The automotive sector - connected

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Dear Readers,

What do you expect your car to look like in 2041? At first glance, it will probably look much like the one you drive today. But will it have a steering wheel, and if so, how often will you use it? Will it be powered by fossil fuels, synthetic fuels, or perhaps batteries or hydrogen fuel cells? And will it even be yours? If not, to whom will it belong?

The fact that these questions are so difficult to answer underscores the depth of the automotive sector’s ongoing transformation, as the technologies that enabled the Internet of Things – ubiquitous sensing, cheap and abundant processing power, and wireless communication – firmly establish themselves on the list of components needed to build cars.

In this edition of the u-blox technology magazine, we explore the challenges and opportunities created by increasingly autonomous vehicles. In our feature articles, we examine some of the technologies behind this transformation, including increasingly sophisticated satellite-based positioning solutions. We offer our perspective on how wireless technology can add value to electric vehicle charging stations. And we take you on a whistle-stop-tour of the five largest automotive markets.

Our expert interview brings together Mathias Reimann, Vice President Engineering, GNSS & Inertial Sensors at Bosch with u-blox’s Stefania Sesia, Head of Application Marketing Automotive, to discuss the trends driving innovation in the automotive sector, and how they are already impacting car OEMs and their suppliers.

Finally, looking inwards, we present Sapcorda, our latest strategic acquisition, which we see playing a key enabling role in making highly autonomous vehicles a reality.

We wish you an insightful and enjoyable read!

Sincerely,

Thomas Seiler, CEO
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Automotive's big leap

Vehicles are currently undergoing what might be their most profound transformation since they hit the mass market.

As you read these pages, the automotive sector is in the early days of a huge evolutionary leap. At its core is the collision between environmental, societal, and economic drivers on the one hand, and technological innovation on the other. Specifically, ubiquitous sensing, abundant and affordable processing power, and wireless connectivity. For the first time since mass-produced, combustion-engine-powered vehicles hit the roads, cars – once mere mechanical devices controlled by their drivers – are becoming “sentient.” Not like you and me, but still capable of sensing their environments, communicating with their surroundings, and assisting their drivers, often helping them overcome their – human – limitations. In the near future, they will take over the wheel altogether.

Contributing around 16 percent of global CO₂ emissions¹, the road vehicle transport sector is being challenged to curtail its greenhouse gas emissions to limit the impact of climate change, with national governments driving a shift towards new propulsion systems and net-zero-carbon fuel sources. There is an expectation to increase safety on our roads, on which around 1.3 million people die in crashes each year, and up to an estimated 50 million more suffer non-fatal injuries.² And to compensate for the higher component cost of today’s more sophisticated vehicles and the stagnation of global output, automakers are updating their business models to remain profitable, while private and commercial customers are changing their consumption patterns to adapt to the new normal.

This is a unique and exciting time in the automotive sector. For the first time in history, the industry has the technological toolkit it needs to rise to the occasion and meet these challenging demands. The very trends that transformed society through the internet, smartphones, constant real-time communication, and social media are now getting ready to transform every aspect of the automotive sector, too. Because of the industry's long production cycles, the first legs of its journey – spanning the coming three to four years – have already been charted. Automotive research and development teams are busily laying the groundwork for the vehicles that we'll see on our roads by the end of the decade. But where this ongoing evolutionary leap will take us over the course of the coming decades is anyone’s guess.

¹ https://www.oica.net/category/climate-change-and-co2/
New propulsion systems and fuel sources

Amidst the uncertainty, one thing is clear: with regulations on CO₂ emissions beginning to show their teeth, the heyday of fossil-fuel-powered vehicles is over. Norway’s ban on sales of new ICE (internal combustion engine) vehicles will take effect in 2025. Ireland, Iceland, and Denmark will no longer sell fully fossil-fuel-powered cars as of 2030.³ And, starting in 2035, China, the world’s largest automotive market, will follow, banning the sale of standard ICE vehicles and limiting the sale of hybrids to 50 percent.⁴ Meanwhile, Volkswagen will phase out the development of fossil-fuel-powered vehicle platforms by 2026, with investments of US$ 80 billion to transition to electronic vehicles (EVs).⁵ Jaguar will become all-electric by 2025, with Bentley and Volvo among those to follow by 2030, and GM by 2035.⁶,⁷

““The very trends that transformed society through the internet, smartphones, constant real-time communication, and social media are now getting ready to transform every aspect of the automotive sector, too.””

According to a survey by the World Economic Forum and McKinsey, consumer sentiment is evolving too.⁸ During the first year of the COVID-19 pandemic, the appreciation of automotive OEMs by consumers improved around the world. In Asia, the share of respondents that viewed them positively went up by 12 percent. In North America and Europe, it increased by 7 percent. At the same time, 83 percent of North American and Asian respondents reported an increased interest in purchasing an EV, while in Europe, where opinions were already very positive prior to the pandemic, two-thirds reported that their interest had either stayed the same or increased.

Despite clear indications of a shifting tide, fossil-fuel-powered vehicles will stick around for some time, and not only due to their lower cost. Cars have an average lifespan of over 11 years.⁹ Semi-trucks can average around 15 to 16 years.¹⁰ So, even if new sales of plug-in hybrids and battery-powered electric vehicles grow to over 25 percent by 2029, as ABI Research anticipates,¹¹ it will take much longer for them to outnumber ICE vehicles on our streets.

In the interim, ancillary services and infrastructure will be given time to adjust. Auto workshops will be hit by reduced demand, as electric motors, which have far fewer parts and do not need oil changes, require less maintenance than ICE vehicles. Unlike gasoline, electricity is available more or less everywhere. As a result, gas stations will be forced to charge their offering to meet the needs of the new vehicle fleet and grow the network of EV charging points. And homes, commercial buildings, and offices will see the need to install charging points to meet increasing demand.

Fuel cells, which produce electricity by letting hydrogen and oxygen react, offer an alternative way to power EVs. Like today’s fossil-fuel-powered fleet, fuel cell electric vehicles (FCEVs) need to go to dedicated charging stations to top up their hydrogen tanks. But while standard vehicles emit a cocktail of noxious gases, FCEVs simply emit water. With roughly the same drive train as any electric vehicle, FCEVs can outperform EVs in terms of range without putting on too much weight: hydrogen offers 120 megajoules per kilogram compared to around 5 megajoules per kilogram for batteries. While the US foresees a vast expansion of FCEV-powered commercial vehicles, Japan, Korea, China, and Europe have set ambitious targets for passenger vehicles as well.

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⁵ https://www.autonews.com/automakers-suppliers/vw-brand-will-phase-out-combustion-engines-ceo-says
⁸ https://www.weforum.org/agenda/2021/03/survey-shows-how-automotive-consumer-buying-habits-are-changing/
Finally, synthetic fuels may offer a way to leverage the existing distribution infrastructure for gasoline and diesel, while eliminating their environmentally harmful side effects. Porsche is only the latest of many automakers investigating the development of synthetic fuels, which have the potential to make existing vehicles as “green” as electric ones, with no required changes to the engine. The fuel they are trialing will be made by using renewable energy to combine CO₂ and hydrogen to create a combustible liquid very similar to today’s fuels. But while fossil fuels introduce carbon sequestered underground for millions of years back into the atmosphere, the synthetic fuels proposed by Porsche and other automakers use CO₂ that is already in circulation.

Assisted and autonomous driving
Automakers have consistently worked to increase the safety of their vehicles, often egged on by legal mandates. Windscreen wipers, seat belts, and airbags, as well as different forms of assistance, such as ABS, parking cameras, and blind-spot warnings, are among the features that have been added over the years. Now, the technological triumvirate that brought us the Internet of Things – ubiquitous sensing, cheap and abundant processing power, and wireless connectivity – is raising assisted and autonomous driving to new heights, transforming cars and other vehicles into active agents capable of contributing to increasing road safety, and, frankly, making us better drivers.

While all highly assisted and autonomous vehicles share the need to be able to sense their surroundings, there are about as many sensor setups dedicated to perceiving the environment as there are automakers, drawing on a diverse set of sensing technologies. Bluetooth, for instance, can be used to detect and authenticate an approaching driver and unlock the vehicle’s doors. While parked, a GNSS (global navigation satellite systems) receiver can retrieve the last stored position or, if outdoors, proceed to get a

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9 https://www.consumerreports.org/car-repair-maintenance/make-your-car-last-200-000-miles/
10 https://www.commerceexpressinc.com/2020/01/09/5-quick-facts-about-semi-trucks/
11 Vehicle and Mobility Market Data 3Q 2020, ABI Research
new position fix and feed that to the in-vehicle navigation system. Ultrasound or millimeter band radar can detect low-lying obstacles surrounding the car and, in collaboration with cameras with an increased field of view, help the vehicle leave the parking space and engage into traffic. And once on the road, a combination of cameras, radars, and lidars can continuously gather information about surrounding traffic signs, obstacles, and other traffic participants. All the while, a complementary set of connected sensors will be monitoring the vehicle’s performance as well as the driver’s preparedness to take over the wheel when necessary.

Wireless communication extends the vehicle’s sensors beyond its own boundaries. With vehicle-to-everything (V2X) communication, based either on short-range (DSRC) or cellular technology (C-V2X), vehicles will be able to exchange information amongst themselves to negotiate complex maneuvers such as lane merging, overtaking, or managing four-way stop signs. It can be used to deliver vehicles real-time information of nearby traffic signs, the status of traffic lights, and alerts when vulnerable traffic participants such as cyclists or pedestrians are present. The technology is even being designed to allow the vehicle to access other vehicles’ cameras and sensors in what is referred to as collective perception, for example, to better assess the safety of planned maneuvers.

Finally, the communications will extend up into the cloud, connecting the vehicle with a variety of added-value services and features. This will allow them to download always-up-to-date high-definition (HD) maps of their surroundings required to make sense of their environment, localize themselves in space, and inform them of any obstacles in their route. Together with satellite-based positioning, HD maps will be essential to authorize autonomous driving features in designated areas in highly but not fully autonomous vehicles. And the data pipe to the cloud will also let car manufacturers stay in touch with their vehicles post-sale to track their performance, detect any signs of deterioration before they cause harm, and enhance their functionality.

Processing the wealth of the data gathered by in-vehicle sensors and incoming wireless communication and translating it into actions
requires a high-performance computing platform designed for image recognition, path mapping, and performance optimization, as well as an advanced human-machine interface. Companies like NVIDIA have developed dedicated supercomputing platforms that leverage AI to offer the compute power highly automated and autonomous vehicles will need. Panasonic, meanwhile, recently presented an advanced augmented reality heads-up display (AR HUD) that it expects to see deployed in vehicles as soon as 2024. The HUD presents relevant information, such as navigation guidance, advanced collision warnings, traffic information, and more by projecting it into the driver’s field of view.

At the time of writing, the very first commercial vehicles are transitioning from offering advanced driver assistance (ADAS) – in which the driver always needs to remain at the wheel (referred to as Levels 1 and 2) – to automated driving (AD) – in which the driver can relinquish control in well-defined scenarios of increasing scope (referred to as Levels 3 and 4). The Honda Legend, available as a limited edition in Japan, enables Level 3 autonomous driving in traffic jams. The path to full autonomy – all the time, everywhere (Level 5) – will be a cautious, incremental journey that will still take years to unfold. Getting there safely will depend on being able to manage the various levels of risk involved, from sensor and connectivity performance outages to sensor jamming, spoofing, and other cybersecurity threats.

**Back to the drawing board**

Developing business models that enable scaling up production will likely require as much ingenuity as developing the connected vehicles themselves. As with electrification, Tesla, based out of Silicon Valley in the US, has been setting the pace of innovation while selling its vehicles to the mass market, demonstrating what can be done. Building on talent from the nearby Big Tech industry, the company designed its vehicles from scratch around their ability to sense, process, and act on data. This has forced established automakers, many of which were already playing catchup in the electrification arena, to fundamentally rethink their vehicle platforms and ramp up investment in software development as well. Ultimately, it is leading to a return to the drawing board – a radical redesign of the car’s hardware and software architecture.

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One approach that automakers are adopting to bring down the hardware cost of electric vehicles is by embracing a modular vehicle design comprising elements that can be reused across their entire portfolio. The Renault-Nissan-Mitsubishi alliance, for example, has developed its CMF-EV (Common Module Family – Electric Vehicle) platform, upon which it intends to build several of its upcoming electric cars. Daimler-Mercedes’s EVA platform for EVs, Volkswagen’s Modular Electric Drive (MEB) Matrix, and GM’s Ultium platform are just some other examples. Not only does concentrating research and development as well as manufacturing on a modular hardware architecture undergirding a variety of models help automakers lower costs by achieving benefits of scale; it also lets them optimize the performance of their vehicles.

As more and more of the functionality of our vehicles is controlled by computers, their computational architecture is evolving as well. Most advanced cars have more than one hundred electronic control units (ECUs), each dedicated to a particular task, such as controlling the powertrain, the suspensions, or the brakes. These can be organized in a way that increases their ability to collaboratively implement more complex functions.

Going forward, there will be a push to consolidate the computational power into a small set of function-specific domains before, ultimately, running the entire automotive stack on a single, high-performance computational unit that will host the function-specific systems on virtual domains. This transition will be paralleled by an increasing separation between the hardware required to implement a functionality and the software required to control it, with the vehicles becoming less and less defined by the hardware that they are made up of, and more and more by the software and applications that they run.

This shift from horsepower to petaflops, and from classy leather upholstery to software-powered augmented reality presents a particular challenge to established automakers for whom the IT and service mindset are not yet ingrained in their DNA. Whereas new joiners such as Tesla may have been optimally prepared for these demands, incumbents in Detroit, Munich, or Seoul are having to catch up by investingmassively in partnering with software development capacities, acquiring them, or building them from the ground up. That isn’t to say that they are lagging far behind. According to a report by Deloitte, BMW and Mercedes expect to have centralized electronic and electrical architectures in their vehicles in 2021, resp. 2024.

The first step in a long journey

The confluence of environmental, societal, and economic drivers with new enabling technologies in sensing, data processing, and wireless communication is reshuffling the automotive sector across all major markets. Established car OEMs are making massive investments to secure their leadership position into the future as emerging players based predominantly on the US West Coast, but also in China, demonstrate the value of designing cars around software, sensing, services, and data. As the automotive industry and its suppliers adjust to these momentous changes in drivetrain technology, vehicle automation, hardware and software architecture, and business models, it’s worth remembering that this is but the first step of a long journey.

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20Software-defined vehicles – A forthcoming industrial evolution, Deloitte, 2021
For over a century, the success and safety of automobiles have depended on a highly sophisticated sensing and computing solution, one that fits comfortably behind the steering wheel: their drivers. The driver, and the driver alone, was called on to stick to the speed limit, abide by the traffic rules, engage in difficult and potentially consequential maneuvers, chart the optimal course to the destination, and safely pilot the vehicle along its journey.

The cars we drive today are meticulously designed around our innate human skills and aptitudes, which we continually perfect throughout our driving lives. But with the World Health Organization reporting 1.3 million road fatalities each year and near misses more common still, humans can hardly claim to be infallible behind the wheel. Easily distracted, prone to stress and fatigue, victims of our own egos, and worse at reading maps than we would like to admit, there continues to be plenty of room for improvement.

Many past enhancements in traffic safety have been the result of mechanical changes or additions to the car: seatbelts, baby seats, airbags, optimized designs informed by crash testing. The current wave of improvements goes beyond that. As a result of the massive progress in sensing and computing hardware, wireless communication, data processing, and algorithmic sophistication, technology has matured to the point that it can begin to overcome some of our human limitations.

The bottom line? In addition to saving hundreds of thousands of lives, the financial benefits of automation add up. Back in 2018, Swiss Re and Here estimated that widespread adoption of advanced driver assistance systems could cut global car insurance premiums by US$ 20 billion by 2020. And with the PwC strategy consulting team estimating the global value of the automated driving technology market to hit US$ 270 billion by 2030, automakers and their suppliers around the world are competing for their slice of that pie.

ADAS explained

But first, what are advanced driver assistance systems (ADAS), what functionalities do they offer, and from what point on, precisely, do they classify as advanced? According to the Society of Automotive Engineers (SAE), cruise control, which lets a vehicle maintain a set speed, falls short of being considered “advanced” (see infographic). Because it only assists drivers by controlling a single functionality – here, speed – it’s merely a “driver assistance system.” Driver assistance systems that control both speed and steering, on the other hand, are considered advanced.

The list of technologies that make up ADAS solutions is long – longer still if you account for the diversity of marketing terms automakers use to describe their proprietary implementations of roughly the same feature set. To simplify the ADAS technology landscape, the American Automotive Association has proposed a terminology comprising twenty technologies, which can be grouped into five categories:¹

<table>
<thead>
<tr>
<th>Category</th>
<th>Technologies</th>
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<tbody>
<tr>
<td>1. Automated driving tasks</td>
<td>Adaptive Cruise Control, Dynamic Driving Assistance, Lane Keeping Assistance</td>
</tr>
<tr>
<td>2. Collision alerts</td>
<td>Blind Spot Warning, Forward Collision Warning, Lane Departure Warning, Parking Obstruction Warning, Pedestrian Detection, Rear Cross Traffic Warning</td>
</tr>
<tr>
<td>3. Collision mitigation</td>
<td>Automatic Emergency Steering, Forward Automatic Emergency Braking, Reverse Automatic Emergency Braking</td>
</tr>
<tr>
<td>5. Miscellaneous driving aids</td>
<td>Automatic High Beams, Driver Monitoring, Night Vision</td>
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Each of these technologies represents a stepping-stone on the path towards higher degrees of assistance, and then towards full autonomy. The SAE represents this as a progression from vehicles that only provide warnings or

¹ [https://newsroom.aaa.com/2019/01/common-naming-for-adas-technology/]
momentary assistance (Level 0) to vehicles that drive autonomously in all conditions (Level 5).

A safer, more convenient ride
For all the hype around automated driving, the road leading us there will likely be long and bumpy. No doubt, progress has already been impressive, with each new feature – blind spot warnings, automatic emergency braking, etc. – doing its part to increase road safety for those inside and outside the vehicle. Still, with a few lonely exceptions, even the most advanced cars for sale today offer Level 2 automation at best. While a growing number of vehicles may have the technological chops needed to shuttle passengers around, regulators continue to be wary of letting drivers take their attention off the road environment – the hallmark of Levels 3 and above.

In other words, in the SAE’s chart, we are still in “blue” territory: Levels 0 to 2. Even in today’s most advanced Level 2 autopilots, sometimes referred to as Level 2.9, the driver is required to remain engaged and prepared to take control of the vehicle at all times, and, critically, assume responsibility in the case of an accident.

According to projections by ABI Research, Level 2 will continue to dominate passenger vehicles
well into the future, with Level 3 and higher expected to make up just under 15 percent of new vehicle sales in 2030. By that time, roughly half of new vehicles will still classify as Level 1 at best. And mass adoption of the highly autonomous vehicles is unlikely to begin with consumers. Because of their higher cost of acquisition and repair, and because they will only be permitted in a restricted set of conditions, vehicles sporting automated driving features will likely enter the market via businesses and business-driven use cases.

**The benefits to business**

The business rationale behind highly automated vehicles is clear: reduced operational costs, increased safety, and optimized efficiency. At least in the early days, fleet owners will see the strongest case to invest in more costly highly autonomous vehicles. They will be in the best position to offset the otherwise high per-mile cost by maximizing vehicle allocation and keeping them on the road virtually non-stop while saving costs in the form of insurance fees, salaries for highly qualified drivers, or by eliminating the driver altogether, sometimes replacing them with remote supervisors.

Robo-taxis are one popular use case that maximizes vehicle utilization – and, consequently, return on investment – that several OEMs including Ford in the US and Didi in China are investing in. While, initially, they will largely be made up of vehicles featuring Level 4 autonomy and requiring a (remote) driver, as the technology matures, they are expected to graduate to driverless Level 5 autonomy. In addition to offering passenger services, these vehicles could engulf other use cases as well, automating the delivery of groceries, meals, packages, and other goods.

The trucking industry also has a strong incentive to adopt higher levels of vehicle autonomy, with Daimler, Einride, Embark, and Volvo among the big names in the mix. While it will still take a few years for driverless trucks to transport goods from coast to coast, fleet owners can benefit from a variety of already-available forms of assistance that increase efficiencies or otherwise save costs. Parking assist and reverse assist, for example, take over the wheel to deal with maneuvers that otherwise require highly qualified, expensive drivers.

“As a result of the massive progress in sensing and computation hardware, wireless communication, data processing, and algorithmic sophistication, technology has matured to the point that it can begin to overcome some of our human limitations.”

Platooning, where several trucks automatically trail each other in a convoy, reduces drag, saving fuel and cutting down CO₂ emissions. While one pilot study carried out in Germany by DB Schenker, MAN Truck & Bus, and Fresenius University of Applied Sciences measured fuel savings of three to four percent, the US National Renewable Energy Laboratories demonstrated fuel savings between ten and 17 percent, depending on the truck’s position in the convoy. And in ports, where vehicles operate in a structured and obstacle free environment, driverless terminal trucks already relay containers from the shipping yard to the container ship.

**First successes, more in the pipeline**

Next time you’re driving, look around. At least some of the vehicles around you today are likely to boast Level 2 autonomy. Tesla, one company that sells consumer vehicles with Level 2 autonomy, has been racking up miles with their autopilot, which gives drivers a sampling of what

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5 Advanced Driver Assistance Systems (ADAS) and Autonomous Driving Market Data, 1Q 2021, ABI Research


7 https://www.nrel.gov/transportation/fleettest-platooning.html
full autonomy will feel like. But because it still requires them to remain fully aware behind the wheel, the level of autonomy it offers drivers falls short of Level 3. It isn’t alone. Daimler-Benz, General Motors, and BMW all have vehicles with advanced Level 2 autonomy in production. And with the European New Car Assessment Programme (Euro NCAP) including many Level 2 ADAS features in their star-based safety rating, it’s safe to assume that these features will slowly begin to appear in mid- to low-segment vehicles as well.

While breaking into Level 3 has proven to be a real challenge, there’s little doubt that it will be a game-changer: starting at Level 3, the driver will be able to let go of the wheel and do something else. Until SAE Level 5 is attained, such eyes-off-the-road, hands-off-the-wheel service will only be available when specific conditions are met, or, in autonomous driving jargon, when the vehicle is within its operational design domain (ODD) for that specific autonomous functionality.

In SAE Level 3, it will be up to the vehicle to judge, for example, whether the operating conditions for autonomous driving are fulfilled based on its geographical location, traffic density, the time of day, and other conditions such as which lane it is driving in. As a result, Level 3 vehicles will need to be sufficiently “self-aware” to determine whether the sensor data they are fed can be trusted, and, if so, to request the driver to take over control.

The first company to hit the consumer market with a Level 3 production car is Honda, which started selling its Honda Sensing Elite ADAS system in a Japan-only version of the Honda Legend sedan in March of this year. Granted, only 100 vehicles will be sold at first, and the restrictions on the use of the technology will still be quite stringent. Drivers can only let go of the wheel and engage in other activities when they are stuck in slow-moving traffic jams. In other scenarios, the car offers additional driver assist functionality.

Drive across Phoenix, Arizona, and you might come across vehicles completely lacking a driver. There, Waymo, the Alphabet company operating the fleet of driverless taxis, is offering what might be considered as “supervised Level 5.” What passengers do not see is that the cars can fall back to human support if they encounter a situation that they are not qualified or able to handle. Examples might include an unexpected, blocked road or a traffic warden directing traffic using hand signs. And in China, Baidu, the tech giant, and AutoX, an Alibaba-backed company, have rolled out commercial service in Beijing and Shenzhen respectively.

Safety first. Full autonomy? Later!
Look at the big picture, and the signs are clear: while the initial hype and optimism surrounding driverless vehicles has given way to a more realistic assessment of the situation, momentum towards vehicle automation to increase road safety continues to grow. Driver assistance is already preventing injuries and saving lives on our roads today. And as vehicles begin to take over, first in narrowly defined scenarios, then in increasingly all-encompassing ones, they will likely prove themselves to sense more, react faster, and drive more safely than we do. And, who knows, a few decades from now, it might be considered reckless to even let a human sit behind the wheel...
Clearing the roadblocks on the path to full autonomous driving

It may feel like we are closing in on driverless vehicles. Look more carefully, however, and you’ll find several bottlenecks that the industry and regulatory authorities are working to overcome.
Progress towards ambitious goals is rarely linear. The effort to achieve fully autonomous driving is no exception. It may disappoint those that had anticipated a “self-driving-car revolution” to learn that getting there will be more of a multi-year, step-by-step, feature-by-feature evolution. The approach adopted by automakers and regulatory authorities to safeguard lives and bolster trust in the technology: start small, authorize a limited number of features in narrowly defined conditions, and grow the scope of the technology from there. Cautiously. Incrementally. Safely.

That said, it would be misplaced to call the evolution slow. OEMs today are already selling models boasting Level 2 autonomy features that control driving speed, keep a safe distance from the car ahead, stay in their lanes, and offer countless other forms of assistance, from parking and overtaking to blind-spot and “backing up” alerts. The condition, however, is that drivers remain focused behind the wheel and prepared for the vehicle to turn off support at a moment’s notice.

The next stop, already visible on the horizon, is Level 3 autonomy. While it’s just another increment on the roadmap, in terms of the demands it places on the vehicle, it’s a huge leap. Level 3 requires the vehicles to autonomously authorize self-driving mode when permitted and puts the autopilot in charge. Meanwhile, drivers get a chance to kick back, enjoy a movie, or focus fully on a phone call, at least until the vehicle exits the authorized self-driving zone or loses confidence in data coming in from its sensors. Achieving the context-awareness this requires in a broad range of environments will be a tipping point on the road to higher levels of autonomy.

But the journey to Level 5 – no steering wheel, with no geographical restrictions – is fraught with technological, practical, and regulatory bottlenecks. These are some of the most challenging ones we see on the horizon.
Roadblock #1: Safe sensing and cognition
Developing safe autonomous driving solutions hinges on four main pillars: reliability, integrity, redundancy, and validation. As all components that make up the automotive supply chain, autonomous vehicle sensors are required to comply with extremely stringent quality criteria, allowing them to withstand and perform reliably in harsh conditions, including temperature, humidity, vibration, and RF-interference, throughout the vehicle’s long expected life.

Because the data they provide is relied on by the autonomous driving computer to make mission critical decisions, the sensors, and, potentially, the artificial intelligence and machine learning algorithms that analyze the gathered data must always know just how much their output can be trusted – in other words, its integrity.

Assessing the level of integrity requires an end-to-end approach, extending beyond the sensor itself to the outside environment. Is the image captured by the camera an actual car, or is it just a cardboard cut-out? Are the GNSS signals authentic or spoofed? Is the GNSS correction data needed to achieve lane-level positioning accuracy trustworthy? Are the algorithms being fed valid data, or is it a case of “garbage in, garbage out?” And what about the high-definition map? In each case, sensors and algorithms need to be capable of assessing the integrity of the input they receive and the output they provide.

One way to achieve this is to design redundancies into the system. These can offer a means of cross-checking the output from multiple independent data sources (which have a far smaller probability of failing simultaneously). Alternatively, data from multiple independent sources can be fused, or combined intelligently,
to achieve a more reliable output. Such redundancies are also exploited to calibrate sensors, such as the wheel tick sensor, which can drift due to temperature variations.

Consider, for example, the GNSS receiver and the inertial measurement unit. Inertial sensor data can be used, on the one hand, to detect faulty GNSS signals and bridge gaps when GNSS service is interrupted, for instance, in tunnels. Fused, on the other hand, the two data streams can deliver a higher accuracy than GNSS alone. Combining this with the wheel tick measurements as well as GNSS correction data delivers a complementary position in addition to the one obtained using the vehicle’s cameras, radars, and lidars with respect to landmarks recorded on a high-definition map. With each additional redundancy, the overall reliability of the system increases. But before any such solution can be deployed in production, it needs to be rigorously validated.

Validating an autonomous driving solution requires logging millions of miles on the road and even more in simulated road tests to expose the sensors and, when present, any image recognition algorithms used to as many plausible scenarios as possible. In mission-critical activities, such as driving, all components are typically required to comply with functional safety and SOTIF (safety of the intended functionality) specifications (ISO 26262 and ISO 21448). This requires a meticulous hazard assessment and risk analysis, classifying the functions into automotive safety integrity levels (ASIL) ranked from level A to D, or below ASIL-A, a quality management (QM) level.

Roadblock #2: Connectivity in the vehicle and beyond

The number of wirelessly connected sensors in our vehicles is fast increasing. In-vehicle infotainment systems are evolving into high-bandwidth wireless hubs capable of streaming high-resolution video, often to multiple different screens in parallel, download an up-to-date HD map in real-time, and upload relevant observations to the cloud. Rearview mirrors are already beginning to give way to LCD displays that
wirelessly relay images captured by cameras mounted at the rear of the vehicle. At the same time, cooperative intelligent transportation systems (C-ITS) leveraging V2X technology are on the rise.

Not all of these applications operate at the same frequencies and the same range. V2X operates at 5.9 GHz over distances on the order of one kilometer. Wireless connected sensors in the vehicle likely operate at 2.4 or 5 GHz, but with limited power and over a tightly confined range. And any communication to and from the cloud is likely to use the cellular LTE network, with an operational range of around 10 kilometers. In each of these cases, spectrum is becoming a scarce resource that needs to be carefully managed.

These challenges are being addressed with each incremental update to the wireless technology standards, which continually up the ante in terms of spectral efficiency and, consequently, capacity. Wi-Fi 6, for example, more than doubles the maximum data rate compared to Wi-Fi 5 and can serve up to twice as many end devices per access point. As a result, it is being designed into more and more in-vehicle infotainment systems to deliver in-vehicle connectivity. With specs defined in partnership with key automotive OEMs, such as Ford and Volkswagen, automotive Tier 1s, including Bosch, and component manufacturers, such as Qualcomm, 5G is also slated to play a key role, raising the bar in terms of bandwidth, latencies, device density, and reliability of cellular connectivity. The technology will be used to connect vehicles to cloud-based services and, with C-V2X, to nearby vehicles and road-side infrastructure.

Roadblock #3: Security
Like smartphones today, tomorrow’s vehicles will be privy to reams of personal data about their drivers and their passengers, making them lucrative targets for hackers. In addition to protecting personal privacy in order to comply with data privacy regulation such as Europe’s GDPR, the vehicles will have to be secured against data sniffing, which could expose sensitive data such as banking information, and false inputs. Additionally, sensor jamming and spoofing will have to be carefully dealt with to ensure the safety of the vehicles’ passengers and everyone else nearby.

Achieving high levels of cybersecurity will be no small task. Encrypted communications with frequent key rotation or replacement will help keep hungry eyes off sensitive data. Authenticated communication will ensure reliability of incoming data, from traffic infrastructure, other vehicles, or GNSS satellites, with Galileo’s OS-NMA service being just one example. Sophisticated system design will be critical to ensure that sensed data is cross-checked in real-time against independent sources. And machine learning algorithms will be trained to catch outliers and discrepancies between independent data sources and provide early warnings that something is awry before any harm is done.

Roadblock #4: Human-machine cooperation
In the run-up to full (Level 5) autonomous driving, humans will continue to play an essential role ensuring the safety of the passengers and other traffic participants. First available within their specific operational design domain (ODD) (Level 4) before extending to all circumstances, autonomous driving functionalities will give drivers the freedom to shift their focus from the roads to more pressing, entertaining, or relaxing matters.

Virtually all of today’s most cutting-edge commercial vehicles offer advanced driver assistance at best (referred to as SAE Level 2 by the International Society of Automotive Engineers), with the human drivers still calling the shots.

“Validating an autonomous driving solution requires logging millions of miles on the road and even more in simulated road tests to expose the sensors and, when present, any image recognition algorithms used to as many plausible scenarios as possible.”
The next step towards full autonomous driving, Level 3, will involve offering conditional autonomy, with an important caveat: when requested by the vehicle, the driver will have to take over the wheel on short notice. Ensuring that their human drivers are prepared to take over when called upon to do so will become more and more difficult.

Implementing solutions to safely manage the takeover has proven difficult. Because automakers are liable in the event of an accident while the vehicle is in charge, many have been reluctant to switch on Level 3 autonomy features in cars that could potentially offer them until they are able to assure that the transition will go smoothly every time. It remains to be seen whether most automakers find ways to overcome this roadblock or if, instead, they simply decide to skip Level 3 and go straight to Level 4 autonomy once the technology is sufficiently mature.

To ensure that drivers remain vigilant when the vehicle is providing advanced support, automakers have started to equip Level 2 and potential Level 3 cars with driver monitoring systems (DMS). Sensors in the steering wheel catch drivers that let go for prolonged periods of time. Dashboard cameras analyze facial expressions and use machine learning to detect early signs of fatigue, distraction, stress, or anger. If drivers become too distracted, the vehicles either alert them that autonomous driving will be deactivated or and nudge them into being more prepared.

**Erring on the side of prudence**
Mass market adoption of Level 5 autonomy may still be a few decades away, but, make no mistake, it is coming. Automakers, regulators, and the public are all doing their part to ensure that, once they hit the roads, the technologies they use are safe and mature. Addressing the four roadblocks examined: safe sensing, connectivity, security, and human-car-cooperation, may increase the time its to get there. But it will also help ensure that we err on the side of prudence and advance cautiously, incrementally, and safely.
Satellite-based positioning technology will play a growing role as vehicles offer more assistance, gain increasing autonomy, and, finally, take over the wheel.
GPS technology conquered the car via satnav. Integrated into the dashboard pre-sale, stuck to the inside of the windscreen as dedicated devices later, or brought up on demand using our smartphones, satellite-based navigation solutions have displaced paper maps and road signs as the main means of finding the way. Since then, the technology’s presence in vehicles has been cemented by widespread mandates for automatic emergency response systems such as the EU’s eCall. Today, each and every new car that hits the roads has a GPS receiver built in.

When it comes to locating the vehicle and finding the quickest route home, first-mount navigation solutions hold an advantage over after-mount and smartphone-based ones. Their larger, better-placed antenna and, increasingly, their ability to integrate data from around the vehicle, including inertial and wheel-tick sensors, mean that they can deliver a much more accurate position. Remarkably, however, many drivers of cars with built-in navigation systems still turn to their smartphones for the quickest route to their destination because of their often-superior user experience, which improves continuously from one software upgrade to the next.¹

Despite being well established, today’s navigation solutions still have room for improvement, says Frédéric Duhem, Regional Application Marketing for Automotive at u-blox. “Drivers don’t want to have to wait for their navigation system to boot to get their position. They want to know where they are as soon as they turn on the ignition and see their itinerary on the map. They expect to be localized immediately when they exit a tunnel – and inside the tunnel as well. Delivering such performance requires a global navigation satellite system (GNSS) receiver with a dead reckoning solution based on inertial measurements, assisted GNSS to speed up to time to achieve a position fix, as well as the ability to store the car’s last position and heading when it is parked.”

**Lane-level accuracy**
Responsiveness is one challenge. Accuracy is another. Lane-level accuracy – the ability to reliably determine which lane a vehicle is driving in – is the next step up in terms of positioning performance, enabling new use cases such as augmented reality heads-up displays (AR-HUD).² Achieving this requires more advanced multi-band, multi-constellation GNSS receivers capable of reliably locating the vehicle within a specific lane on a map. Tracking satellite signals from multiple GNSS constellations increases the number of GNSS satellites that are within line of sight, even from deep within urban canyons. Tracking them on multiple frequency bands, on the other hand, helps mitigate signal delays incurred in the ionosphere and can help reduce multipath errors caused when signals bounce off built structures or the surrounding topography.

Still, even multi-constellation, multi-band GNSS receivers alone are not enough to consistently deliver the submeter-level positioning performance required for lane-level accuracy. GNSS receivers need to be able to further enhance their performance by integrating GNSS correction data in real-time. The precise-point positioning real-time kinematic (PPP-RTK) algorithms that this requires are able to correct satellite clock and orbit errors, and other error sources. “We address these challenges with our u-blox F9 platform, which has had a lot of success among most automotive OEMs, with growing demand for these kinds of solutions coming in particular from China, Japan, and Korea,” says Duhem.

**Authenticating advanced driver assistance features**
Before advanced driver assistance system (ADAS) features and fully autonomous driving roll out everywhere, they will most probably become available on dedicated sections of the road network and under specific operational conditions. One example is that of the highway chauffeur, offering fully autonomous driving on precisely geofenced stretches of the highway.

¹ https://money.cnn.com/2016/10/10/autos/car-navigation-frustration/index.html
² https://www.telematicswire.net/augmenting-gnss-technologies-for-v2x-and-automated-driving/
According to Duhem, this use case is becoming increasingly common in RFQs (requests for quotation) from automotive OEMs and is already a reality.

Determining whether the conditions are met for such ADAS features is a high-stakes decision, which is why it imposes even more demanding requirements on the GNSS receiver than the lane-level navigation use case.

Carmakers are moving towards relying on functionally safe GNSS solutions as the only possible source of a safe absolute position to complement other relative positioning solutions (radar, lidar) for authorizing autonomous driving. “The GNSS receiver will play a vital role in informing that the car is in an authorized section of the highway, where the autonomous driving feature can be activated. In the future, we see OEMs moving towards ASIL-B types of solutions for safety-critical applications in which the vehicle takes control and makes decisions,” he says.

The automotive safety integrity level (ASIL), defined in the ISO 26262 standard on functional safety, specifies which of the standard’s requirements and safety measures apply to each element of the vehicle’s electrical and electronic systems, with ASIL-A the least and ASIL-D the most stringent level. Compliance with the standard requires fulfilling specific rules in software development and assessing, in detail, how the vehicle’s hardware might fail, and how these failures can be detected or mitigated.

Ultimately, safety is a combination of both functional safety and safety of the intended function (SOTIF), defined in ISO 21448. Whereas functional safety covers hardware and software, SOTIF, also referred to as integrity, focuses on the weaknesses of the technologies themselves, such as the impact of reflections, weak signals, or misuse by their users. In the case of a GNSS receiver, this typically means that a so-called hazardous misleading information (HMI) event, in which the position error exceeds its alert limit (AL) for longer than the time-to-alert (TTA), can only occur with a probability defined by its integrity risk (IR).

The system’s protection level is bound on the position accuracy, which ensures that, as long as the alert limit is not exceeded, the integrity risk is met.

The sensor of last resort
Once firmly established in the highly automated vehicle’s vast suite of sensors, enabling navigation, geofencing, and participating in localizing the vehicle, the GNSS receiver will likely take on additional responsibilities.

The GNSS receiver’s technological independence from the vehicle’s remaining sensors brings another crucial benefit. Tier 1 and OEMs often combine the output from the various sensors onboard the vehicle, e.g., its cameras, lidars, inertial sensors, and GNSS receiver. If for some reason the sensors fail due to poor weather or lack of visible road markings or other landmarks, the GNSS receiver becomes the data source of last resort. “Because you need a technology that works globally and in all weather conditions, GNSS is the only available positioning technology of last resort,” says Duhem.

Keeping hackers at bay
More and more cybercriminals – and cybersecurity researchers – are demonstrating their ability to hack cars. The easiest way to disrupt GNSS is to jam the receivers by drowning out the weak satellite signals in a sea of radio-frequency noise, disrupting their operation. A more sophisticated approach involves spoofing them by feeding them fake signals, essentially tricking the receivers to provide false data.

Alert limit (AL): Maximum tolerable position error for the system to be safe. Time-to-alert (TTA): Maximum acceptable time window during which the position error can remain above the AL without an alert. Hazardous misleading information (HMI): Position error exceeds the AL without alert for longer than the TTA. Integrity risk (IR): Probability that an HMI event occurs within a given time window.

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4 https://www.iso.org/standard/70939.html
firmware, encrypting communications, all in addition to the measures required to detect and mitigate jamming and spoofing.

A growing role with increasing automation

There is an ongoing paradigm shift in the automotive industry. In the past, vehicles rolled off the production line with a fixed feature set. The new trend is to design vehicles in such a way that they can be software upgraded even years after they were purchased to deliver previously unavailable features. This typically requires provisioning the vehicle in terms of hardware at the time of production in such a way that advanced functionalities have the physical resources they need once they have been sufficiently tested, validated, authorized, and are ready to hit the road. This trend will impact requirements that OEMs place on strategic components in the system, including the GNSS receiver.

Frédéric Duhem sees a growing role for GNSS technology as vehicles become increasingly automated. “There will likely be more and more advanced features that will rely on high precision and safe positioning as cars acquire higher levels of automation. The GNSS receiver and related location services from GNSS correction data to other types of GNSS augmentation services will only become more important as this evolution continues,” he concludes.

Another emerging approach involves authenticating the incoming GNSS signals, a feature provided by the European Galileo GNSS constellation. “Galileo’s OS-NMA feature allows you to ensure that the signal you get is correct thanks to an authentication message that contains a key that is private to you and that confirms, via a webserver, that the measurement you receive has not been hacked.”

But the RF interfaces are by no means the system’s only attack surfaces. Hackers could also attempt to reconfigure the GNSS receiver, target the IP connection to any servers it communicates with, or target the communication between the GNSS receiver and the host. All this points at the need to consider security end-to-end throughout the entire process, protecting physical and software interfaces, authenticating firmware, encrypting communications, all in addition to the measures required to detect and mitigate jamming and spoofing.
Automotive

Playing to their strengths

Five key markets. Five approaches to drive automotive innovation
It could hardly be a more exciting time for the automotive industry. Its merging with software, sensing, and the cloud – all enablers of highly autonomous vehicles – is shifting the tectonic plates of automotive innovation. As cars, trucks, and other road vehicles evolve from fossil fuel-powered mechanical products to increasingly software-defined, battery-powered ones, increasing vehicle autonomy and the emergence of self-driving cars, trucks, and robo-taxis is calling the very act of driving into question.

The forces driving the industry are technological, but not only. For all the technological innovation taking place in the R&D departments of automakers and their suppliers, governments, regulatory bodies, and, ultimately, the end users driving the vehicles have a role to play, too. Government incentives can steer the market towards desired outcomes, such as a greater share of electric vehicles. Regulatory bodies and legislators can update legislation to meet new demands, for instance, for increased vehicle autonomy. And consumers need to see enough value in the technology to be willing to invest in it.

When it comes to automotive innovation and production, established players including in the USA, Japan, Korea, and Germany, France, and Italy continue to represent a formidable force. At the same time, new players around Silicon Valley, in China, and elsewhere are playing a growing role in driving innovation, uptake, and scale, selling primarily to tech-affine audiences. With so many moving parts, the jury is still out on who the innovation leaders of tomorrow will be. One thing is clear: the next decades will be critical, with the newcomers seeking to build out a strong market position and the incumbents determined to maintain theirs.
The US automotive industry’s center of gravity, long established around Detroit, Michigan, is being pulled west, as Tesla, Waymo, and other new players set a faster pace for vehicle automation and electrification.

California passed a law permitting autonomous car tests on public roads as early as 2018, with Florida following suit in 2019.

Alphabet’s Waymo has been operating its fleet of autonomous taxis in and around Phoenix, Arizona, without a backup driver since November 2019.

EV adoption is slower than elsewhere due to the low price of fuel, but US$ 175 billion earmarked to promote EVs and vastly build out EV charging in the Biden Administration’s stimulus bill could change that.

It’s transnational: Over two years, the EU’s L3Pilot program collected data from over 400,000 kilometers of road tests – across seven countries and at different autonomy levels.

To meet demand, the EU may need to deploy one million EV charging stations by 2024, and three million by 2029, according to the European Automobile Manufacturers’ Association (ACEA).

Barcelona’s APM Terminals shipping port is set to deploy 5G-based C-V2X to connect cranes, vehicles, people, and fixed infrastructure to manage traffic and increase safety.

European OEMs seek to gain more control over software, with Volkswagen employing around 5000 specialists to develop its cars’ in-vehicle software, and Renault more than 1000.

Batteries, too, should be locally sourced, according to the EU, which invested close to three billion euros in battery cell technology for EVs earlier this year to become a global hotspot for battery innovation.
South Korea

- With Tesla growing its footprint in South Korea, the Hyundai Motor Group (HKMC), the country’s leading car OEM, is seeking to drive innovation through electrification, mobility services, and hydrogen fuel cells.
- South Korea leads global sales in hydrogen vehicles, with ambitious goals of having 200,000 hydrogen-powered cars on its roads by 2025.
- To bring down the cost of electric vehicles, South Korea is planning a national battery leasing program, initially targeting taxis and trucks.
- Jeju Island will be South Korea's first test-bed for autonomous driving, hosting a fully driver-less airport shuttle service on designated roads starting later this year.
- The public is ready for new automotive technology: Advanced in-vehicle infotainment systems are popular among the country’s technology-affine drivers.

China

- Supported by its government, the world's largest automotive market – with over half of the world’s annual vehicle sales – is bent on becoming a global leader in vehicle electrification and autonomy.
- Because they are largely absorbed by the huge domestic market, China’s leaders in EVs – BYD, NIO, Li Auto, and Xpeng – have yet to become household names in Europe and the US.
- Beyond monetary subsidies, the Chinese government’s incentives to promote EVs include faster delivery of license plates, exemptions from specific urban traffic restrictions, and dedicated parking spaces.
- Left unchecked, China will continue to dominate global battery production, with almost three quarters of lithium-ion battery plants planned by 2029.
- This year, AutoX launched the country’s first driverless taxi service that is open to the public in Shenzhen.

Japan

- The Japanese automakers continues to do what they do best: producing large volumes of high-quality vehicles at low cost.
- In 2010, the country was the first to produce a fully electric mass-market vehicle, with the Nissan Leaf.
- Still, the industry boasts some of the most advanced autonomous driving technology, with the Honda Legend, for sale this year, becoming the first commercial car to offer Level 3 autonomy, taking over the wheel in traffic jams.

- The right-hand-side driving Japanese are, with Europe, the most stalwart supporters of Wi-Fi based (DSRC) vehicle-to-everything communication, with other markets leaning heavily towards cellular-based C-V2X.
- Like Korea, Japan, which already hosts over 130 hydrogen recharging stations, is placing high hopes on hydrogen to meet its CO₂ reductions targets, with a one-million fuel cell vehicle target for 2030.
Automotive

EV chargers need connectivity. Wireless connectivity.

For true mass adoption of electric vehicles, the charging experience needs to be a value add, not an obstacle – for drivers, service providers, and public utilities.
Early car owners were pioneers. Bravely trading in a horse and fodder for a combustion engine and fuel, they were the first to experience the benefits of motorized personal mobility. Prepared to pay a price for the prestige that came from being an early adopter, they would pour fuel into their Model T’s gas tank—located under their driver’s seat—using a funnel. It was a messy, inconvenient process that not everyone was willing to put up with.

Smoothing out these and other early wrinkles took time. But once gas stations had proliferated, using standardized fuel and a common nozzle (designed to fit the Model T), others began to see value in gasoline-powered mobility, as well. Entrepreneurs entered fierce competition over a growing customer base, improving quality of service and driving down prices. And once the public, businesses, and national authorities had aligned their forces, the sale of internal combustion engine cars, and thus of car ownership, truly took off, leaving battery-powered vehicles behind.

“National governments are becoming more assertive in their efforts to promote electric vehicles, recognizing the role they will play to meet CO₂ emissions targets.”

Fast-forward to today, and the growing electric vehicle market is facing a similar challenge.¹ Plugging an electric vehicle is less messy and smelly, but charging times are long. And because charging station networks are still under development, “range anxiety” has become common among today’s early adopters. Meanwhile, around a century of constant improvement has made the quick stop at the gas station a painless or even welcome ritual for drivers, who see it as a moment to take a break, stretch their legs, and grab a snack or a coffee.

Electricity’s trump cards
As the incumbent fuel source, gasoline and diesel have several advantages over new joiners: a long history resulting in well-forged consumer habits, powerful vested political and commercial interests, and an extensive and well-established supply chain. EV charging will have a very high bar to clear, both in terms of user experience and support from businesses and public authorities, just to be able to compete. Fortunately, electricity has a few trumps of its own.

While fossil fuels are notoriously scarce, electricity can be generated sustainably and delivered anywhere, piggybacking on existing infrastructure. It’s far less prone to exploding, and, when produced using renewable sources, it neither smells nor pollutes. While standard AC charging is slow, fast AC charging and even faster DC charging considerably cut charging times. And with the advent of automatic charging devices that connect to the vehicle using a robot arm, or of inductive (wireless) charging, topping up the battery could become an entirely hands-off affair. There’s a lot there for users to like, today and well into the future.

National governments, too, are becoming more assertive in their efforts to promote electric vehicles, recognizing the role they will play to meet CO₂ emissions targets, with the list of countries phasing out fossil-fuel-powered vehicles in favor of greener electric ones getting longer every year. And more and more automakers are backing the transition as well, with Volvo, Volkswagen, and General Motors among those having publicly shared their roadmap on how they intend to achieve this ambition. To meet demand for electric vehicle charging, the EU, to cite but one example, estimates that it will need another 3 million public EV charging stations on its territory by 2030, up from around 200,000 installed at the end of 2020.²

Front-end communication and back-end communication channels commonly used by EV charging stations.

- **Charging service provider**
- **Car manufacturer**
- **Mobility service provider**

**Back-end communication**

- **OpenADR**
- **IEEE 2030.5**
- **EEBUS**
- **IEC 61851**
- **ISO 15118**
- **CHAdeMO**

**Front-end communication**

- **Wired**
- **Bluetooth**
- **Wi-Fi**
- **NFC**
- **Cellular**
And power utilities also have an interest in pushing adoption as well. While gasoline and diesel can be stored in gigantic tanks, allowing the creation of reserves, storing electricity at scale remains difficult. By and large, the production and consumption of electricity need to be balanced at all times to avoid destabilizing the power grid. Power utilities have mastered this balancing act on today's grid. But the rise of renewable and largely intermittent energy sources, primarily solar and wind, both subject to the whims of the weather, threatens this accomplishment. Meeting the additional power demand of 770 terawatt hours required by electric vehicles in China, the EU, and the US compounds the challenge further still.3

"The trend is for vehicles to take on an increasingly sophisticated role as active elements in electricity networks through grid integration, which is mediated by vehicle-to-grid communication (V2G)."

Grid and cloud connectivity
Electric vehicles spend most hours of the day parked at home or at the workplace, often plugged in to the grid. While today's EVs simply draw power from the power grid, the trend is for vehicles to take on an increasingly sophisticated role as active elements in electricity networks through grid integration, which is mediated by vehicle-to-grid communication (V2G). With the considerable power storage their batteries offer, electric vehicles represent a massive, decentralized battery, capable of absorbing electricity from the grid when produced in excess and supplying it to cover spikes in demand. Achieving this requires a high level of grid integration, with bi-directional energy transfer, and, to manage that, bi-direction information exchange between then EV, the building's energy management system, and the grid.

CharIN, an industry alliance promoting a combined charging system that covers slow and fast AC and DC charging, has laid out five levels of grid integration. In Level 1, service providers can influence the charging power and scheduling to optimize grid performance at a system level. Level 2 goes one step further, allowing the EV and the charging station to determine a charging profile that meets monetary and grid constraints. Finally, Levels 3 and 4, defined by the ISO 15118 standard, allow for bidirectional energy transfer between the EV's battery, domestic power sources (PV), and the power grid at large, with an increasing scope (from the user's own energy system to the neighborhood and beyond.)

The role of wireless connectivity
Because of its flexibility, ease of installation, and affordability, wireless connectivity will play an essential role in creating a streamlined charging experience for end-users, whether at home, at commercial venues, or at highway service stations. Additionally, it will offer a vitally important data pipe connecting the EV with the local power generation infrastructure and the grid at large. And finally, it has the potential to enable a vast suite of added-value services that benefit end customers and generate revenues for service providers.

Because it is the only wireless technology specifically mentioned in the ISO 15118 standard, Wi-Fi is perfectly positioned to become the main communication channel connecting the charging station to the EV as well as to the cloud, in particular in domestic and commercial deployments. Cellular connectivity will likely offer fallback to handle outages in Wi-Fi connectivity, and, in deployments that lack Wi-Fi connectivity altogether, as an alternative communication channel that can be set up anywhere.

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Bluetooth will also find use complementing Wi-Fi to handle certification, identification, authentication, and authorization. In charging stations offering automatic connection devices or inductive charging, Wi-Fi can be used to mediate fine positioning of the vehicle relative to the charging infrastructure. And finally, there is a negotiation phase where the targets are set and the energy transfer is scheduled.

**Value-added services**

As gas stations proliferated in the 1930s, they found themselves in the challenging situation of having to compete at selling a highly standardized product. The result was a wave of differentiation, which led to the variety of filling stations we are accustomed to today – with mini-markets, diners, self-service stations, and so on.

EV charging stations and the companies that manage them will likely face a similar situation as charging poles become more widespread.

Wireless technology and the value-added services it enables could become a differentiating factor persuading users to subscribe to one service provider or another, while generating revenue for the charging station operators. Think complementary highspeed Wi-Fi access while your car is charging, or reduced rates for food deliveries to the charging pole to make the most out of your break.

A seamless charging experience will be vital for electric vehicles to convince anyone but the pioneers - all those that are reluctant to give up the conventional cars that have served them well until now. From reserving charging stations and managing the charging process to coordinating the charging of millions of electric vehicles at the level of the power grid and leveraging their storage capacity to stabilize the grid as a whole, wireless connectivity will be relied upon on every step of the way.
Emerging technologies in automotive

Always online, constantly communicating, and software upgradeable over the air, our cars are morphing into smartphones on wheels.
Innovation is apace in the automotive industry. Synthetic fuels, electric drive trains, and new ways to store the electricity they need are transforming the car as we know it. Innovative ownership models, driverless delivery vehicles, and robo-taxis are disrupting well-established businesses, forcing them to adapt to a radically transformed landscape. And advanced driver assistance systems, next-generation human-machine interfaces, and driver-monitoring systems are redefining our relationship with our cars.

Behind many of these innovations lies the head-on collision between the automotive industry and the Internet of Things, which is transforming vehicles from chefs-d’oeuvres of mechanical engineering to masterpieces of software-hardware integration. Chief among the technologies plucked out of the IoT’s toolkit: extensive sensing, data analytics, and real-time decision making. Not to forget the glue that holds it all together: communication, largely wireless – within the vehicle, beyond it, and all the way up into the cloud. Call it an evolution or a revolution. Either way, it will be transformational.

**Vehicle-to-everything communication**

It was only a matter of time before vehicles would be able to communicate with their surroundings. And while it has been long in the making, it is quickly becoming first a reality, then the norm. The list of use cases comprised in the term V2X (vehicle-to-everything) is long. Vehicle-to-vehicle communication will let vehicles exchange information with each other to increase road safety by negotiating dangerous maneuvers, relaying early warnings of obstacles, or sharing camera feeds and other sensed data in real-time beyond line of sight, essentially allowing them to see around corners.

Vehicle-to-network communication will provide a constantly open data pipe to the cloud to share sensed data pertaining to the vehicle with
the OEM’s quality assessment teams, and to crowdsource data on the traffic conditions and deliver them to third-party service providers. Vehicle-to-infrastructure communication will help orchestrate traffic flow, manage intersections, and flag potential safety hazards to protect drivers, in the same way that vehicle-to-pedestrian communication will make vehicles aware of those most vulnerable on the streets. Crucial at every step of the process: precise and trustworthy location data on all the vehicles comprising the intelligent transport system, and reliable information on their status.

Individual vehicles will not only become part of the overall traffic system. With vehicle-to-grid communication, battery-powered electric vehicles will also become a critical component of smart power grids, which are already having to deal with managing a greater share of highly intermittent renewably generated power. By offering massively distributed power storage capacity to absorb electricity when produced in excess and release it again to smoothen peaks in demand mediated by V2G communication, electric vehicles, and the batteries they carry, will help stabilize the power grid.

**5G**

Smartphone users aren’t the only ones excited by the prospects of the record-shattering performance specs promised by the 5th generation of cellular communication technology (5G). Its increased capacity and higher data rate are expected to level up in-vehicle infotainment services, offering new services such as real-time gaming, real-time audio and video streaming, and more. Automotive OEMs and Tier 1s have been at the drawing table as members of the 3GPP shaping the development of 5G since day one. As a result, cellular communication, 4G today and 5G in the coming years, is poised to become the main communication channel for V2X, particularly in the US and China.

Some basic V2X use cases have already been implemented using 4G C-V2X; 5G specifications address the needs of more advanced ones. Vehicle platooning, for example, enables trucks to travel in dense convoys, considerably reducing fuel consumption by minimizing drag. Extended sensors let vehicles access the cameras and other sensors on vehicles in their vicinity, allowing them to extend their field of view and increase safety through what is referred to as “collective perception.” And remote driving, which leverages 5G’s ultra-reliable low end-to-end latency capabilities, will allow professional drivers to pilot vehicles from afar.

The C-V2X sidelink communication feature enables direct device-to-device communication, allowing vehicles to communicate directly with each other, with roadside infrastructure, or with other traffic participants. In 3GPP Release 17, this feature will be further enhanced to support
new radio (NR) sidelink replay to extend coverage and improve power efficiency. And, additionally, it will include a dedicated power-saving mode to implement vehicle-to-pedestrian communication that doesn’t drain pedestrians’ smartphone batteries.

5G has a prominent role to play in positioning for automotive applications. In particular in dense urban canyons, it could complement GNSS-based positioning, enhancing positioning performance by leveraging the expected dense base station networks to deliver highly accurate location services. By analyzing the time difference of arrival of cellular signals from multiple base stations, receivers will, for example, be able to determine their position relative to them using multilateration, while advanced approaches using antenna arrays could be used to implement angle-of-arrival and angle-of-departure based positioning solutions.

**Real-time high-definition maps**

Cameras and lidars are heavily relied upon by autonomous vehicles to perceive their environment, detect obstacles, and inform decisions on the safest way to reach the intended destination. In order to determine their absolute position in space, the vehicles’ autonomous driving computers can match up the data they sense with a high-definition (HD) map of their surroundings, which offers a detailed representation of the surrounding environment. SD maps, offering meter-level resolution, have long been used by OEMs to enable features such as speed assist and predictive powertrain control of trucks to reduce fuel consumption by anticipating upcoming curves and slopes on the road and other functions related to automatic cruise control. HD maps, which are required to implement advanced ADAS Level 2 and Level 3+ features, demand decimeter-level accuracy of the map, as well as of the position of the vehicle and surrounding objects. To ensure that the data can be used by the autonomous driving systems of as many vehicles as possible, HD maps are typically designed to comply with the ADASIS v3 interface specification, which is the de-facto industry standard used by OEMs around the world.

As the central repository of static geographical information surrounding the vehicle, the trend is for HD maps to increasingly take advantage of low-latency and reliable data links to deliver dynamic information as well. To this end, they will have to be continuously updated, crowdsourcing data from as many vehicles’ sensors as possible, and making it available to vehicles around them. To do so, vehicles will be able to publish relevant information from their sensors to the base map, which is made available on the cloud.

Accurately positioning obstacles detected by vehicles on the HD map is essential, yet challenging, in particular when traveling at high speed.
down a highway lacking obvious landmarks. High precision satellite-based positioning becomes a necessity to first accurately and reliably locate the vehicle itself, determine the relative position of other obstacles, and warn nearby vehicles.

**Sensor fusion**

No single sensing technology can come close to matching the performance of a human driver. Human brains intuitively combine a broad variety of inputs to draw meaningful conclusions. Machines need to be instructed precisely how to fuse the data their sensors gather, leveraging expertise more commonly available in data-heavy industries than in the traditional automotive sector. But when well done, sensor fusion allows to increase the reliability of sensed data and extract information that only becomes available when multiple sensors are used in conjunction.

Positioning is one area that can benefit from sensor fusion. Accurate satellite-based positioning requires constant line of sight between the vehicle and the orbiting GNSS satellites. Underpasses, tunnels, dense forests, mountainous terrain, and urban canyons can all degrade positioning performance, ultimately leading to signal loss in indoor environments. By augmenting satellite-based positioning with inertial sensor measurements used to reconstruct the vehicle’s trajectory in dead reckoning solutions, intermittent gaps in GNSS coverage can be bridged.

This approach can be extended further by incorporating camera, lidar, and radar data that allow the vehicle to position itself relative to landmarks, as well as using the HD map, and potentially indoor positioning solutions based on ultra-wideband, short-range, or cellular communication technology. Together, these complementary solutions can extend the availability and coverage of reliable and precise positioning to a broad variety of environments.

By taking advantage of redundancies, sensor fusion can also help stabilize the vehicle’s overall sensing performance. Sensors can drift, go offline, or fail altogether. By constantly cross-checking the input across sets of sensors, machine learning algorithms can be trained to detect incongruities and flag sensors that cannot be relied on. While the situation may be easily remedied by recalibrating the sensor in question on the fly, it could also signal that the sensors are deliberately being jammed or spoofed by hackers.

**Augmented and virtual reality**

Augmented reality is transforming in-vehicle infotainment systems by projecting relevant information right into the driver’s field of view. Mercedes Benz, for instance, already offers an advanced AR heads-up display in some of its latest vehicles, providing information on the speed limit, the driving speed, and GPS navigation instructions. Panasonic has presented its latest heads-up display solution, offering crisp 4K projection that follows the gaze, delivering even more content, including advanced collision detection to increase traffic safety, visual highlights of relevant environmental information, and easy-to-follow navigation instructions to help keep the driver’s eyes focused on the road.

Unlike augmented reality, which superimposes artificially generated information into a user’s field of view, virtual reality fully immerses users into a virtual world. Innovative companies, such as holoride, have found creative ways to leverage high data rates and low latencies to build next-generation passenger entertainment solutions: Using a headset, passengers can experience their journey as a first-person adventure game in which the hero’s movements are perfectly synched up with the car’s motion. We often forget that our smartphones can make phone calls. If holoride’s immersive experiences catch on, we might forget that our cars were originally designed to get us places.
The automotive sector is being disrupted by a wave of technological innovation with sensing, data processing, and wireless communication at its core. As cars become increasingly autonomous, OEMs, Tier 1s, their suppliers, and service providers are adapting to a new reality, defined to equal measure by mechanical and software engineering. Mathias Reimann of Bosch and Stefania Sesia of u-blox discuss these trends and how they are already impacting automakers and their suppliers.
What do you see as the major trends in today’s automotive industry?

**Stefania Sesia** – One trend is the car turning into a software platform on wheels. In the future, the differentiating factor will no longer just be the brand, the look, the mechanics, and the hardware, but also the applications that can be embedded in it, with the possibility to continuously upgrade the vehicle and introduce new functionalities during its lifetime. Upgrading software and related features will raise the value of the vehicle by limiting its obsolescence.

Secondly, the increasing complexity of the functionalities embedded in the vehicle is driving the evolution in the direction of a more centralized vehicle architecture. We are moving from an electrical/electronic, pure feature-based architecture towards a domain-based partitioning and, ultimately, a more centralized electronic control architecture based on high computing power units. This comes with more and more sensors embedded in the vehicle, which could lead to more extended use of short-range communication in the vehicle to avoid large amounts of cabling, which, today, is also seen as a problem.

**Mathias Reimann** – After enabling users to get online during a trip, the car itself and its technology are going online as well to enable new features and functionalities during its lifetime. As Stefania mentioned, these constant technology upgrades are only possible thanks to a software-friendly architecture and an updatable platform. Some OEMs were a big step ahead, revolutionizing the industry with this remarkable concept that a lot of other OEMs are now following. As a Tier 1 supplier, we at Bosch see this in a lot of requirements coming onto our table and have integrated these into our product roadmap.

A second major trend is the push for more sensors inside the car. Why? After a very big hype in the last years about everything becoming automated, we’ve seen a slight cool-down in this discussion. Still, ADAS (advanced driver assistance systems) and AD (automated driving) systems are conquering more and more of the mid-class car market, across three major segments.

For the first segment, the classic privately-owned car market, the first step involves moving from assisted driving to ADAS. In other words, towards SAE Level 2 which, for example, offers hands-free functionality that is very popular right now in the US and in China. It is a move towards more comfortable driving, but with a driver who remains in charge. We will see Level 3 with the first real hands- and eyes-off capabilities this year or next on the market. It will be a stepwise approach for privately owned passenger cars.

The second segment is shared mobility driving, where the target is SAE Level 4 or even 5, with
cars that are able to drive themselves to the workshop and offer taxi or ride hailing services. And, finally, the third segment consists of commercial vehicles, not only for the last mile, but for long drives as well, demanding Level 4 or 5 automation.

Each of these three segments needs its own sensor setup in combination with updatable services. It is, therefore, important that the sensors overfulfill today’s specifications, because customers want to bring in new functionalities throughout the car’s lifetime. So, it’s an interesting time for us sensors suppliers, GNSS manufacturers, Car-2-X infrastructure providers, and hardware suppliers.

“We are moving from an electrical/electronic, pure feature-based architecture towards a domain-based partitioning and, ultimately, a more centralized electronic control architecture based on high computing power units.”
Stefania Sesia, u-blox

S.S. – Related to the evolution of ADAS and AD, there is another trend unfolding regarding communication: the introduction of V2X technology as a means to enhance a vehicle’s local perception, basically as a set of sensors that is complementary to those the vehicle already has. These have quite different demands compared to typical sensors and create new challenges in terms of communication and the overall end-to-end system, with requirements in terms of reliability, trustability, and availability that become fundamental.

To continue on the topic of trends, I expect more AD-capable vehicles to bring the need for more infotainment content in the vehicle to entertain the passengers, such as rear-seat or front-seat augmented reality, gaming, and video conferencing. This will bring higher requirements for short- and long-range connectivity to offer independent entertainment to the rear and the front passenger seats.

The last trend I see is the electrification of the vehicle. As of today, this market segment makes extensive use of short-range connectivity, with Bluetooth used to identify the customer at the charging pole and Wi-Fi for direct communication with it. EVs currently represent approximately five percent of the automotive market share and are foreseen to grow rapidly to approximately 50 percent in the next decade. This entails the need for quite a large deployment of charging stations and an evolution of charging methodologies to offer an easier end-user experience.

M.R. – The electrification trend is also one of the major future growth market fields for us at Bosch. The entire technology setup is part of our portfolio, so we are investing everywhere from our own semiconductors for power ICs to complete systems. You may have noticed that the Bosch logo is part of an electrical motor, so you see that this has been in our company’s lifeblood from the very beginning.

Are these trends global, or do you see regional differences?

M.R. – We clearly see regional trends when it comes to ADAS and AD. There is an innovation hub in Silicon Valley, and we see a very strong push for SAE Levels 3 and 4 from our US West Coast customers, who want to be the first worldwide. We also see a strong push from China, where the goal is to save time in traffic jams. On the other hand, the push we see for Level 2, coming primarily from Europe, aims at making driving more comfortable. And we see the first Level 3 announcements in Europe for 2021/22 – really exciting times we’re living in!

The same goes for connected services. We still don’t have a very good mobile network here in Europe, whereas China, where there is a strong push for higher connection speeds and faster cloud-based solutions, is very well connected. It’s not that we don’t see these trends in Europe, it will just take a bit more time.
S.S. – What we see is that OEMs, regardless of where they are, support similar applications but with quite different architectures and requirements, and there are some regional trends. There are, for instance, several ongoing discussions about the introduction of a safe solution for the positioning system, e.g., for AD Level 3. The need for a safe absolute positioning system does not represent 100 percent of the AD Level 3 market, but only a portion of it. In particular, we see in Europe that the demand for safe solutions for GNSS is increasing. In China interest is growing, but the architecture trends are not yet very clear. However, for the time being we don’t see such clear demand for safe GNSS in the US, at least for passenger cars.

M.R. – You’re right. On the other hand, we see a regional bias and can distinguish between urban and highway use cases. For the classic highway use case in the US, for example, truck automation is a clear driver for safe and precise GNSS, whereas in China, this discussion is always linked to BeiDou satellite system integration. In urban use cases, the focus is more on video-based and relative localization technologies. However, for automation on highways, we see a technological necessity for safe and precise GNSS worldwide.

Coming back to GNSS versus feature localization, in rural use cases, we see the dominance of camera- and radar-based solutions. Customers often ask us: “Why can’t we solve the localization problem with camera-based feature localization?” We see a lot of complementarity between the two. On featureless highways in the US or Northern Germany, for example, particularly in poor weather conditions, it is difficult for radar and video to recognize features. On the other hand, there are situations where GNSS signals can be lost, such as among high buildings and...
in multi-path scenarios. Our strong belief is that GNSS and feature localization are complementary technologies and will both be needed in Level 2 and above systems.

**Do you foresee a revolutionary change in the vehicles' architecture? If so, what are the consequences for OEMs and the various Tiers?**

M.R. – On January 1, Bosch founded a new business unit called Cross-Domain Computing Solutions, which my team and I belong to, drawing on people from several other business units to develop the required data management concepts, cloud services, and a flexible hardware platform to enable new features. This is one clear internal sign of the trend towards a centralized architecture and our desire to address demand from our customers in a professional and incentivized manner.

Maintaining and upgrading features in the field on an architecture with intelligence distributed across many different ECUs is difficult, in particular with several suppliers, each with their own software architectures on their respective ECUs. That’s why we clearly see a trend to distribute the car into zones, each with an individual zone ECU, and central vehicle computers with a very clear and standardized software and system architecture behind them. And, of course, the possibility to update the software over the air.

S.S. – I completely agree, Mathias. As we mentioned earlier, there is a trend towards centralization, but each car OEM will have its own strategy to achieve a leaner and more efficient architecture capable of scaling in terms of complexity with more and more functionalities added during the vehicle’s lifetime. Today, typical architectures are based on three main vehicle computers: one for telematics, one for infotainment, and one for ADAS, plus some smaller ones. I think it will be harder for car OEMs to completely break with the legacy architecture and start from scratch; probably this will be easier for newcomers entering into these verticals. What we expect is that there will certainly be a stepwise approach. As Tier 1 and 2 suppliers, it will be important to be flexible and adjust our solutions to evolving architectures, operating systems, requirements, and constraints the customers might have.

Of course, u-blox is well positioned to achieve this with our existing, flexible offering. In particular in the GNSS space, with chipsets and modules for single-band standard precision GNSS offered by the u-blox M8 GNSS receiver family, with high precision GNSS technology offered by the u-blox F9 family, and, recently, thanks to the acquisition of Sapcorda, with our high-precision correction services that deliver best-in-class performance with all the necessary host libraries and security measures. And we have also invested a considerable amount into functional safety and integrity solutions.

On top of that, we also address evolving environments with our short-range communication solutions – Wi-Fi and Bluetooth – which closely follow the evolution of each technology. For example, with the introduction of automotive-grade Wi-Fi 6, offered by our JODY-W3 module family with concurrent support for the 2.4 and 5 GHz bands and, in the future, for the 6 GHz band that was recently released by the European Commission and the FCC. Finally, let’s not forget that some of our cellular offerings can be used in the automotive domain.

**What are the major enabling wireless technologies for cars? And what role will GNSS localization play in delivering increasingly high levels of assistance and automation?**

S.S. – You can’t talk about wireless technology without talking about 5G. Together with V2X, 5G will no doubt bring the possibility to share more and more awareness data, alerts, and sensor data with cloud- or edge-based platforms to enable a huge amount of services to increase safety or convenience for the end user. Mathias already mentioned some of them: shared mobility, last mile deliveries, ride hailing services – ultimately, societal trends that are bound to happen in the future enabled by a reliable and higher capacity communication link.
When it comes to Wi-Fi, there are several applications today requiring higher data rates and parallel data streams in addition to concurrent and independent front- and rear-seat infotainment. Wi-Fi Fixer, for example, uses FDMA and multi-user MIMO to multiplex, in frequency, communications to several parallel devices, each with different data rate requirements. This allows for much more flexibility to serve several users in the same vehicle.

And there are other applications as well. We already mentioned EV charging, but there is also keyless entry into the vehicle, a use case that car OEMs are increasingly offering. Today Bluetooth technology is used to detect the presence of the driver using a positioning method based on signal strength. Leveraging enhancements to Bluetooth 5.1, it will use an angle-of-arrival type of detection to open the vehicle and let the driver in. There are also some discussions in the Car Connectivity Consortium® (CCC) in which ultra-wide band technology is emerging for automotive use cases such as keyless entry. This is also a technology inspired by customer needs.

When it comes to positioning, GNSS technology continues to evolve. It is already highly present in the vehicle for several applications, such as eCall, augmented reality, navigation, geofencing for AD, and longitudinal and lateral control of the vehicle. While initial use cases do not necessarily require very precise positioning and meter-level accuracy is sufficient, applications such as...
geofencing and autonomous driving require lane-accurate positioning, a certain level of integrity, and compatibility with the ISO 26262 and ISO 21448 standards for functional safety and SOTIF (safety of the intended functionality). Depending on the use case, the main KPIs are robustness, data trustability, integrity, resilience against cyber-attacks, broad availability, and high accuracy. Correction services such as RTK or PPP-RTK that bring down achievable accuracies to the decimeter-level are gaining in importance.

On that note, u-blox is investing a lot to develop methodologies that achieve very low levels of integrity risk while controlling the complexity. We are monitoring where the technology trends and evolutions are headed, and, in particular, where the customer requirements are going for these highly demanding types of use cases.

M.R. - Let me just add a good example. Since 1995, Bosch is in the business of IMUs (inertial measurement units) and we are doing everything from micromechanics, ASIC design, and production to system and vehicle integration. And even after such a long time, there is still a lot of potential for innovation like our ultra-precise IMU MMP2 for highly automated driving and safe stop maneuvers. Out of that background, five years ago, a Bosch team had the idea to combine our IMU knowledge with high precision GNSS. After some first discussions with our automated driving colleagues, the need for lane-accurate and safe localization became clear. Stefania mentioned the need for geofencing, but I would say it’s even more than that. For function developers, a precise position ensures you’re operating in your desired ODD (operation design domain). To achieve this safe positioning, the need to combine IMUs with high precision and safe GNSS was deducted. This is how the product idea of a vehicle motion and position sensor (VMPS) came on board. And what seemed at first glance to be an impossible task is now coming into life. With series introduction of the VMPS, Bosch will launch the first ASIL-B rated GNSS system on the market. Our customers are using the VMPS with u-blox technology inside as a platform for several innovative use cases, which even we had not foreseen several years ago.

Now if we look into the future, Stefania mentioned cybersecurity. For GNSS this means that anti-spoofing and anti-jamming algorithms will gain in importance in the next years as well as scalability and flexibility for our target markets. For China, BeiDou satellite systems will be in focus, and L1 and L5 frequency bands will be an

“Our strong belief is that GNSS and feature localization are complementary technologies and will both be needed in Level 2 and above systems.”
Mathias Reimann, Bosch
important step into the next era, as is Galileo authentication. There are a lot of new challenges coming up, and we are looking forward to continuing to work together with u-blox over the next years.

As cars become more and more computerized, they are also generating huge amounts of data. How can these data be best put to use?

S.S. – In Europe, the ITS directive regulates data among other things. It promotes the possibility to exchange more and more data between the vehicle and the cloud to stimulate the development of new vehicle services. My understanding is that the ecosystem is still struggling to solve data ownership issues, develop a viable business model, and so on. I’d say that it is coming, but not at the pace that had been expected at the very beginning. I think that car OEMs should change the way they think about data, which could become a valuable source of revenue for a large portion of the ecosystem and really raise the value for the end user.

M.R. – Big data is nice, but let’s be clear that all the raw data coming out of a vehicle’s built-in sensors cannot simply be pushed into the cloud. There needs to be an intelligent way to compress the data first and extract only the relevant features. That’s why Bosch is investing heavily into AI algorithms for data curation that would extract relevant content out of the data stream before uploading them to the cloud. Here it is very important to be able to update the filters when you think: “I need some more details here,” or “I need to dig more into the raw data there...”.

Managing data is a complicated matter because it crosses several physical interfaces and legal entities, so making responsible use of people’s personal data is a top priority for Bosch. That includes transparency regarding what data is stored and processed, and for what purpose.

Fast forward twenty years. What do you personally think a car will look like in 2041?

M.R. – As I am coming from the ADAS and AD area, for me a car in 2041 is completely automated, allowing me to read the NZZ newspaper, for example, as it drives me to my destination. But I’m sure we will also see a lot more shared vehicles driving around. And for long distances, I’m very fond of high-speed trains, like the Japanese Shinkansen, or the project of the Gotthard Base Tunnel in Switzerland.

S.S. – 2041 is 20 years from now, so it is clearly what you said, Mathias: shared mobility and completely autonomous vehicles. I think it will happen little by little, but it will happen. What I would like to see is the possibility to use all the freedom of mobility not only on the ground, but in space as well, as this would make transportation much, much faster. Of course, there are issues, many related to regulations and how to make the best use of such completely autonomous flying objects. But it would definitely be nice to be able to read the newspaper and reach our destination faster. Let’s see if it happens!
Here are some facts and figures.

**$1.3tn**
Estimated annual savings to the US economy thanks to driverless cars
Source: Morgan Stanley

**$270bn**
Estimated global value of the automated driving technology market by 2030
Source: strategy& (PwC network)

**$17.5bn**
Fully autonomous car market by 2030
Source: Altran (Capgemini Group)

**90%**
Percentage of road fatalities due to human error
Source: WHO
$135bn
Electric vehicle powertrain market by 2027
Source: Market Research Future (MRFR)

$48.77bn
Global connected car market size by 2027, exhibiting a CAGR of 26.3% during the forecast period
Source: Fortune Business Insights

2030
Year that Britain’s ban on new petrol and diesel car and van sales takes effect
Source: Reuters

60%
Percentage of road accidents that could be avoided with a seamless 5G network
Source: 5G Automotive Association

40%
Increase in plug-in EV sales in 2020
Source: McKinsey

2030
Year that Britain’s ban on new petrol and diesel car and van sales takes effect
Source: Reuters

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Percentage of road accidents that could be avoided with a seamless 5G network
Source: 5G Automotive Association

40%
Increase in plug-in EV sales in 2020
Source: McKinsey
As intelligent vehicles evolve toward fully autonomous driving, a key aspect of safe operation is the vehicle’s localization capabilities. Core to any autonomous driving solution, high precision, accuracy, and reliability are paramount to the driving experience and overall safety of the vehicle and its occupants.

Vehicles use various technologies to locate themselves in the environment and within road lanes. A Global Navigation Satellite System (GNSS) receiver provides the core and is often complemented by perception sensors such as cameras, vehicle odometry (wheel ticks), and inertial measurement units. This multi-modal ensemble not only provides collective precision and diversity, but also the redundancy and “dead reckoning” capability to ensure localization can function when GNSS satellite signals are impaired. A state-of-the-art, multi constellation, multi-band, dual RF path GNSS receiver is important – making u-blox an ideal candidate to join NVIDIA’s autonomous driving ecosystem.

NVIDIA’s pioneering work in accelerated computing and AI is reshaping trillion-dollar industries, including transportation and autonomous vehicles (AVs). The company offers end-to-end hardware, software, and platforms for the development and deployment of autonomous driving and AI cockpits. NVIDIA DRIVE Hyperion™, an AV reference architecture with a compute engine, software, and sensor suite that includes navigation, offers developers and engineers a production platform that can be installed in test vehicles to evaluate autonomous system development.

“The u-blox GNSS is a robust solution for our turnkey DRIVE Hyperion platform, which is designed to help accelerate the path to production of AVs,” said Glenn Schuster, senior director of sensor...
ecosystems at NVIDIA. “NVIDIA was looking for a GNSS ecosystem partner like u-blox, which offered a cost-effective, automotive-grade solution.”

u-blox offers several GNSS receiver options for various markets. Modules are typically soldered onto a motherboard, but NVIDIA opted for a different systems approach, whereby the modular GNSS receiver is packaged in a compact, protective enclosure that can be flexibly placed in various locations of the vehicle. NVIDIA and u-blox worked closely together to ensure the receiver addressed specific requirements surrounding operating/data modes, update rates, connectivity (physical interfaces), form factor, and mounting.

The u-blox C103-F9K application board with ZED-F9K module addressed NVIDIA’s needs for its next-generation DRIVE Hyperion reference architecture. GNSS positioning from the ZED-F9K, along with odometry and feature matching via camera perception and HD maps, provide continuous lane-accurate localization. When deployed, the C103-F9K will be mounted in a component rack that also houses the NVIDIA DRIVE Orin™ compute platform as well as other system and networking components.

The companies’ collaboration establishes the u-blox technology as the DRIVE Hyperion reference sensor for its GNSS-based positioning accuracy and a core sensor for localization. It also gives u-blox access to NVIDIA’s DRIVE ecosystem, which affords the opportunity to leverage other NVIDIA solutions and gain momentum among OEMs.

Learn more:
www.u-blox.com/en/product/zed-f9k-module
In the spotlight

The latest in positioning and wireless communication technologies and services
Combining industry-leading quality, robustness, sensitivity, and performance with innovative features, u-blox delivers solutions, services, and components that meet the needs of even the most demanding designs. We focus on business-critical applications where products need to perform 24/7 with maximum reliability, handling exceptions with minimal disruption to the overall system. Our customers expect improved productivity, quick turnaround, and a head start on their competition.

u-blox ALEX-R5 integrates cellular and GNSS technology into a miniature SiP form factor with zero compromises

ALEX-R5 is a miniature LTE-M / NB-IoT SiP module with integrated u-blox UBX-R5 and UBX-M8 chipsets, as well as Secure Cloud functionality. With a footprint of 14 x 14 x 1.5 mm, it occupies less than 50% of SARA-R5’s PCB without affecting LTE or positioning performance. It is ideal for size-constrained devices like people and animal wearables, small asset trackers, healthcare devices, and other small IoT applications.

ALEX-R5 is optimized for low power consumption, supporting Super-E mode for the GNSS receiver and featuring a market-leading sub-μA current consumption in PSM mode. ALEX-R5 offers a dedicated GNSS serial interface and a dedicated GNSS antenna interface, providing highly reliable and accurate positioning data concurrent with LTE communication.

Learn more:
www.u-blox.com/en/product/alex-r5-series

u-blox’s first timing solutions based on L1 and L5 GNSS signals

In March, u-blox introduced L1/L5 timing modules and an L1/L5 antenna to offer product developers maximum design flexibility and performance.

The ZED-F9T-10B and LEA-F9T-10B timing modules, and the RCB-F9T-1 timing card deliver nanosecond-level timing accuracies required to synchronize cellular network base stations and smart power grids. The ANN-MB1 L1/L5 multi-band antenna completes the offering, making it easy to evaluate the performance of the timing modules and to develop high precision solutions such as heavy machinery, ground robotics and unmanned aerial vehicles.

With satellite constellations transmitting signals on the L5 band nearing completion, L1/L5 is becoming a viable option to complement the L1/L2 u-blox product portfolio. Modernized L5 signals deliver improved performance, especially in difficult urban conditions, and less RF interference problems thanks to the protected ARNS frequency band.

Learn more:
The quick, easy, and cost-effective path to market for dual-band Wi-Fi 4 and Bluetooth 5 combo applications

The MAYA-W1 series, a compact dual-band Wi-Fi 4 and dual-mode Bluetooth 5 module, is the latest addition to u-blox’s host-based multiradio wireless module portfolio.

Based on NXP’s IW416 chip, MAYA-W1 can select Wi-Fi channels from the entire 2.4 GHz and 5 GHz Wi-Fi spectrum, reliably connecting end devices and access points even in dense networks.

Qualified for operation up to 85 °C and fitting on a 10-by-14-millimeter footprint, MAYA-W1 is ideal for size-constrained applications that operate in harsh industrial environments but also tailored to power management, EV charging, professional appliances, or fleet management, to name a few.

Pre-integrated in NXP’s MCUXpresso development environment and available with antenna pins, a U.FL connector, or an embedded PCB antenna, MAYA-W1 delivers design flexibility as well as ease of integration.

Learn more:
www.u-blox.com/en/product/maya-w1-series

IoT Location-as-a-Service, for reliably delivered and globally available location data.

IoT Location-as-a-Service provides reliable, fast position information and delivers accurate assistance and error correction data for constrained IoT devices, even in challenging conditions. It combines best-in-class services with the highest levels of availability and quality via Thingstream, our cloud-based delivery platform and administration interface for enterprise IoT services.

AssistNow is our A-GNSS service that boosts GNSS acquisition performance and lowers energy consumption for devices with or without network connectivity.

CellLocate delivers mobile network-based positioning data that is proven, scalable, and ready to virtually eliminate “no-position scenarios.”

CloudLocate enables positioning in the cloud, granting power autonomy to constrained IoT devices, with up to 10X energy savings over stand-alone GNSS power savings approaches.

Learn more:
https://www.u-blox.com/en/iot-location-service
Climbing up the value chain

The acquisition of Sapcorda complements our mass-market high precision GNSS offering with in-house GNSS augmentation services.

On March 18, 2021, u-blox acquired full ownership of Sapcorda Services GmbH, a joint venture originally formed in 2017 by u-blox, Bosch, Geo++, and Mitsubishi Electric. Designed to bring scalable, affordable, and high quality GNSS positioning solutions to industrial, automotive, and consumer applications, Sapcorda has gone on to develop and successfully launch an advanced PPP-RTK GNSS augmentation service capable of reducing satellite-based positioning accuracies to less than ten centimeters.

Sapcorda’s correction data is generated by processing data collected across a broad network of GNSS base stations. Each base station constantly monitors the signals broadcast by orbiting GNSS satellites to measure any delays incurred as the signals traverse the charged upper layers of the atmosphere. The observations are then processed in correction service data centers. The result is a GNSS correction data stream that models the individual components.

“Being part of u-blox enables us to combine the capabilities of the IoT services delivery platform, the high precision positioning modules, and the augmentation services to offer a seamlessly integrated, high performing, and future-proof solution.”

With mass-market scalability in mind, Sapcorda’s services are tailored to the needs of industrial application areas including autonomous vehicles, such as unmanned aerial vehicles (UAV) and unmanned ground vehicles (UGV), machine automation, surveying, monitoring, and other advanced navigation applications. Emerging automotive applications include automated driving (AD) and advanced driver assistance system (ADAS), lane-accurate navigation, telematics, and vehicle-to-everything (V2X) communication.
of the GNSS errors and is valid over broad geographic expanses, delivering a robust, reliable, and secure GNSS augmentation service to mass-market applications.

“Already as a joint venture company we were in perfect alignment with u-blox in terms of our strategic vision to develop scalable high precision GNSS solutions for the mass market and enable emerging applications and use cases that are far beyond the capabilities of classic GNSS correction services,” says Botho zu Eulenburg, CEO of Sapcorda. “Being part of u-blox enables us to combine the capabilities of the IoT services delivery platform, the high precision positioning modules, and the augmentation services to offer a seamlessly integrated, high performing, and future-proof solution.”

Sapcorda’s SAPA services were launched in the US and Europe in January 2020 and have since been expanded to full coverage of the contiguous US and 33 countries in Europe. Because they are based on open GNSS correction data formats, their use is not restricted to a single hardware manufacturer. Initially only available via the internet, Sapcorda launched the distribution of the service via an additional geostationary satellite L-Band signal in December 2020, just before being fully acquired by u-blox.

The acquisition of Sapcorda expands u-blox’s IoT Location-as-a-Service offering, complementing its existing GNSS assistance data and communication service offerings. Sapcorda has focused on establishing a platform from which to bring GNSS augmentation services to the mass market by delivering on robustness, reliability, and end-to-end security as it relates to performance.