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The Vehicle Industry Is Moving Fast

2020 and 2021 IEEE Vehicle Power and Propulsion Conference

After the successful 2019 edition in Hanoi, Vietnam [1], the IEEE Vehicle Power and Propulsion Conference (VPPC) rotated to Europe and was held for the first time in Gijon, Spain, for the two last editions due to the COVID-19 pandemic [2], [3]. The ticklish situation in the spring and summer of 2020 around the world forced it to move to a virtual conference. As the organization committee, led by Prof. Pablo Arboleya, set out an excellent program to receive the international attendees, the VPPC steering committee decided to give the opportunity to the Gijon organization to have an on-site conference giving them the organization of the next VPPC edition in 2021. This is an opportunity to keep appointments with the event center, catering, hotels, and so on. Unfortunately, the pandemic situation remains difficult during 2021 and the VPPC 2021 edition was also prepared as a remote event between 25 October and 14 November. A very motivated team from the University of Oviedo—Gijon campus organized the last two editions with the motto "Connect green e-motion worldwide in a complete network," and the Technical Program Committee (Prof. G. Gruosso, Italy; Prof. R. de Castro, the United States; and Prof. J. Garcia, Spain) prepared a very attractive program, including outstanding keynote speakers, tutorial lectures, and the remote presentation of 303 papers (VPPC 2020—163 and VPPC 2021—140) from 29 countries (see Figure 1). VPPC 2020 and VPPC 2021 were the first VPPC virtual conferences in its history of 18 editions. VPPC continues to be the venue for researchers, educators, and engineers to share the latest results in research, teaching, and development of electric and hybrid vehicles and related technologies. It is an important forum where the academic and industrial community and policy makers discuss new technology trends and collaboration for mutual development in the important moment where new resolutions were taken by international leaders after 2021 United Nations Climate Change Conference.

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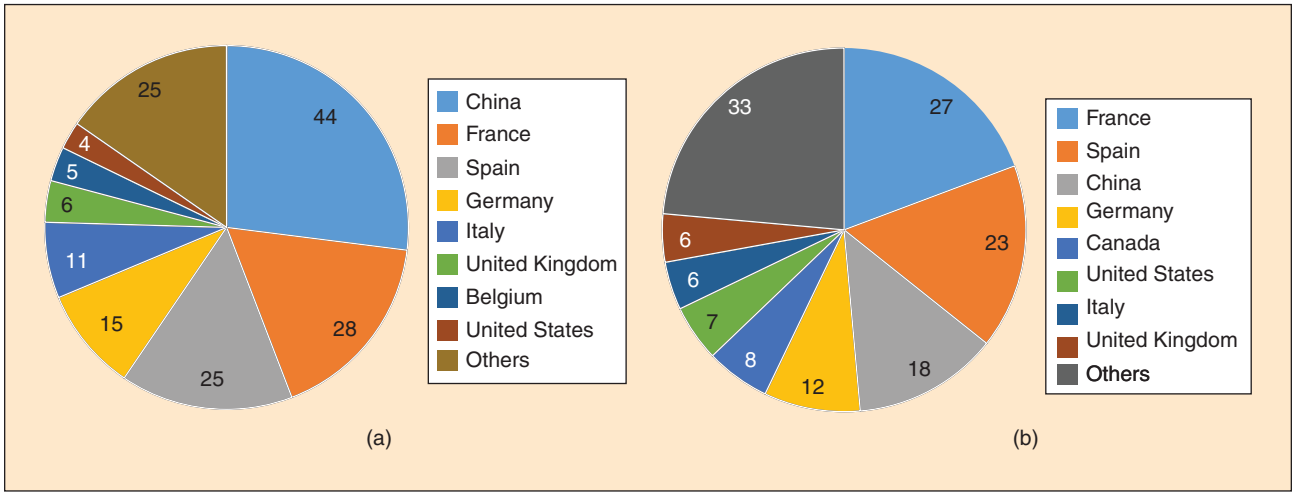

FIGURE 1 The paper distribution for (a) VPPC 2020 and (b) VPPC 2021.

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VPPC, one of the IEEE Vehicular Technology Society flagship conferences, is annually organized in a rotation basis in America, Asia–Pacific and Europe–Africa. The 2022 IEEE VPPC will be held in North America in November 2022 (https://events.vtsociety.org/vppc2022/) and all of the community hopes and wants an on-site conference to come back to the traditional face-to-face networking and exchange of ideas to spread electromobility everywhere.

Automotive Industry Outlook

Various trends in the automotive industry are affecting its future. Essentially, these trends are associated with how vehicles are powered, driven, applied, and acquired [4]. Emerging automotive trends are causing and creating several major changes in customers' habits. For instance, U.S. dealerships and auto parts stores account for 20% of retail sales in the United States. It is the largest total retail sales sector in the United States. In 2020, the automotive industry in the United States had 4.1 million employees and contributed with US$562.2 billion to the country's gross domestic product (GDP). This is 2.5% of GDP. Electric vehicles (EVs) emit 54% less CO_2 emissions into the atmosphere than even newer gasoline vehicles. There are 1.2 million EVs on the roads in the United States today. It is expected to be 18.7 million by 2030 [4].

Also, under the new North American Free Trade Agreement (NAFTA), 75% or more of American car components must be manufactured in the United States, Canada, or Mexico. Currently, vehicles assembled in the United States are made from around 40–50% of imported parts. However, 30% or more of the car workers who assemble those vehicles are expected to earn US$16 an hour or more. That number will increase to 40% next year and this will be reflected into the vehicle final price [4].

Auto industry experts predict that by 2022 and beyond, car subscriptions will become the most popular alternative to private car ownership. They have found that car subscription programs account for a 23.9% share, with car-sharing and ride-handling representing just 1% each [4].

The global autonomous truck market is expected to exceed US$1.699 billion by 2025. About 50% of small companies claim that their truck fleets will be fully self-sufficient in 20 years. More than 35% of them say it could happen in 10 years [4]. Based on the statistical figures, experts indicate that the top 10 trends shaping the future of the fast-moving carmakers industry include [4]:

- *Production increase of EVs with digital technology*: Carmakers and original equipment manufacturers (OEMs) continue to integrate more digital technology into vehicles, as expected. Figure 2 presents a futurist proposition for the Mercedes-Benz EQS EV interior with a large inclusion of digital technology. Also, technology companies like Google and Tesla are working on electric and autonomous vehicles. As a result, a new generation of vehicles will be brimming with technology to address digital touchpoints. Competition is fierce to develop software, digital, and electronic operating systems to power and control innovative zero-emission EVs.
- *Digital automobile sales rising*: European and North American carmakers in have started giving customers the option to skip visiting the showroom and select and buy the vehicles they want online. Customers can shop whenever they want, explore and select the features targeted in a vehicle, and get the financing they need. In addition, dealerships now offer online sales, allow an online shopper to use virtual tour technology, facilitate door-to-door test drives, and perform door-to-door delivery of their vehicles.
- *Increased sales of secondhand vehicles*: Recently, there has been a boom in used car sales. Car industry experts predict a 9% growth rate in secondhand car sales between 2019 and 2025. Demand for used cars is high and growing, especially for four-year vehicles. These vehicles feature the latest automotive technologies but are not as costly as new ones. This includes used electric and hybrid cars.
- *Connected cars*: Connected cars are vehicles connected to the Internet of Things (IoT) wirelessly. These vehicles provide a safe, comfortable, and convenient multimedia experience using

FIGURE 2 The Mercedes-Benz EQS electric vehicle interior. (Source: daimler.com; used with permission.)

on-demand features that let you do whatever you want on the web in your vehicle. Connected cars can communicate bidirectionally with a variety of other systems outside your local network. For instance, the Thales group offers automotive-grade machine-to-machine technology based on cellular IoT connectivity to provide new mobile lifestyles for both drivers and passengers, offering high-speed, low latency connectivity, and a suite of advanced features including a mobile Wi-Fi hotspot, Internet radio, Web services, and an improved navigation system, as shown in Figure 3. Vehicles can share Internet access and data with devices inside and outside them. Connected cars now send digital data and remote diagnostics, vehicle condition reports, telematic data only, access 4G or 5G LTE Wi-Fi hotspots, get step-by-step instructions, warn of car health issues, and intervene directly to avoid breakdowns. Connected car technology will explode in many ways in next decade through predictive intelligence and maintenance technology.

FIGURE 3 Connected cars and smart city resources. (Source: thales.com; used with permission.)

FIGURE 4 Hyundai and UQTR will partner on fuel cell development. (Source: uqtr.ca; used with permission.)

- *Pioneering online marketing policies*: Car dealers use third-party e-commerce platforms to market cars, schedule visits, and book test drives in China. Social media influencers will play a greater role in engaging customers and generating interest in new vehicles that will hit the market this year. Technology enablers like Roadster, G Forces, Digital Motors, Sophus3, and CitNow are fueling the automotive ecosystem and engaging customers digitally with its attractive images and presentations and powerful arguments.
- *Fuel-cell EVs*: The global emergence of fuel-cell EVs is about to take place with recent development on energy management strategy and improved health care usage of the fuel cell [5]. More and more people are adopting fuel-cell EVs because they charge faster, have a range up to five times greater than other types of EVs, and only emit water through their tailpipes. Several commercial solutions are already under tests to reach massive production, as the one presented in Figure 4. A growing number of carmakers are investing in the development of fuel-cell EVs (car, truck, and SUV). In addition, China, Germany, Japan, South Korea, and the United States are supporting fuel-cell electric automotive technology. So, the next few years could be the breakthrough for fuel cell EVs.
- *Shared mobility*: Shared mobility is an increasingly popular new business model, an alternative to owning a vehicle in the traditional sense. With shared mobility, two or more people use the same vehicle with short-term access.

Mobility as a service like Uber or use of a personal rental is growing in many cities. This demand-based car-sharing deal has become much more popular in recent years. New companies offering shared mobility options are emerging every day, creating a creative, affordable, and practical alternative to the high costs and many responsibilities that come with owning a vehicle. Shared mobility is expected to experience spectacular growth in a couple of years. For instance, Daimler is currently providing free-floating as well as station-based car-sharing services to over 470,000 customers in China who have completed over 20 million km in car-sharing journeys (see Figure 5).

- *Autonomous self-driving vehicles*: Autonomous self-driving vehicles are available and will be more prevalent in the near future. We are very far from the iconic Google self-driving car project (see Figure 6) that started 12 years ago with more structured and commercial solutions [6]. Research has shown that autonomous vehicles are safer, reduce downtime, extend last mile delivery range, reduce driver fatigue and driver negligence accidents, improve fuel efficiency by at least 10%, and reduce emissions of CO_2 by 42 Mt per year. Several road transports companies have installed self-driving technology and tested it. Starting in 2022, it will be common to see a fleet of autonomous commercial trucks or an autonomous Tesla, or others on the lane beside us.
- *Truck platooning*: An important automotive trend is the concept of truck platooning (see Figure 7). This is when multiple trucks use vehicle-to-vehicle connectivity to approach each other while traveling at high speed. Truck platooning will become more and more common, as research has

FIGURE 5 The Daimler car-sharing service in China. (Source: daimler.com; used with permission.)

FIGURE 6 The Daimler car-sharing service in China. (Source: daimler.com; used with permission.)

FIGURE 7 The truck platooning concept. (Source: scania.com; used with permission.)

shown that when trucks operate in this type of formation, they increase their fuel efficiency exponentially. Truck platooning is particularly effective when used in combination with autonomous freight transport. As autonomous self-driving trucks become more and more common on the roads, so does the use of platoon trucks. This automotive industry trend you will see more in 2022. This is when multiple trucks use vehicle-to-vehicle connectivity to drive close behind each other while traveling at high speeds. The formation of a platoon of trucks on highways following each other at established close distances are only possible due to the communication capabilities embedded in a new generation of trucks through smart automated vehicle technologies, with capabilities to brake and stop as the situation and road conditions warrant.

- *Carmakers and technology company partnerships*: With the fast pace at which new technological advances are being added to cars and other types of vehicles, it is no surprise that automakers and technology companies are developing more and more partnerships. Electric, connected, and autonomous vehicles require specialized software and state-of-the-art technology to operate properly and safely. Carmakers must invest heavily in their technology divisions or partner with technology companies capable of designing and producing new operating systems, including the next generation of technologically advanced vehicles. Some carmakers partnerships [7] are already known, but in next years new ones will appear.

These 10 trends are considered crucial to the development of the next generation of vehicles from selling to autonomous driving and from electrified to sharing mobility.

In-Cabin Automotive Detection Solutions for Safety and Comfort

Associated with the trends discussed earlier in this article, automotive cabin detection is a quickly evolving area with a variety of applications that use a combination of sensors and intelligent algorithms (see Figure 8) based on camera-based interior monitoring systems of Bosch Mobility Solutions. Today, two main aspects are under development based on cabin detection technologies.

Primary regulations to improve occupant safety are being implemented. European New Car Assessment Programme standards and European Commission (EC) regulations mandate the use of driver monitoring systems (DMS) through 2022, and the U.S. National Transportation Safety Board recommends DMS in semiautonomous cars. A hands-on/-off detection system (HOD) is already required in 2021 to comply with United Nations legislation (R79) relating to lane keeping assist systems (LKAS). Additionally, child presence detection systems will become mandatory in the United States this year. With this legislation, DMS and occupant detection capabilities will become a standard feature of L2+ (Level 2—Partial Driving Automation) and above for driving assistance.

The second key aspect is to improve passenger comfort, for example, through emotional awareness. Original equipment manufacturers (OEMs) have recognized this as a differentiator and will use cutting-edge technologies to address this. For instance, DMS can be a tool to reduce EU traffic fatalities and improve the occupant safety. The European Transport Safety Council estimates that 51 people per million inhabitants in the EU died in road accidents in 2019, in which 95% of the cases were caused by a human factor such as driver distraction, drowsiness, stress, or fatigue [8]. To reduce these values, the EC has drawn a broad range of transport safety proposals with the aim to reduce road deaths and serious injuries by 50% by 2030 and with vision-zero as a main goal for 2050 [9].

Today, DMS already helps other advanced driver assistance systems (ADAS). For example, an LKAS is usually paired with an HOD system to detect the driver's hands on the steering wheel. The system informs the driver to regain control if necessary. In addition, DMSs offer new features to detect a driver's health status and ensure an adequate level of attention.

Vital signs monitoring (VSM) technology introduction in car monitoring system, such as electrocardiography

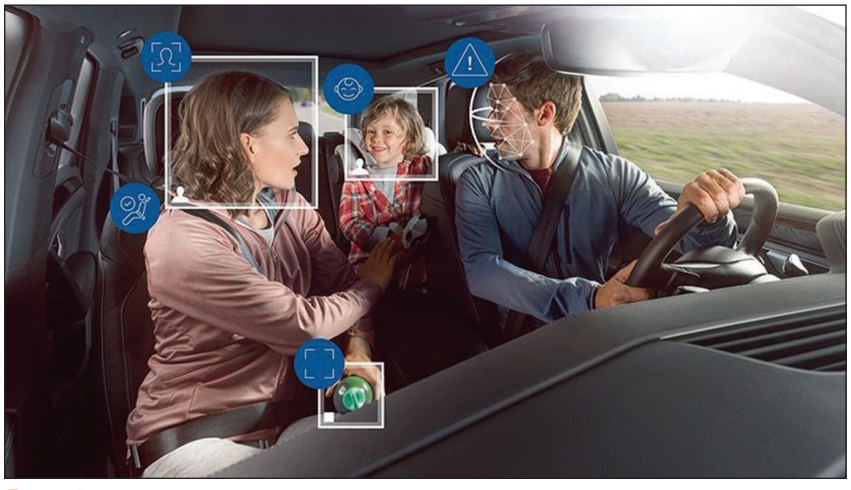

FIGURE 8 Interior and occupant monitoring. (Source: bosch-mobility-solutions.com; used with permission.)

(ECG) or electrodermal activity based on skin impedance to detect electrodermal activity (EDA), offers the possibility to detect the health status and stress level of the driver to avoid potential problems even before they arise using a complex deep learning algorithm that detects, understands, and then responds to a variety of human facial expressions and cognitive state are available and are slowly being integrated into cabin monitoring systems [10]. For example, if the VSM system detects that the driver cannot control the car due to drowsiness or fatigue, as presented in Figure 9, the ADAS can put the car in a safe state (slow down, go into an emergency lane, or stop the car). But, for that, a minimum level of driving automation is required.

Also, ensuring a great driver and passenger experience is more and more important with the integration of self-driving facilities. This framework presents the opportunity to innovate by increasing brand awareness and building new customer loyalty. Growing customer expectations are forcing OEMs to add features that deliver this improved experience. The concepts of personalization and advanced human–machine interface (HMI) as a more intuitive vehicle facility are becoming key elements of the driver and passengers experience. OEMs can reinforce their brands by implementing unique comfort features. For example, automatic climate control or ambient light adjustment depending on the driver's mood and mental state will be more and more common. Contactless HMI systems allow interaction with the driver without having to take your hands off the steering wheel (see Figure 10). Next to voice-activated systems, more accurate DMS using eye-tracking technologies are under development to fill the gap with more traditional touch interfaces. Customer differentiation and captivation push for new and improved user experience.

A large spectrum of applications is covered by in-cabin sensing [11]. Driver monitoring meets the legal requirements, with features such as HOD systems, and becomes a mandatory solution implemented as a standard in future cars. VSM is also an emerging feature that addresses not only health-conscious drivers but also aging trends in the population, monitoring driver health, stress level, well-being, and health. Additionally, biometric authentication not only aids with this personalized experience, such as seat and steering wheel position and infotainment preferred setting, but also

FIGURE 9 A comprehensive understanding of driver and passenger states. (Source: Adapted from [10].)

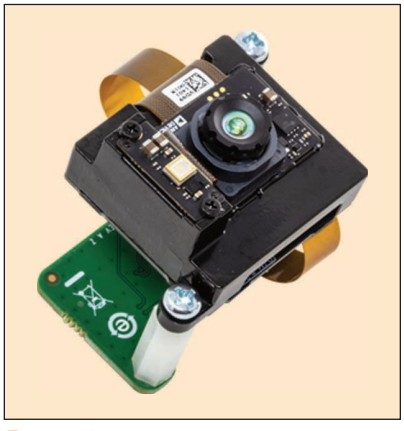

FIGURE 10 ToF Development Kit. (Source: analog.com; used with permission).

provides security with the ability to authenticate the vehicle's driver.

Another vital security application is occupant detection. This guarantees that if a passenger is accidentally locked inside the vehicle, the driver will be immediately notified with the ability to detect the number and age of passengers. Emergency responders can receive additional information prior to their arrival about an accident when the data are combined with the emergency calling system (eCall). A special use case of occupant recognition is the presence of child detection, which will grow to be (depending on the region) a mandatory requirement.

To address all of these new trends' applications, we notice that a single sensing solution cannot address comfort solutions and safety. The clue will pass by sensor fusion with different sensing modalities and several technologies need to be combined and work together to reach the goals of the increasing safety and comfort requirements. To do so, several devices are already available in the market. For instance, a time of flight (ToF) camera is one of the key technologies that can address several of the described applications, offering both image and depth data [12].

A ToF camera positioned in the dashboard or cabin roof can be used for DMS, such as eye-tracking. ToF is already in production at premium OEMs for advanced HMI and gesture control, with the optimum location being in the roof cabin (Figure 11). ToF provides an excellent solution not just for detecting the presence of a rear passenger, but also their body position. Different locations of this sensor can be needed to enable line of sight to the rear seat. With the innovations in image-sensing technology, ToF is a powerful sensing method selected by its smaller form factor, wide dynamic range of sensing, and capability to operate in direct sunlight. The combination of high-resolution distance measurement and medium resolution intensity image (ambient light-insensitive 2D active brightness image) is unique to ToF. Analog Devices Inc.'s (ADI) ToF sensor has the highest resolution (1 megapixel) in the market, which enables larger field-of-view cameras. Although many image applications can be realized using 2D cameras, the 3D (depth) information presents an additional level of robustness. For comfort applications, this explains a better user experience, and for safety applications it is an important differentiator.

Since there will be a variety of cameras in the cabin to support different use cases, it is necessary that cameras support interference cancellation to decrease errors in complexity measurement. Such challenges must be solved at the system level, and ADI is actively engaged in this area with a smart mix of hardware and software elements.

For biometric authentication, ToF can offer a very secure solution, making it very difficult to fool the system, as it has been demonstrated with other implementations. To connect different independent 2D or 3D ToF imaging cameras, ADI also suggests a dedicated automotive camera link technology, the Car Camera Bus (C^2B). C^2B is a low-cost solution for transferring data from cameras up to two megapixels, as well as managing information from cameras installed inside or outside the car [13].

ADI presents various VSM solutions and works closely with software partners to offer an overall system solution for features, such as heart rate variability, stress, and so on. Impedance detection provides a robust and reliable solution for detecting not just hands on the steering wheel but also the quality of handling, which is a fundamental requirement. The location of the hands on the steering wheel can also be provided. Information from the EDA can be used to detect the driver's current stress level.

Combining impedance sensing components with a high-precision amplifier for electrocardiography, ADI offers a complete VSM solution consisting of just two components. The ECG and EDA can monitor the driver's health status, but the ECG can also be used to process biometric authentication applications.

Currently, sensor fusion is already required for accurate and robust L2+/L3 (Level 3—Conditional Driving Automation) driver assistance solutions. To meet the needs of this market with a friendly ecosystem of hardware and software algorithm to recognize gesture control, eye-tracking, and so on, and adding VSM

Figure 11 The John Deere fully electric autonomous tractor. (Source: deere.com; used with permission.)

(e.g., ECG analysis) functions is under growth to have more comfortable and safety vehicles.

Autonomous Tractor for the Future of Agriculture

Tractor maker John Deere has announced that it acquired a U.S. startup Bear Flag Robotics, a Silicon Valley-based company, for US$250 million to make its agricultural equipment autonomous, from tractor to harvesting operations [14]. Founded in 2017, Bear Flag Robotics develops autonomous driving technology compatible with existing machines and has raised US$11.4 million from investors. Early, John Deere bought a artificial intelligent seed planting company Blue River Technology for US$305 million in 2017. The deal accelerates John Deere's long-term strategy and creates a major competitor to European autonomous and agricultural equipment makers, such as Claas and New Holland, which are currently developing new approaches to autonomous systems.

The perception is that autonomous equipment will act as transformative for well-known mechanized agriculture, as presented in Figure 11. That will be the platform that agriculture needs to fulfill the pledge of digital farming, which has struggled to drive value from insights alone. To create new value in digital-agriculture technology, you need to connect perception and information to the action and then run that loop at high speed. Robotics will be the key to unlocking this new concept. Combining analytics with robotics and automation will allow monitoring and growing each plant individually. This approach will reduce labor costs and enable economically viable regenerative agriculture practices. It will also improve safety for one of the most dangerous professions on the planet. It will permit the use of fewer chemicals and fertilizers while reducing input costs. Robotics will benefit the small farmer who will be able to focus on high-value decommoditized yields and help large growers who will be able to do more with less, while having less of an impact on the environment.

John Deere company first began working with Bear Flag in 2019 as part of the company startup collaborator program, an initiative focused on enhancing work with startup companies whose technology could add value for John Deere customers. Since then, Bear Flag Robotics has successfully implemented its autonomous solution on a limited number of farms in the United States. One of the biggest challenges farmers face today is the availability of skilled labor to execute time-sensitive operations that impact farming outcomes, autonomous tractor and harvested machinery.

The success of the Bear Flag Robotics is supported by a multidisciplinary team with agriculture professionals, engineers, and technologists focused on autonomy, sensor fusion, vision, data, software, and hardware. They will remain in Silicon Valley where they will work closely with John Deere development offices to accelerate innovation and autonomy for customers across the world. John Deere and Bear Flag are highly complementary from both a technology and mission perspective. They look forward to working even closer together with the ultimate goal of helping farmers to achieve the best possible outcomes through advanced technology like autonomy in a large sense.

Highways for Electric Trucks with Frequent Recharges

In Germany, there are already three highways equipped with higher power lines designed to power electric trucks through a pantograph (like trains, trams, or trolley cars) to reduce the number of batteries on board. The future of freight transport also depends on EVs to reduce emissions, but waiting for new effective solutions for recharging the use of a well-known solution from the past could be an initial answer to have more electric trucks in roads. Instead of relying only on batteries, heavy vehicles are equipped with pantographs capable of feeding directly from superior power cables through a solution that have been applied in trains, trams, and trolley cars in several European cities.

Articulated heavy trucks, commonly known as semitrailers, have a generous load-carrying capacity but usually cover large distances, for which they have autonomy of between 800 and 1,000 km. However, in the case of long-distance electric trucks, there are those in the industry who estimate that it will be necessary to transport around 10 tons of batteries, the cost of which is enormous, with the extra consequence of removing capacity for cargo-loading. Of course, it remains to be seen whether these values are confirmed when the first examples of this type of vehicle appear.

One of the solutions to answer this load capacity and range lost involves reviving a technological solution that is more than 100 years old, feeding electric motors with energy taken from upper lines through pantographs. This solution is currently defended by a German partnership between Continental and Siemens. To be possible, it is necessary to build electric highways as presented in Figure 12, which have electric cables run over the right-hand lane, intended for heavy vehicles with pantographs, but that do not prevent their use by other types of vehicles.

Continental Engineering Services and Siemens Mobility, in coordination with the German federal ministry for transport, have already installed overhead cables for power supply on three German highways, capable of recharging the batteries even while heavy vehicles are circulating. This makes it possible to greatly reduce the capacity of embarked batteries, as well as their weight and cost,

since the bulk of the consumption of heavy cargo transport vehicles is carried out on the highway.

The German transport ministry estimates that it is only necessary to electrify 4,000 of the 13,000 km that make up the German road network used by most heavy vehicles, since two-thirds of trucks only use one-third of the highway network. The effectiveness of the system is already known, and the three areas of the local expressways where the system is being tested aim to create a standard for the pantograph. A single system must be approved to be adapted to all types of vehicles. The pantograph will also be designed to be automatically retracted whenever the driver decides to overtake and will be rearmed as soon as the truck returns to the electrified track.

New MAHLE/Allotrope Battery Technology

MAHLE Powertrain and Allotrope Energy have unveiled a new battery technology for small EVs that combines supercapacitors with lithium-ion batteries to offer ultrafast charging coupled with good power density (see Figure 13). The two companies looked at how an electric motorcycle could be powered by a cheap, small-capacity battery that could be recharged between stops in just 90 s.

Allotrope technology includes a high-rate battery-type anode and a high-capacity double-layer electric capacitor (EDLC)-type cathode, separated by an organic electrolyte. The company claims that its battery cell does not suffer any of the thermal degradation effects that affect traditional lithium-based batteries. Even at high temperatures, the proposed concept can deliver high current and quick recharge, all without the need for complex external cooling or elaborate battery management systems. Allotrope claims that the battery "capacitor-type cathode" offers a lifetime of over 100,000 cycles, uses rare earth metals, and is fully recyclable.

The two companies looked at how an electric moped could be powered by a cheap, small-capacity battery that could be recharged between stops in just 90 s. Allotrope technology includes a high-rate MAHLE Powertrain and studied the scenario of an electric motorcycle used for food delivery, with a range of 25 km. A conventional 500 Wh Li-Ion battery would require at least a 30-min charge midshift, and frequent fast charging would shorten battery life. A lithium-carbon pack could, however, be recharged to 20 kW in 90 s, enough time to pick up the next delivery.

Adding the concept of superfast charging, the battery size can be optimized to suit scenarios in which the vehicle will be used, resulting not only in weight savings but also in cost savings, as deduced by MAHLE Powertrain. The real challenge will be to design the electrical architecture capable of transferring these high charge rates. Furthermore, in the absence of adequate charging systems on the market that can provide these rates at a domestic supply, MAHLE Powertrain has developed a customized design to supply this kind of request.

MAHLE Powertrain and the Allotrope team has proposed using its built-in capacitor energy storage to provide ultrafast charging of up to 20 kW, increasing the power of a typical 7-kW single-phase connection, thus reducing costs and complexity, while eliminating the need for expensive power grid connection updates. The MAHLE/Allotrope battery team pointed out that with ultrafast charging, the size of the batteries can be optimized depending on the vehicle and its purpose. The reduced battery size also will lead to weight and cost savings and give a new degree of freedom to optimize vehicle powertrain regarding its application.

FIGURE 12 The Continental and Siemens electric highways concept. (Source: continental.com; used with permission.)

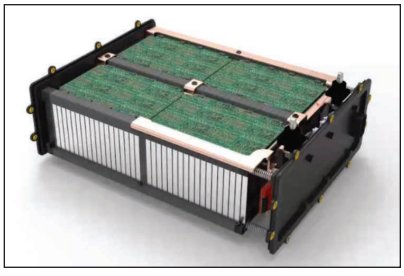

FIGURE 13 The Allotrope new battery technology. (Source: mhale-powertrain.com; used with permission.)

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