenge here is to make the image on the screen as lifelike as possible. To keep areas of overlap between the various cameras as free of distortion as possible when stitching the images together, the developers dug deep into their box of tricks. As a result, Bosch is the first supplier in the market to dynamically adjust image borders depending on perspective. This means objects are always clearly visible, even at the points where images have been stitched together. What's more, the ECU combines the camera images with distance information from ultrasonic sensors in a process known as sensor data fusion. Bosch uses the resulting data to generate a dynamic, three-dimensional wireframe around the virtual vehicle model, the shape of which is adjusted to match the changing surroundings. Bosch then projects the real-time images from the near-range cameras onto this wireframe. "It's the same technology used for special effects in movies," Hoheisel says. Unlike in two-dimensional systems, this allows objects that rise up to be portrayed more realistically instead of being seen from a top-down bird's-eye view. Drivers benefit in two ways: first, the on-screen image shows the horizon, so they can better orient themselves; second, it makes even small obstacles easier to see.

Driverless parking in garages

Data from the near-range cameras and the ultrasonic sensors also enable the car to drive itself – for example into and out of a private garage. Drivers control the maneuver from outside the vehicle, by pressing a button on the key. This saves them having to squeeze in or out of the vehicle when it is parked in a tight space. From up to four meters away, the central Bosch ECU uses near-range cameras to detect the garage-door opening. It doesn't matter whether the vehicle is standing directly in front of it or at a slight angle. If necessary, the angle of entry can be corrected by up to plus or minus 20 degrees. The multi-camera system then calculates the final parking position in relation to the vehicle's current position. On the basis of the sensor data, the ECU constantly monitors the vehicle's environment, thus preventing any collisions on the way into the garage.

For Bosch, automated parking begins in the vehicle – but it goes much further than that. Bosch active parking lot management, for instance, makes it easier to find a parking space. Bosch sensors installed in the pavement detect whether a parking space is free. The sensors forward this information to a server, where it can be entered into a real-time map. Drivers can then call up the map over the in-

ternet, and find out exactly where there are free parking spaces. And in conjunction with Daimler, Bosch is going even further. The two companies' aim is an ambitious one. They want to revolutionize parking. Instead of customers parking and then looking for their cars again, vehicles will drive autonomously to a vacant parking space, then drive back autonomously and conveniently to the drop-off point when their drivers return. To this end, Bosch is developing the necessary infrastructure for parking structures, including occupancy sensors, cameras, and communications technology. The supplier of technology and services is also responsible for the in-vehicle communications unit which will control the parking maneuver, and is working with Daimler to define the interface with existing automotive components.

Press photos: 1-CC-21501, 1-CC-21500, 1-CC-21499, 1-CC-21498

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Cars that drive themselves Highway pilot technically viable in five years

September 15, 2015

PI 9016 BBM joe/Na

- ▶ Automated driving requires extremely reliable technology
- ▶ Bosch technology paves the way for artificial intelligence in test vehicles
- ▶ More than 10,000 kilometers of test drives completed on public roads
- ▶ Legal framework must keep pace with technological developments
- ▶ Increasing automation will cut traffic accidents in Germany by up to a third

Frankfurt/Stuttgart, Germany – Drive or be driven? Bosch is just a few years away from premiering a technology that will give drivers the choice between the two. “Thanks to our highway pilots, from 2020 we could see highly automated cars driving themselves on the freeway,” says Dr. Dirk Hoheisel, member of the board of management of Robert Bosch GmbH. In highly automated driving, the vehicle temporarily assumes full responsibility for driving tasks. “The car becomes the chauffeur, and the driver the passenger,” Hoheisel says. This improves safety on the roads, but also places great demands on technical reliability. Moreover, it requires fundamental changes to vehicle architecture. “As far as developing the technology goes, Bosch is in a good position,” Hoheisel says. However, it is equally important for governments to establish the necessary legal framework for automated driving. “Legislation must keep pace with what is technically possible,” Hoheisel says.

Bosch test vehicles: artificial intelligence on four wheels

On the German A81 and U.S. I280 freeways, Bosch is demonstrating what is already technically possible. Since the beginning of 2013, engineers have been driving highly automated vehicles on public roads – at first in test vehicles based on the BMW 3 Series Touring and, since mid-2015, in the Tesla Model S. “Our engineers have now completed more than 10,000 kilometers of test drives without a hitch,” Hoheisel says. The vehicles guide themselves through traffic – accelerating, braking, and overtaking as necessary. They also decide for themselves, and depending on the traffic situation, when to activate the turn signal and change lanes. The basis for all this is sensors that provide a detailed picture of the vehicle’s surroundings. In addition, Bosch’s partner TomTom

supplies highly detailed map data. A computer uses all this information to analyze and predict the behavior of other road users, and on that basis makes decisions about the highly automated vehicles' driving strategy. "Bosch technology is making cars smart," Hoheisel says.

Modifying the test vehicles: 1,400 hours of work and 1,300 meters of cable

Before the test vehicles could start driving themselves, a number of modifications were necessary. In the case of the Tesla, Bosch spent 1,400 hours installing 50 new components, such as a stereo video camera, and laying 1,300 meters of new cable. There is a good reason for all this work. Highly automated vehicles must be capable of operating safely even if a component fails. The only way to achieve such operational reliability is with a design strategy that includes redundancy in safety-critical systems such as braking and steering. For example, the Tesla test vehicles feature both the iBooster electromechanical brake booster and the ESP braking control system. These Bosch components can brake the car independently of each other, without any need for driver intervention. Back-up systems are also available for the power supply and vital ECUs.

At first glance, however, the Bosch test vehicles barely differ from production models. For Hoheisel, it is clear that "the interior is where we will see the biggest difference in comparison to today's production models." Highly automated driving will change the human-machine interface, and calls for modern concepts for communication between car and driver. The driver must be able to intuitively understand and use the system. With its innovative display instruments, Bosch is already offering promising solutions in this area as well: the TFT instrument cluster featured in the Audi TT, for instance, offers maximum flexibility in processing combined with brilliant clarity. And using head-up displays, Bosch puts information such as speed, navigation prompts, and warnings directly in the driver's field of view. This information is superimposed on the vehicle's surroundings in such a way that the two seem to blend seamlessly at a distance of around two meters ahead of the vehicle.

In-depth understanding of all vehicle systems the key to success

Automated driving impacts the entire car: its powertrain, brakes, steering, display instruments, navigation and sensors, as well as connectivity inside and outside the vehicle. The key to success is an in-depth understanding of all vehicle systems. Few automotive companies worldwide have as much knowledge in this area as Bosch –and the complete acquisition of the steering specialist ZF Lenksysteme GmbH, now known as Robert Bosch Automotive Steering GmbH, at the start of the year has reinforced this further. Driver assistance systems are the backbone of automated driving. Even today, they help drivers change lanes, stay in their lane, and brake or take evasive action

when encountering an obstacle. “As we move toward self-driving cars, we will be premiering many new assistance systems,” Hoheisel says. The insights that Bosch gains from these will feed directly into the development of automated driving, giving it a further boost. Bosch has 2,000 engineers worldwide working on driver assistance systems. They support the two teams – one in Abstatt, Germany, and one in Palo Alto in northern California’s Silicon Valley – that have been developing automated driving since 2011.

Automated driving is first and foremost about making road traffic safer. Each year, an estimated 1.3 million people around the world are killed in road accidents. In 90 percent of cases, the accident can be attributed to human error. “In critical traffic situations, the right support can save lives,” Hoheisel says. Bosch accident research predicts that increasing automation can lower accident rates even further – by up to a third in Germany alone. This is something that insurers are now beginning to recognize. In the U.K., for example, vehicle owners are granted a more favorable insurance status if their cars are fitted with certain driver assistance systems, such as an emergency braking function for urban driving (AEB city). And automated driving makes road traffic not only safer, but also more efficient. U.S. studies indicate that applying predictive driving strategies when on the freeway can result in fuel savings of up to 39 percent.

Legal requirements: governments and associations need to act

Highly automated driving cannot become a reality unless there are changes to the law. One current legal constraint is the 1968 Vienna Convention on Road Traffic, which dictates that drivers must retain control of their vehicle at all times. Up to now, this has ruled out highly automated driving. Nonetheless, there are signs of impending changes to the regulations that apply both in Germany and in many other countries. One possibility would allow automated driving so long as the driver is able to override or disable it. Discussions are underway on how to revise the regulations to permit this exception. Quite apart from regulatory law, vehicle licensing law presents another hurdle. Regulation R.79 of UNECE, the United Nations Economic Commission for Europe, only allows automatic intervention in steering up to a limit of 10 kph. Up to now, there have been only half-hearted attempts to change this. However, an informal UNECE working group is now working on the issue. “We have every confidence that governments and associations will make the right move soon,” Hoheisel says. Following that, the only remaining problem is validation: using current methods, a highway pilot has to complete several million kilometers’ worth of testing before it can be released for production. Bosch is now working on new approaches that rely more heavily on simulation.

Press photos: 1-BBM-21367; 1-BBM-21369; 1-BBM-21371; 1-UBK-20767;
1-UBK-20782

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Thermal management system **Bosch smart temperature regulation increases electric cars' range by up to 25 percent** Optimum temperature for passenger compartment and battery

September 8, 2015
PI 9013 BBM FF/Na

- ▶ Power for temperature control can consume up to half of battery charge
- ▶ Heat conduction: similar to a domestic fridge
- ▶ Solution is basis for future vehicle generations

Frankfurt/Stuttgart, Germany – Electric cars' limited range, especially in the winter months, has provoked a lot of discussion. Having the heating on can mean that the range of a lot of electric cars shrinks considerably. "Smart thermal management means a big step forward for electric cars," says Dr. Rolf Bulander, member of the board of management of Robert Bosch GmbH and chairman of the Mobility Solutions business sector. In wintry urban conditions, this technology can enable an increase in range of up to 25 percent – without modifications to the battery. Bosch is now presenting its thermal management system at the IAA 2015 in Frankfurt.

In the publicly funded GaTE project (integrated thermal management in electric vehicles), Bosch, Mahle, Behr, and other companies developed the basis for optimized thermal management. In battery-driven powertrains, heating and cooling play a significantly greater role than in gasoline or diesel engines, since without a combustion engine, the vehicle does not have a generous supply of heat. For this reason, the passenger compartment is heated using a purely electrical system. The electricity it needs comes from the battery. This in turn impacts range: in winter and summer, roughly half the energy stored in the battery goes into regulating the temperature of the passenger compartment.

Moreover, in order to maintain the best possible supply of power to the electrical consumers drawing on it, the battery needs to be kept at a constant temperature of some 35 degrees Celsius – again with heat or cold generated electrically.

Heat-pump principle: like the domestic fridge

The new thermal management system distributes heat and cold solely on the basis of the vehicle's coolant fluid. The combination of a heat pump with coolant pumps and valves makes this possible. The heat-pump principle is something everyone is familiar with in their fridges, where the heat created in the process of making the fridge cool is released into the kitchen. With the new vehicle thermal management system, a heat pump with an electrical rating of 1,000 watts will generate heat equivalent to an output of 2,000 to 3,000 watts. Conventional heaters used in hybrids and electric vehicles are only half as effective.

Bosch's system features precisely controllable pumps and valves which collect heat and cold at source and transport them to where they are needed. The need for heating and cooling is additionally reduced by the innovative use of waste heat from the electric motor and the power electronics, plus controlled air circulation that draws moisture from the air.

System made up of already existing components

The pump makes use of the small amount of heat that is generated in an electric vehicle. For example, heat is released when supplying the electric motor with electricity. And when braking energy is converted into electricity and fed into the battery, usable heat is again created. This is also the case when the battery has to be cooled in order to remain within the optimum operating window. Most of the individual components used in this approach are already to be found in commercially available applications. Technically speaking, this innovation has the potential to bring significant and rapid improvement to electric vehicles. With its smart thermal management, Bosch is premiering a solution that will have a decisive impact on electromobility. After all, efficient temperature regulation will be a requirement for future generations of electrically powered vehicles.

Press photo: 1-BBM-21512

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Boost recuperation system

The hybrid for everyone: Bosch's 48-volt system makes sense even in compact vehicles

First generation to be production-ready by 2017, new second-generation prototype to also help drivers park

September 4, 2015

PI 9051 BBM FF/SL

- ▶ Cuts fuel consumption by 15 percent and enables boost function
- ▶ New function: all-electric driving in stop-and-go traffic
- ▶ New function: electric, automatic parking – via app and key

Frankfurt/Stuttgart, Germany – Be honest: did you think about choosing a hybrid the last time you bought a car? You will the next time. That is because Bosch has developed a hybrid powertrain that makes economic sense even in smaller vehicles. The system will go into production with the next vehicle generation and costs just a fraction of today's hybrid systems. "The boost recuperation system is the hybrid for everyone," says Dr. Rolf Bulander, member of the board of management of Robert Bosch GmbH and chairman of the Mobility Solutions business sector.

At the same time, drivers benefit from the well-known advantages of a hybrid, which make the car significantly more fuel-efficient. This makes it possible even for modern vehicles to operate 15 percent more economically, not only in controlled tests, but also in everyday driving situations. In addition, gasoline and diesel engines are capable of more dynamic acceleration thanks to the electronic boost feature. The electrical powertrain provides the combustion engine with an additional 150 Newton meters of support during acceleration. That corresponds to the power of a sporty compact-car engine.

Unlike conventional 400-volt hybrids, the system is based on a lower voltage of 48 volts and can therefore make do with less expensive components. Instead of a large electric motor, the generator has been enhanced to output four times as much power. The motor generator uses a belt to support the combustion engine with up to 10 kW. The power electronics forms the link between the additional

low-voltage battery and the motor generator. A DC/DC converter supplies the car's 12-volt on-board network from the 48-volt vehicle electrical system. The newly developed lithium-ion battery is also significantly smaller.

“The entry-level hybrid with 48 volts is going to become an attractive option for drivers in Europe, North America, and Asia,” Bulander says. Bosch expects some 4 million new vehicles worldwide to be equipped with this type of hybrid powertrain in 2020.

Second-generation prototype: parking at the press of a button

At the IAA 2015, Bosch will also be presenting a new second generation of the entry-level hybrid that is currently still in development. In the prototype, the more powerful motor generator is connected directly with the powertrain rather than with the combustion engine.

This allows the entry-level hybrid to provide all-electric driving even at low speeds – such as in stop-and-go traffic – in addition to immediate electric support for a short period of time.

The new hybrid makes it possible to include in compact cars a function that will celebrate its debut in premium vehicles at this year's IAA: a remote-controlled parking assistant that allows drivers to direct the parking maneuver from the curbside. The fully automatic parking assistant steers the vehicle into even the tightest parking spaces and garages safely and conveniently, without any stress or hassle.

The assistant uses ultrasonic sensors and is based on the fully automatic parking system found in vehicles with an automatic transmission. Thanks to the built-in electric motor, the system is capable of accelerating by itself and independently shifting between forward and reverse gears. And because the parking process is started by pressing a button on the ignition key, drivers do not even have to be in the vehicle. Bosch has also developed a smartphone app that allows drivers to operate the parking assistant from outside the vehicle.

Press photos: 1-GS-21523, 1-GS-21207-e, 1-BBM-21561

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Combustion engines, hybrids, all-electric vehicles Bosch presents the powertrains of the future

September 15, 2015

PI 9014 BBM FF/SL

- ▶ Some 15 percent of new vehicles to have an electrical powertrain by 2025
- ▶ Clean combustion engines for Euro 6, China 4, and U.S. LEV emissions standards
- ▶ Longer range for electric vehicles: new batteries and intelligent thermal management
- ▶ Dr. Rolf Bulander: “Bits and bytes are making cars more efficient”

Frankfurt/Stuttgart, Germany – Downsizing and electric motors: in the years ahead, quite a lot is set to change under the hood. Downsizing will become the standard, instead of just a trend. These days, nearly every vehicle – whether compact car, SUV, or powerful sports car – has a turbocharged engine. Equipped with ever more innovative technologies, the internal-combustion engine will continue to play a major role in global mobility. In five years’ time, 98 percent of new vehicles will still be powered at least partially by fossil fuels. This is particularly true of markets such as China and the United States. “Modern combustion technology is the bedrock of efficient mobility,” says Dr. Rolf Bulander, member of the board of management of Robert Bosch GmbH and chairman of the Bosch Mobility Solutions business sector.

At the same time, we are seeing the beginning of a transition to electromobility. Bosch expects roughly 15 percent of all new cars built worldwide to have an electrical powertrain by 2025, while in Europe more than a third of all new cars will be partly electrically powered – the majority as hybrids. For Bulander, there is no doubt that electrification “will take combustion engines to new heights.” Vehicles are becoming cleaner and more efficient – and the additional electrification will provide a boost to driving enjoyment.

Internal-combustion engine as the bedrock of efficient mobility

Modern IC engines have made significant technical advances in recent years. The figures for Europe clearly illustrate this. Since 2000, CO₂ emissions from

cars in Europe have sunk by a quarter – even though performance and vehicle weight have increased over the same period. Drivers are noticing this improvement at the pumps: standard fuel consumption per 100 kilometers is often less than seven liters for compact cars with gasoline engines, and less than five liters for those with diesel engines.

But fuel economy on its own is no longer enough – powertrains need to become even cleaner as well, as a look at stringent emissions legislation such as Euro 6, China 4, or LEV in the United States shows. Making powertrains as clean as they are efficient calls for particularly sophisticated technology. At the IAA 2015, numerous innovative Bosch products show how this can be done. In diesel engines, Bosch is increasing injection pressure to 2,700 bar. For gasoline engines, the latest generation of gasoline direct injection now delivers 350 bar instead of 200 bar. The increase in pressure means the fuel is more finely atomized and burns much more cleanly.

Diesel: engineering turns its attention to real driving emissions

Bosch is also paying particular attention to refining the diesel engine. “Diesel technology is key to achieving fleet CO₂ emissions targets. Especially in Europe, these targets could not be achieved without the diesel,” Bulander says. Over the next five years, engine refinements alone can help make even the most modern diesel engines up to 15 percent more economical. In real driving conditions, even lower fuel-consumption figures are attainable. Coasting is one example. In this mode, the engine is stopped temporarily – even at high speeds – so that it uses no fuel.

When it comes to emissions, too, the Bosch engineers are interested in more than just improvements on paper. The European Union is considering the introduction of real driving emission tests starting in 2017. For diesel vehicles, this measuring method concentrates primarily on emissions of nitrogen oxides and carbon monoxide in real driving conditions. Even now, there are a number of production vehicles whose emissions are already extremely low, and this even in operating modes not covered by present certification cycles – for example, during rapid acceleration or at high speeds. The task now is to make such technologies more widely available and cost-effective.

Hybrid: electrification will take combustion engines to new heights

When it comes to big, heavy vehicles, however, merely optimizing the IC engine is no longer enough. It is Bosch’s belief that the EU’s stringent fleet CO₂ targets for 2021 will mean that drivers will always also have the option of choosing an SUV with a hybrid powertrain. Bosch plans to be ready for this development. Each year, the supplier of technology and services invests nearly 400 million

euros in advancing electromobility. There are currently around 30 production models featuring Bosch electrification technology – in the U.S., in China, and from premium German automakers. Bosch components can be found in Porsche’s hybrid sports car, in Mercedes hybrid models, as well as in vehicles such as the BMW i3 with range extender. In the future, Bosch sees especially good market potential for hybrids and plug-in hybrids. In 2020, over 10.5 million of them are expected to roll off the production lines.

“Electrification and internal combustion are not mutually exclusive, but complementary,” Bulander says. Bosch’s boost recuperation system, which will be available from 2017, is a case in point. In compact vehicles, this entry-level 48-volt hybrid enables a roughly six percent reduction in CO₂ emissions in the driving cycle. This fuel saving is above all the result of the efficient recovery of braking energy. By means of a coasting function, this fuel economy can be improved still further, with the engine offering the benefits of a start-stop system at high speeds as well. The 48-volt hybrid also features a boost function – which goes to show that fuel saving goes hand in hand with driving enjoyment in entry-level hybrids as well. When drivers step on the accelerator pedal, the electric motor supports the IC engine with up to 150 newton meters of extra torque.

Electromobility: powerful battery, economical heating

High-voltage solutions are even more dynamic, since electric motors deliver the full amount of torque right from the start. But if electric cars are to become widespread over the coming years, they must become significantly cheaper. Battery technology will play a key role here. To research the next generation of lithium-ion batteries, Bosch has joined forces with GS Yuasa and Mitsubishi Corporation in the Lithium Energy and Power joint venture. Here, the partners have pooled their strengths: in its collaboration with Bosch, GS Yuasa can contribute its experience in cell chemistry to develop cells with a higher energy density. In addition, Bosch brings its expertise in complex battery management and systems integration to the table.

In addition, Bosch has acquired the U.S. start-up company Seeo, Inc. (Hayward, CA). With the purchase, Bosch now possesses essential know-how in the area of innovative solid-state cells. This technology complements the developments the company has already achieved with its Japanese partners GS Yuasa and Mitsubishi Corporation. To date, the aim has been to double energy density and halve its costs by the end of this decade. With the Seeo technology, Bosch sees the potential to increase the energy capacity of lithium-ion cells even further. “Bosch is applying its knowledge and a great deal of financial resources to help electromobility achieve a breakthrough,” said Dr. Volkmar Denner, the Bosch CEO.

But a larger battery is not the only way of extending the range of an electric vehicle. After all, the air-conditioning and heating can also significantly reduce range. Bosch now offers a smart thermal management system. Because it works much more efficiently than previous versions, it can extend range by up to 25 percent. “We also want the various engine components to communicate with each other,” Bulander says. A system of controllable pumps and valves collects cold and heat at source – in the power electronics, for example. The heat can then be used for things such as heating the passenger compartment. Such an integrated system of thermal management reduces the heating system’s wintertime power requirement by up to 60 percent.

Electric cars are good but connected electric cars are better

Finally, increasing internet connectivity will make electric vehicles a more practicable everyday option: “Electric cars are good but connected electric cars are better,” Bulander says. This is underlined by a new Bosch Software Innovations smartphone app. The Bosch Group’s software and systems unit has developed an app that makes it significantly easier to find the charge spots of different providers and pay for the electricity. Up to now, doing this would have required a different customer card for each provider. Now all drivers need to recharge anywhere in Germany is a smartphone, the app, and a PayPal account.

But connectivity in electrical powertrains does not stop there. After all, only connected vehicles can fully exploit the potential of electrification. “Bits and bytes are making cars more efficient,” Bulander says. One example of this is the connected electronic horizon solution, a Bosch technology that will provide essential traffic information about mobile construction sites, traffic jams, and accidents in real time. This is something all vehicles can benefit from, whether powered by electric motors or IC engines. The highly accurate data will serve to improve existing functions, such as start-stop coasting. At the same time, plug-in hybrids can use the system to implement a predictive operating strategy. Even in powertrains that are already very efficient, technologies such as these will cut CO₂ emissions by a further double-digit percentage.

Press photos: 1-BBM-21151, 1-RB-21099, 1-UBE-20209-d, 1-UBK-19636, 1-UBK-19637, 1-GS-19999, 1-GS-20000-d, 1-DS-19451-d, 1-GS-21205-d, 1-GS-21206-d, 1-GS-21207-d, 1-RB-20741, 1-UBK-20832, 1-BBM-21521, 1-BBM-21522, 1-BBM-21511-e

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