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Digitization, autonomous driving, connectivity, and electric mobility – these are the four megatrends that are currently driving the automotive industry. The ability to master and unite these topics requires a wide range of knowledge and experience. With its HARRI innovation platform, Bertrandt has provided evidence of the combined application of these areas and has created a technology demonstrator that is battery-electric on the road to SAE level 5.

COMBINING THE MEGATRENDS

Engineering partners are facing increasing demands. Fewer individual projects are being awarded, whereas instead there is an increasing need for development solutions along the entire automotive value chain. Furthermore, development partners are expected to work on new mobility concepts for the future and to provide corresponding support for customers in their business models.

For this reason, Bertrandt has created the HARRI innovation platform [1] on the basis of group-wide and interdisciplinary cooperation with the aim of showing potential customers the bandwidth of its technology expertise – not only in the automotive industry, but in many other sectors as well. In this innovative technology demonstrator, Bertrandt brings together the four megatrends of digitization, automated and autonomous driving, connectivity, and

Development of a Technology Demonstrator for Autonomous and Electric Driving

electric mobility. It proves how the complex interrelationships between the individual megatrends can be implemented through intelligent solutions.

ON THE ROAD TO SAE LEVEL 5

Autonomous driving is already a reality. The dramatic developments in driver assistance systems are accelerating the arrival of driverless transport solutions. Artificial intelligence is becoming increasingly widespread and a new approach is needed to human-machine interaction. Together with sensor technology and functional safety, the artificial intelligence is the key catalyst for autonomous driving. Algorithms for environment recognition sensor systems and data analysis tools based on machine learning [2] need to be developed. In numerous projects in the field of automated driving on SAE levels 3 and 4 and autonomous driving on level 5, there is in-depth engineering knowledge in areas such as localization, connectivity, and cloud applications.

One central consideration involves the planning and implementation of autonomous movement. In an overall project, Bertrandt developed its HARRI technology demonstrator as an intelligent autonomous driving system that can react and make decisions independently using information about the environment. The focus was on developing the software and also gaining an overall understanding of the interactions between the software, the hardware, and the mechanical systems. The objective of the project was to enable the passenger car to drive autonomously and safely to a predefined parking location, to return when requested to do so, and to start its charging process independently. This meant that the engineers had to address the many different problems that the vehicle will encounter on the road in everyday driving: high-precision localization, obstacle detection, problem strategy planning, etc., **FIGURE 1**.

In addition, other important factors are environment detection, trajectory planning, lateral and longitudinal control, and additional superior functions. The environment detection helps with various sensors to record the environment and, for example, to recognize and classify objects. Other topics that play a key role in the development process toward autonomous driving are connectivity and the back end, ADAS validation, electric storage systems, charging systems and charging infrastructure, power electron-

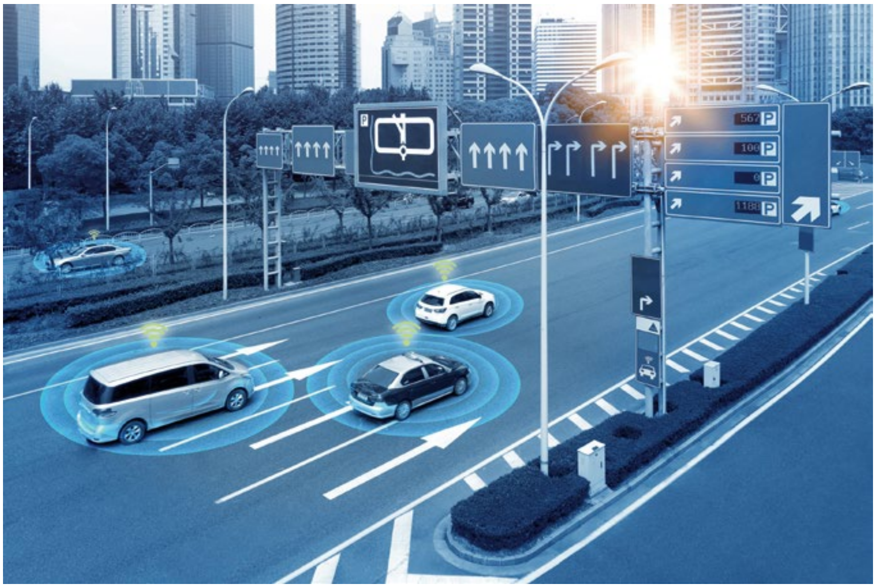

FIGURE 1 Autonomous driving requires a lot of know-how in fields like localization, obstacle detection, and problem strategy planning (© Zapp2Photo | shutterstock)

ics, and Human-machine Interface (HMI), as well as innovative concepts, processes, and methods. Last but not least, quality and safety must be guaranteed at all times.

The HARRI innovation platform integrates all of these necessary components and also demonstrates the company's competence in the field of software engineering. The project combines agile development approaches with applications for the assessment standard Automotive Spice. Furthermore, the platform presents an exceptional user experience based on psychological investigations and technical approaches, even going as far as intuitive human-machine communication via a user-friendly HMI.

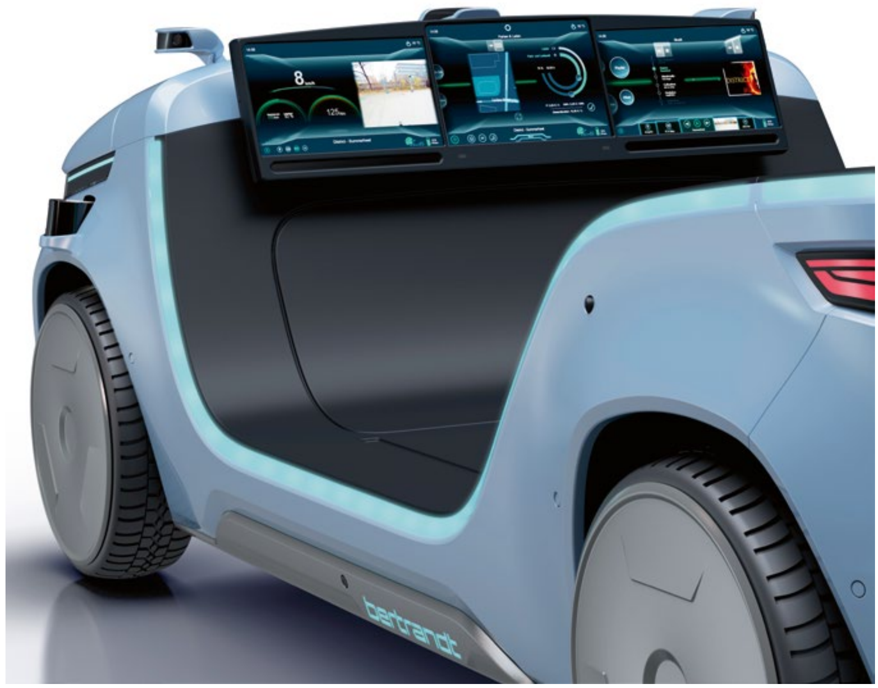

FIGURE 2 For the technology demonstrator, the HMI was completely new developed (© Bertrandt)

DEVELOPING A DISPLAY FOR THE HMI

Displays and machines are becoming increasingly complex and intelligent. The quality of the HMI is what determines how easy they are to utilize by the users. Bertrandt developed new methods that do not involve any switches, knobs, touch screens, and so on, and which will improve the understanding between humans and machines. The main goal was to develop an innovative display for the HARRI technology demonstrator, **FIGURE 2**. Both the technical design of displays of this kind, as well as user issues such as the evaluation of the interfaces were taken into consideration. One important task was the creation of a display and control concept for the technology demonstrator. In addition, a driving simulator was built in order to also carry out user studies. Thus, display concepts were evaluated at an early development phase.

Another focus was on software development of a smartphone app which allows the user to interact with the passenger car – not locally but remotely. Thus, information can be requested about its state of charge or a command could be sent to drive to a particular place at a certain time.

An HMI was also created for external communication that enables to give innovative solutions: How does an autonomous vehicle interact with its environment? How does it communicate with pedestrians and cyclists? In this newly developed design, the company sees huge potential for new opportunities regarding visual functions that provide interaction between the vehicle and other road users.

Data processing both inside and outside the vehicle is the basic prerequisite for successful digitization and connectivity. This technology demonstrator also demonstrates topics such as a solid back end structure, fast recognition and processing of the collected data, and car-2-X communication.

BASIS FOR A CLOUD-BASED ARCHITECTURE

In order to develop the architecture for autonomous driving, it was necessary to establish secure data transmission paths and design a cloud-based platform. This allows vehicle data recorded by sensors to be stored and evaluated in the Microsoft Azure cloud. Bertrandt focused on the communication between the passenger car and the back end systems to process the data needed for autonomous driving. A solution-oriented platform has developed from this. The connectivity experts helped to connect several cars – in the future, this may even be a fleet of vehicles – to the Bertrandt cloud. There were also connections established to additional devices such as smartphones, which can act

FIGURE 3 The newly developed lithium-ion battery system is 60 % lighter than today's conventional systems (© Bertrandt)

as an HMI and switch a car safely to autonomous mode after receiving confirmation from the user.

The Automotive Analytics and Development Platform which Bertrandt developed in-house is a solution for analyzing sensor data and developing algorithms using artificial intelligence. There are interfaces into all areas of autonomous driving. The software and functions need information from the back end systems for the purposes of localization and environment detection, for example. The HMI systems also needed data produced by the back end on the display in the car, together with status messages about what the technology demonstrator was currently doing or will be about to do. The communication channels also had to be open for electric charging infrastructure which provide information about the vehicle and its state of charge. The Modular Tool and Engineering Kit, developed in-house, provides a scalable, holistic solution that can be individually adapted to the customer's needs.

EXECUTION OF AUTONOMOUS MOVEMENTS

Planning and implementing autonomous movements was the central concern of the project. Bertrandt developed an intelligent autonomous driving system that can react independently and make decisions on the basis of information about the environment. One key factor is the development of the software. The technology demonstrator is currently able to drive autonomously in a restricted area using twelve cameras, five lidar systems, and ten ultrasound sensors. The algorithms for this sensor set were created in-house. The autonomous driving system is capable of learning using artificial intelligence and is already able to recognize road signs on motorways and stop lines at junctions.

After movement planning, their conversion into actual movements was developed. To do this, the drive-by-wire system had to be activated. The system controls not only the steering and the brakes, but also the accelerator pedal, and it can be adapted for different prototype applications. Manual steering can be performed using an integrated joystick control. Although this is not actually necessary for a level-4 system, it makes good sense as a fallback level or for the use in level-3 applications, respectively. The actual destination handoff is, however, performed by the app connected to the vehicle. In this example, it was the selection of the parking location and the return request.

HIGH-PERFORMANCE BATTERY MANAGEMENT SYSTEM

The trend toward electric mobility is also considered in the HARRI technology demonstrator. A scalable battery system was created as an in-house development that supplies the vehicle's electrical consumers with the energy and power required. The system uses the latest lithium-ion cells with a high volumetric and gravimetric energy density, which makes the battery system around 60 % lighter and more compact than existing storages, **FIGURE 3**. It consists of several battery modules in a body structure, **FIGURE 4**, a high-performance Battery Management System (BMS), and a bat-

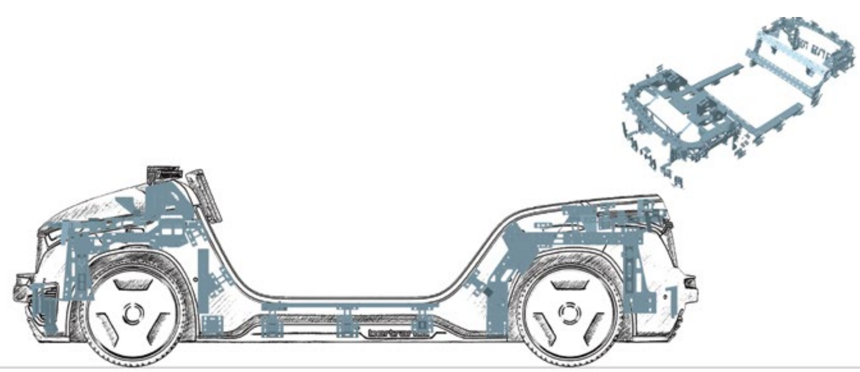

FIGURE 4 Technical inner workings of the technology demonstrator with its body structure (top right) (© Bertrandt)

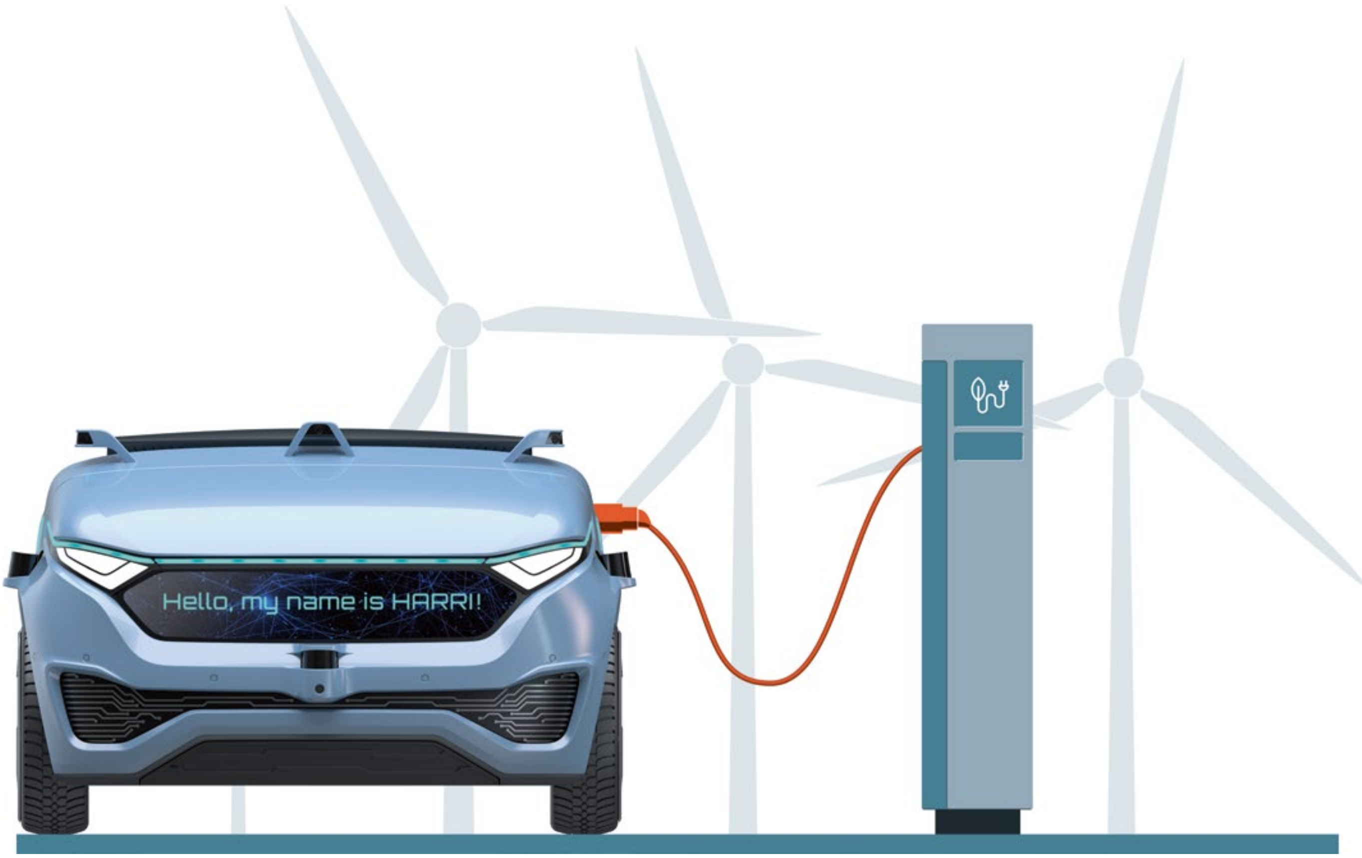

FIGURE 5 Conductive charging possibility for the technology demonstrator (© Bertrandt)

tery junction box. Each module has sensors for monitoring the temperature and voltage. The information is sent to the BMS by cell controllers. Software algorithms in the BMS use the collected data to ensure that the cells operate within a very narrow temperature and voltage range. The BMS data is subsequently transmitted to the vehicle via the CAN.

Autonomous driving gives rise to special energy, performance, and availability requirements that the vehicle's high-voltage system has to meet. This system is made up of the electrical storage device, which provides the energy to drive the vehicle and supply its electrical system, and the power electronics system, which converts this energy into the required form. The battery can be charged from a conventional wall socket via an integrated AC charger or from an external fast charging station, **FIGURE 5**. The battery data is sent from the BMS via CAN communications to the domain controller of the technology demonstrator and presented on the interactive displays by the HMI. The connectivity functions and back end systems send and secure the data to the Bertrandt Automotive Cloud, where it can be accessed by smartphone apps, for example. An in-house software development process and agile development methods enable to ensure that the battery system complies with the functional safety requirements of ISO 26262 and fulfills the quality specifications of Automotive Spice.

FURTHER DEVELOPMENT OF FUNCTIONAL AREAS

Bertrandt is currently working closely on two topic areas. On the one hand, highly automated charging functions are created; these can involve conductive charging using a robotic arm or via an innovative plug connector or an inductive approach. On the other hand, highly dynamic route planning with dynamic object recognition is another exciting topic for the further development of the company's functional areas. The HARRI innovation platform is clear evidence that Bertrandt not only offers solutions for the individual trend topics, but also masters their combined application.

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