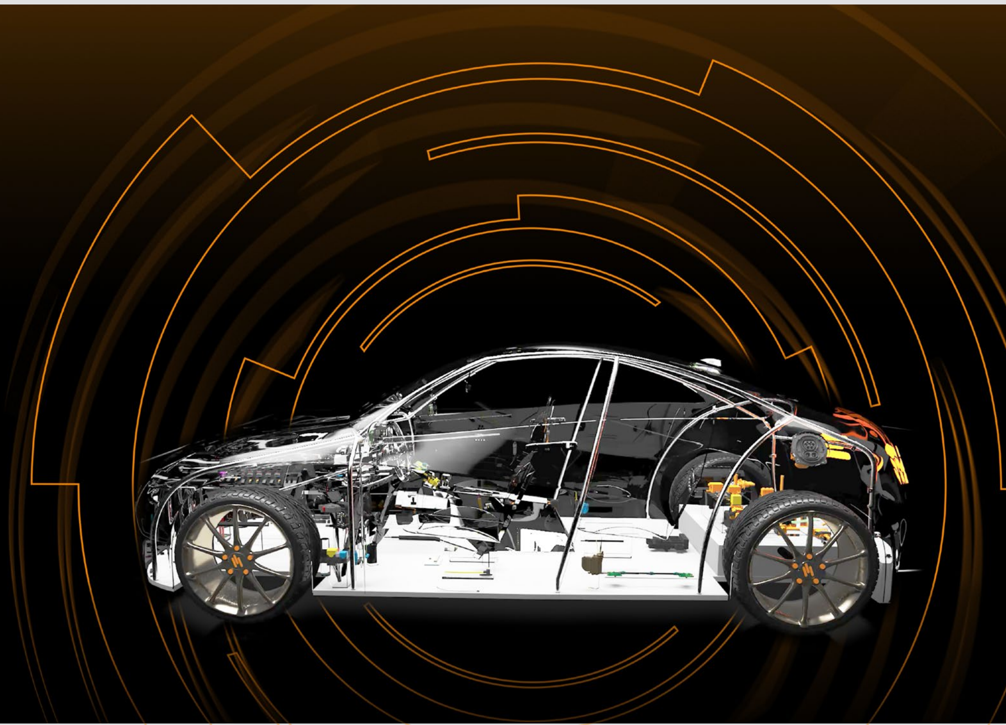
# THE ROAD TO AUTONOMOUS DRIVING

## Transforming Vision into Reality



CONTENTS

## EXECUTIVE SUMMARY

Autonomous driving is fast becoming a reality. Increasing driving assistance and safety features automate basic driving tasks and remove human judgement and interaction from the control of the vehicle. Today, features such as adaptive cruise control and lane departure warnings are already becoming commonplace. Now predictive ride technology is being introduced whereby the car senses the state of the road ahead and adjusts the ride settings to maximize comfort and reduce travel sickness when driving over bumps and uneven surfaces. By 2030, up to 15% of vehicles sold will be fully autonomous.(1) For passengers, that is likely to mean a smooth and comfortable driverless experience but with all the external connectivity to meet lifestyle or workplace requirements.

Key enablers of this rapid market and technology transformation are sophisticated sensor, antenna, and data connectivity technologies that work together. These components sense the environment, within and outside the vehicle, and receive, act upon, and transmit data in real-time to devices throughout the vehicle and in the physical world the vehicle navigates.

The applications that realize these increasing levels of vehicle autonomy can be categorized as in-vehicle networks (e.g. real-time vehicle diagnostics or online applications), infotainment, and safety applications. Each application area has specific technology requirements in terms of data throughput, architecture, design (e.g. miniaturization), robustness and reliability (e.g. EMI shielding), and safety levels (ASIL) that impact the development of automotive electronic components.

These requirements are a driving force behind TE Connectivity's (TE) roadmap for end-to-end data connectivity and sensor solutions.

TE's vision is to co-create end-to-end automotive data connectivity and sensor solutions that are true enablers of autonomous driving by partnering with customers and other industry technology developers.

This paper examines the trends and innovations around autonomous driving and the role of data connectors, antennas, and sensors in various autonomous driving use cases. Specifically, it will look at the new technology challenges and the key technology enablers required to overcome them.

## 1 | INTRODUCTION: AN INDUSTRY IN TRANSFORMATION

**Imagine a day in the not-so-distant future …**

… Your plane lands at the airport in a city you are visiting for the first time. Upon leaving the terminal you decide that you would like to eat dinner before going to your hotel. You tell your smart device to search for a nice, cozy Italian restaurant. In milliseconds, your device offers a few suggestions based on your history and preferences. You choose the first restaurant from the list, and a few moments later a vehicle approaches, slows down, and comes to a stop directly in front of you.

The doors open automatically, exposing the vehicle's elegant interior. Four single seats are in the cabin – all of them empty. As you enter the vehicle it politely greets you, the doors slowly close, and the vehicle accelerates to a safe speed. You can now relax as the vehicle takes the highway towards the restaurant downtown – all by itself.

This and other similar scenarios illustrate how individual mobility needs might evolve in the near future. The possibilities are inspiring an entire industry.

Established tech giants, new start-ups that provide internet and mobility services and apps, and new players in supply-side technologies such as ADAS (advanced driver assistance systems) and infotainment support are joining the automotive industry to help reshape the mobility landscape.

## 2 | THE DRIVERS OF VEHICLE AUTONOMY

Today's car buyers are already benefiting from advanced driver assistance systems (ADAS), adaptive cruise control (ACC), lane departure warning (LDW), traffic sign recognition (TSR), and intelligent high beam assistants with light ranging (HBA), all of which have evolved impressively over the past years. State-of-the-art vehicles offer lane-centering assistants (LCA) fused with intelligent ACC functionality that adapt to speed limits, enabling safe lane changes as well as powering glare-free high beam (GFHB), autonomous emergency braking (AEB), pedestrian detection (PD), and advanced city assistants (ACA).

Engineers are continuously developing safety systems for accident avoidance or severity limitation. Globally, governmental and non-governmental organizations (NGOs) seek to reduce the number of traffic fatalities and injuries: Autonomous driving is the industry's answer to securing zero fatalities.

In the future, self-driving vehicles will be able to accurately evaluate risk and adapt driving appropriately to each situation without experiencing human emotion or fatigue. Self-driving vehicles will react proactively to difficult situations more quickly than human drivers, calculating the lowest risk outcome. Advances in powerful computing systems, coupled with machine learning, will enable self-driving vehicles to provide a safe driving mode.

Changing lifestyles also play a key role in autonomous driving. The importance of owning a private car in urban areas, for instance, is already declining. The sharing economy, including car sharing models, is a growing market today. In the future, autonomous driving and mobility-on-demand will be the first choice in urban environments, leading to the emergence of new business models and services.

Autonomous vehicles will generate a huge amount of data. Companies will take that data, analyze it, and put that intelligence to work developing new services and features. To date, telematic modules and other units, such as rain sensors, are already used for toll collecting, online traffic services, and weather forecasting. Motion data, personal preferences, and profiles, when combined with data from integrated smart devices, could offer huge value to manufacturers, insurance companies, and the entire automotive ecosystem. The price consumers might pay is personal data, time, and attention. However, many believe the value of safety and convenience will far outweigh these concerns.

Simply put, the vision of zero traffic-related fatalities or serious injuries, combined with the opportunities to create new services and business models, is accelerating the arrival of autonomous vehicles.

### Navigating Global Rules and Regulations

Safe and reliable technology is only one part of the solution. The other part is the legal framework that authorizes the operation of highly automated vehicles in day-to-day traffic. Legislation is currently being adapted to accommodate these new forms of mobility and address potential challenges. In a first step, the 1968 Vienna Convention on Road Traffic, which regulates basic traffic rules worldwide, has been amended by a new agreement. The amendment now allows vehicle systems to operate autonomously, provided they can be overridden or turned off by the driver at any time.

As a result, several governments and administrations around the world have begun to permit autonomous driving for testing purposes on public roads from dense cities to the open highways of the German Autobahn.

In 2014, the Society of Automotive Engineers introduced a harmonized classification system (J3016) that defines six levels of autonomy once the driver decides to cede control. These levels define categories that range from vehicles where “the driver is in complete and sole control of the primary vehicle controls – brake, steering, throttle, and motive power – at all times” (Level 0) up to fully automated vehicles that can perform “all safety-critical driving functions and monitors roadway conditions for an entire trip” (Level 5), as depicted in Figure 1 below.


*Figure 1: The levels of vehicle automation according to the Society of Automotive Engineers (SAE)*

## 3 | SIX CONNECTIVITY REQUIREMENTS OF AUTONOMOUS DRIVING

Piloted and highly autonomous driving present several key technical challenges. One of these challenges is the ability to handle and analyze enormous amounts of data. The increasing number of sensors both inside and outside the vehicle is one example. Another example is the sheer number of powerful computers processing high-level control functions and machine learning algorithms.

In addition, the car will need to be able to process over-the-air (OTA) data streams for vehicle-to-backend (V2B), vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-user (V2U) and vehicle to communications infrastructure (V2C) reliably and instantaneously. These functions together can be called V2X.

There are six key enablers to meeting these challenges:

### Architecture

New vehicles soon will have architectures that organize high-performance clusters in functional domains, as seen below in Figure 2. These domains are connected hierarchically via a central gateway in a high-speed data backbone structure and group sensors and actuators. Autonomous driving will increasingly demand more and more reliable network-based structures, requiring redundant, real-time architectures.

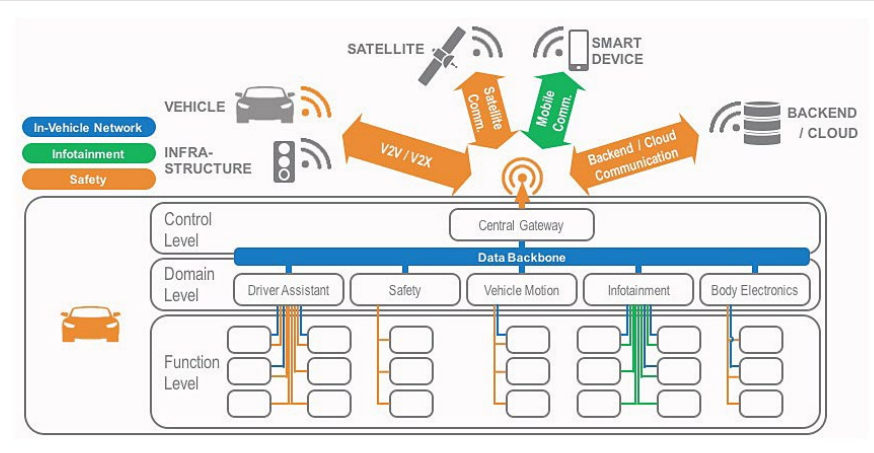



*Figure 2: Potential system architecture for connected vehicles*

### High-Speed Data

High-performance computers and an increasing number of ADAS sensors, such as high-resolution stereo and/or mono cameras, RADAR, and LIDAR; as well as future human-machine interfaces (HMIs), such as large 4K/8K screens or head-up displays (HUDs), will multiply the number of high-speed data nodes.

The increase in nodes will lead to growing net data payloads for each link which will vary depending on the data throughput requirements of each node.

In addition, multiple parallel and bidirectional data streams will need to be managed in switched networks while providing sufficient safety margin. Manufacturers should therefore plan on designing flexible architectures that accommodate continuously increasing bandwidths for point-to-point data pipes and distributed network structures.TE anticipates that by 2020, in-vehicle connectivity will require data rates far beyond 12Gbps.

### External Connectivity

As previously mentioned, a key requirement of autonomous driving is the ability to capture correct and complete data about the surrounding environment. For example, a vehicle autopilot could only execute actions such as braking or accelerating correctly when all necessary information about the vehicle surroundings is available. In addition to sensor technology, which determines the vehicle's immediate surroundings, additional information from beyond the driver's field of vision is required.

V2X (Vehicle-to-Everything) communication relies on radio-based exchange of information between vehicles and between the vehicle and traffic infrastructure such as lights, signs, and tolls. Instead of the vehicle attempting to identify the surroundings, sensors around the car communicate their state. It is therefore possible, at an early stage, for an autonomous car to detect dangerous traffic situations such as stationary vehicles at the back of a traffic jam or approaching rescue vehicles and initiate appropriate countermeasures.

A crucial prerequisite for safe autonomous driving is the real-time transmission of data. Only then it is possible for the driver or autopilot to respond to potential hazards in time. Current cellular radio standards such as LTE have a latency of 30 to 40 milliseconds. As a consequence, they are not sufficient to support this requirement. For fully autonomous driving, developers are focusing on the next generation mobile communications - 5G and beyond. 5G will be characterized by higher data rates of up to 10 Gbps and considerably lower latency. 5G is expected to be available for deployment starting in 2019.

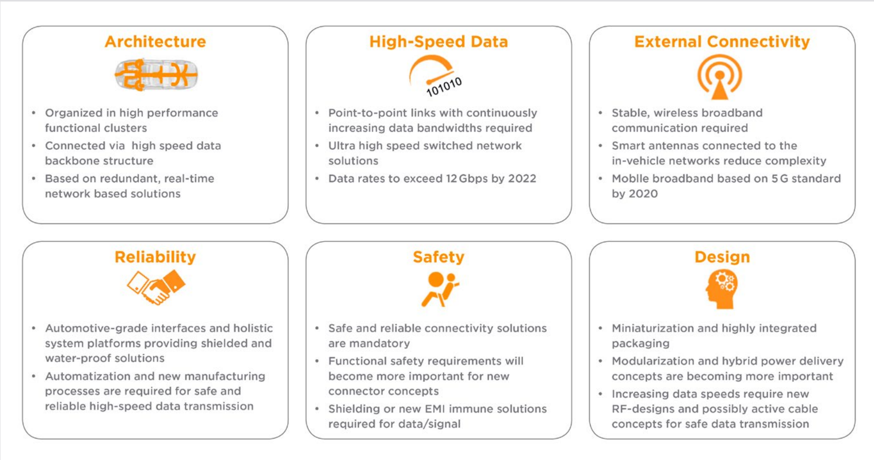



*Figure 3: Six connectivity requirements of autonomous driving*

## Reliability

Reliable sensing and data transmission under all conditions, especially in harsh environments, is mandatory. The solution is highly robust automotive-grade connectivity systems which are the least likely to fail even after thousands and thousands of hours of operation. Manufacturers should team with a competent and experienced partner that develops complete system solutions using a holistic system design approach. The approach should encompass mechanical and electrical system design, aligned process engineering and automation solutions, and new manufacturing procedures.

## Safety

Data integrity within functional safety applications is a mandatory requirement for autonomous driving: Human lives depend on it. For this reason, it is vital that manufacturers ensure safe data transport on the physical layer level and the highest possible protection against corrupted information in electromagnetic noisy environments. This requirement means systems platforms need to be scalable and modular and offer EMI-immune solutions. This includes interchangeable shielded as well as unshielded options or optical for low-EMI risk or EMI immune solutions.

## Design

The trend to build smaller sensors and actuators and the sheer number of links connected to centralized high-performance computers or domain clusters will demand automotive-grade miniaturized and highly integrated connectivity solutions. Platforms should be scalable and modular and offer the possibility of customizing components to OEM demands. The platform should support hybrid solutions with high and low speed data or power delivery ports in an unshielded or shielded variant according to every water protection classification requirement.

## 4 | CONNECTIVITY CHARACTERISTICS OF AUTONOMOUS VEHICLE APPLICATIONS

Autonomous driving requirements define functions, safety levels, and architectures. At the architecture level, real-time settings, data quality, and speed requirements need to be specified for each link. The characteristics of every single link might vary depending on the functions and safety levels of the connected nodes. Despite these variations, all links show common features and can be grouped into the following three categories, as depicted in Figure 4.

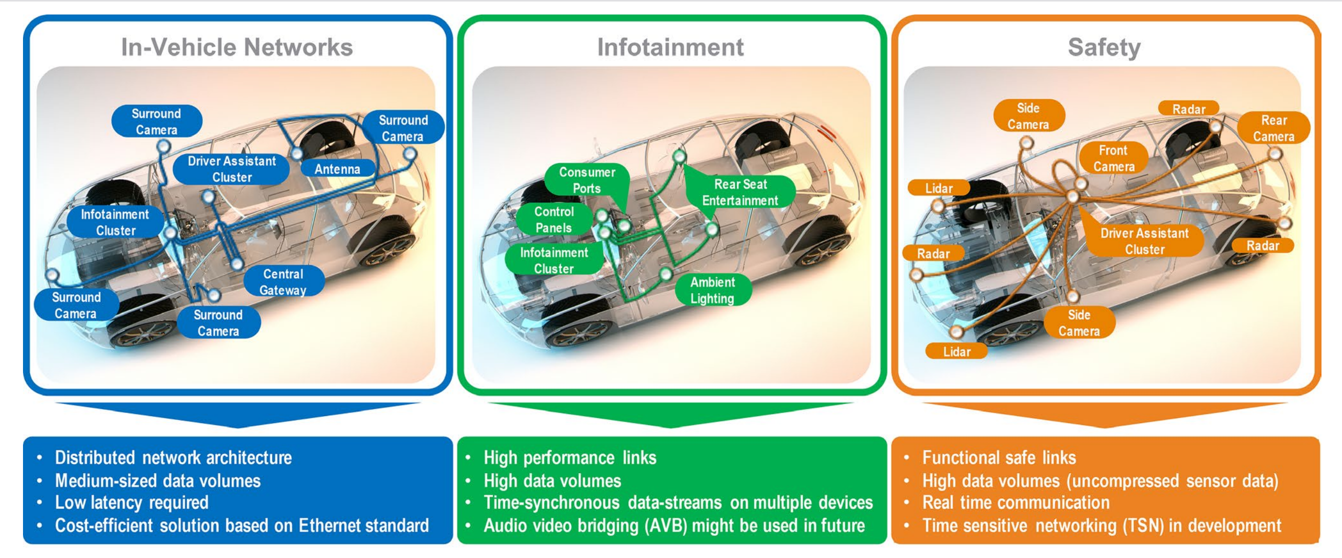



*Figure 4: Applications and system requirements*

### In-Vehicle Networks

In-vehicle network links are cost-efficient solutions that can be used in distributed network architectures with medium-sized data volumes and low latencies. The automotive Ethernet is a key focus for in-vehicle networks because of its flexibility and scalability. Surround-view systems demonstrate the power of network solutions. They offer a cost-effective and scalable way to create different system variants with configurations for up to four connected satellite cameras. Building out these in-vehicle networks with automotive Ethernet-compliant connectors and wiring will support OTA software updates, creating advantages for service and repair. The amount of data an autonomous car is expected to generate is multiple terabytes a day. As a consequence, vehicles will need their networks to look much more like a data center's Ethernet-based network.

### Infotainment

Infotainment links have high-performance requirements for high data rates and time-synchronous data streams on multiple devices. Consequently, appropriate links must be designed for optimal signal integrity properties at high frequencies. Typically, infotainment links are used as point-to-point connections (e.g. display links for high resolution dashboards, control panels or HUDs, and in a ring bus configuration). In the future, open protocols, such as audio-video bridging (AVB), might also enable the implementation of automotive network topologies. They would ensure that multiple data streams are made available in a timely basis across different devices.

### Safety

Safety links incorporate additional requirements that are crucial for the realization of ADAS today and future piloted or autonomous driving applications. This link type must ensure high functional safety levels and real-time computing capabilities. Furthermore, high data volumes must be transported, because sensor data, primarily large image sequences acquired by high resolution cameras, is delivered uncompressed with high refresh rates.

Today, safety links are designed as large point-to-point data pipes using proprietary data transmission technologies. When self-driving vehicles become a market reality, functional safety architectures will be required. Fail-safe and redundant topologies based on ring bus systems is one possible solution. In addition, real-time network technologies with low latency and high availability will also be required. Deploying the open protocol time-sensitive networking (TSN) is one possible solution.

## 5 | THE ROLE OF CONNECTORS

In the same way that functional and safety needs define link types to be applied, requirements for key elements, such as semiconductors, cables and connectors, can be derived from link characteristics. Attributes like bandwidth, attenuation, and shielding effectiveness determine the design of each link component.

In this context, the connector ties the chip and the physical layer together. The connector design depends on both the data transmission technology defined by the integrated circuits (ICs) and the specification of the cable or fiber. Various parameters must be considered, and specific link limits restrict the number of permutations. Therefore, it is crucial to develop connector systems in close cooperation and collaboration with all parts of the automotive data connectivity ecosystem.

The cable assembly process should be considered at an early stage of development to ensure safe and reliable production of cable leads at a later stage. TE offers many classes of connector types based on its collaboration and cooperation with the entire automotive manufacturing ecosystem.

TE is developing its automotive data connectivity product portfolio with solutions that meet manufacturers' requirements for function, safety, link type, chips, and cable type, as well as industry standards and OEM or Tier1 specifications. Our automotive data connectivity solutions for different data rates can be seen in Figure 5. These solutions have the potential to support future technologies, as described in the following sections.

### NanoMQS

The NanoMQS connector supports data rates of up to 100Mbps and provides a solution for differential pair data transmission. NanoMQS contacts enable 100BASE-T1 Ethernet network links with robust automotive terminals. It enables the re-use of standard connectors and can be flexibly configured. This product family takes a tried and tested connector type, MQS, and positions it for use in much tighter space configurations.

### MOST Connectors

The optical connector platform was developed specifically for the needs of infotainment links and adheres to the requirements of the MOST specification. It uses plastic optical fibers (POF) as a physical layer and carries data with speeds of up to 150Mbps. In addition, with the 1000BASE-RH Ethernet standard, 1Gbps network support will be possible. Solutions based on the proven TE optical connector platform are available today.

### MATEnet

TE's modular and scalable network connector platform, MATEnet, was developed for the upcoming connected vehicle architectures which require fast and reliable in-vehicle network solutions. The new system has been proven to meet data transmission requirements according to 100BASE-T1 and 1000BASE-T1. By using existing higher modulated data transmission technologies, the MATEnet connector has the potential to support data rates up to 6Gbps. At the same time, the miniaturized modular connector solution is designed to ensure high-speed communication under harsh conditions. The connector platform accommodates different cabling solutions, such as unshielded twisted pair (UTP) and shielded twisted pair (STP) products, and combines them in a scalable platform.

The use of standard crimp operations and approved automotive contacts and the potential for fully automated cable assembly ensures high volume processes capability and fast cycle times. The two network modules are also equipped with automotive style locking features allowing established harness manufacturing processes to be used.

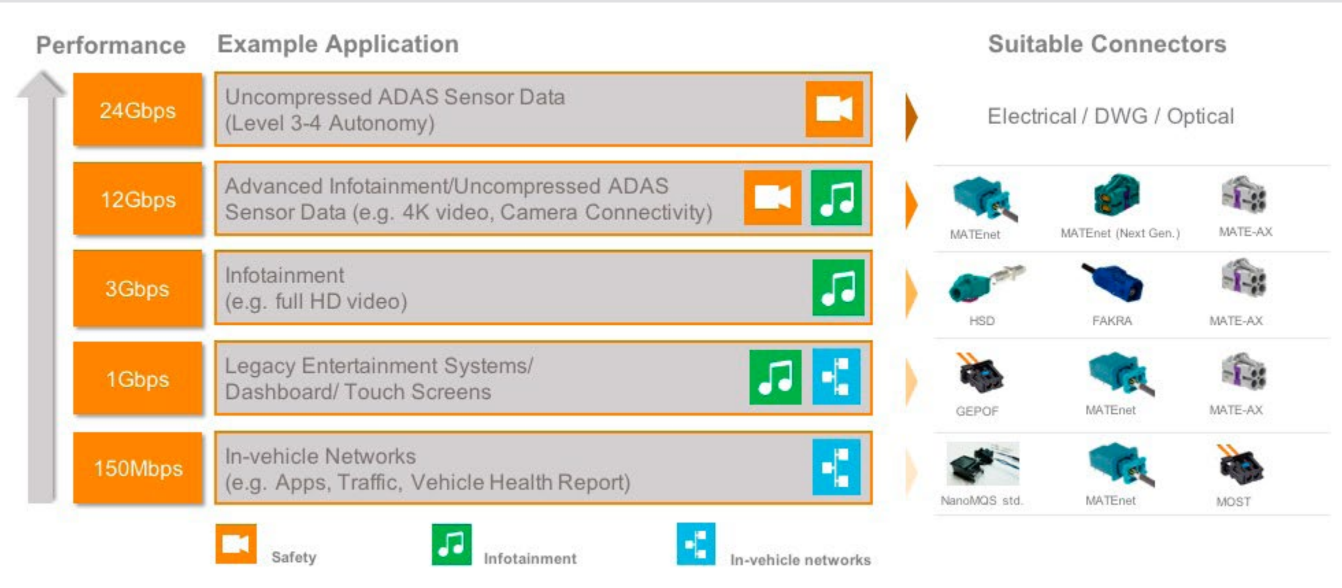



*Figure 5: Connector performance and potential*

### HSD

TE's HSD connector platform offers a robust, fully shielded system for safety links. The systems are validated for a broad range of cable types, including most importantly star quad type cables, since they provide optimal magnetic interference immunity. HSD is suitable for data speeds up to 3Gbps over proprietary data transmission protocols. Soon speeds up to 6Gbps will be possible with the next-protocol generation. The production process for HSD cable assemblies is scalable and can be fully automated.

### MATE-AX

The highest data speeds can be achieved with single-ended solutions, such as TE's FAKRA compliant and MATE-AX connector family. Coaxial cables offer a solution that can be applied for safety links that have high RF-requirements. The MATE-AX connector is designed for high data speeds and RF performance and reduces space to meet today's automotive packaging requirements. The electrical performance meets the link segment and component level signal integrity as well as the EMI requirements.

The robust and compact MATE-AX connector is available in different configurations to meet different environmental conditions. In addition, MATE-AX connectors are developed to fit seamlessly into the existing cable assembly processes, such as the well-established FAKRA compliant-crimping processes.

Future connectivity solutions will be applied in vehicle architectures to meet even higher functional safety levels. By 2020, it is expected that links will have data rates far beyond 12Gbps. TE is working on next-generation systems based on conventional physical layers and new technologies.

### TE's Next Generation Automotive Data Connectors

For advanced high-data volume infotainment systems and next-generation data architectures requiring automotive grade robustness and reliability, TE will offer extended performance versions of its current MATEnet and MATE-AX products. These products will support data speeds in excess of 12Gbps.

In addition, TE is already is in the advanced stages of development for the next generation of extremely robust data connectors for safety-critical, ultra-high data volume applications such as LIDAR and RADAR that will generate very large amounts of uncompressed data. TE will offer electrical, optical, and DWG-based (dielectric wave guide) data connectivity solutions that transmit in excess of 24Gbps and support Level 4 and 5 autonomous driving use cases.

## 6 | THE ROLE OF ANTENNAS

In the same way that connectors and wires exchange information inside the car, antennas are a key component connecting the vehicle to the outside world. Previously their role was to receive analog broadcast services such as radio and TV. Today their role is increasingly about receiving and transmit data that the car and the surrounding world can compute and act upon. With its newly acquired antenna technology, TE has more solutions to offer the automotive industry for the V2X communications that will be necessary for autonomous vehicles.

### Global Navigation Satellite System

A pre-requisite for any self-driving car is awareness of its current position. This is one of the most important input factors for self-driving algorithms. Requirements for position accuracy have been increasing as more and more ADAS features are introduced into vehicles. Today, vehicles only need to know which lane they are in. In the future, fully automated cars will need to provide positioning awareness down to the centimeter. GPS antennas have evolved into GNSS (Global Navigation Satellite System) antennas, meaning they are required to receive several positioning systems such as GPS, GLONASS, Beidou, and Galileo. TE is following this trend closely and offers GNSS antennas which support the high level of accuracy needed in self-driving cars.

### V2X and Cell

Self-driving cars need large amounts of information to make the right decisions in traffic. In additional to sensors that capture the environment, information will soon be exchanged between cars. The objective is to exchange information, beyond the line of sight, that sensors cannot capture. For example, self-driving cars will need to communicate with other cars around a corner. This will involve V2X technologies that communicate with other vehicles and the road infrastructure. However, there are currently two competing standards for the underlying technology: IEEE 802.11p, which is based on the WLAN standard, and C-V2X, which is based on the cellular standard. It remains to be seen which will be adopted by the automotive industry. TE offers antennas for both standards and is therefore able to support autonomous cars, independent of the standard decision. The cellular network standard LTE is used today to connect cars to the infrastructure or to each other. However, LTE's inherent latency is too high for time-critical applications. 5G, which is currently being specified, will offer low latency and high bandwidth in the cellular world. TE has already developed an early prototype for the 5G antenna.

### WLAN and Bluetooth

Bluetooth and Wireless LAN (WLAN) also have a place in vehicle networks. Bluetooth is being used for remote access and allows smart phones to communicate with infotainment systems. It will soon replace a key fob. TE has developed integrated Bluetooth antennas and transceivers in rooftop antennas to provide the interface for such use cases. In addition, remote parking applications, where the car is controlled via a smart phone while it 'self-parks,' can be supported.

WLAN is a good choice when high data throughput is required to connect consumer devices to the car. Cars already offer WLAN hotspots, which allow passengers to access the internet via a built-in LTE modem. Furthermore, WLAN may be used to connect the car to the Internet while it is stored in the garage at home, so that critical software updates can be rolled out overnight via FOTA, or Firmware Over The Air, or the driver's music library is synchronized.

### Smarter Antenna Packaging

As the sheer amount of connectivity within the vehicle grows, it becomes increasingly challenging to find practical locations for antennas and accompanying electronic control units. In addition, the frequencies of newer services, such as LTE or WLAN, are in the GHz range which can mean lower signal strength on coaxial cables. TE is therefore developing a solution which combines antennas and transceivers in a single unit. It will reduce the distance signals have to travel and therefore will increase achievable data rates.

The target location for such a smart antenna is in the roof area. Services that will likely be supported include mobile communication, V2X, GNSS, Bluetooth, and WLAN. Such an architecture also has the advantage of having only one high-speed data interface (e.g., Ethernet), which provides access to all of the above-mentioned services. With the deployment of 5G, even higher frequencies are expected, meaning that such an antenna transceiver combination will be become standard.

## 7 | THE ROLE OF SENSORS

A fully autonomous vehicle will incorporate a sensor taxonomy comprising of internal and external sensors as well as sensors using data communication. As discussed, high resolution stereo and/or mono cameras, RADAR, and LIDAR enable the sensing of the vehicle's immediate surroundings and communication based on V2X data, which provides information about the environment beyond the line-of-sight as well as traffic infrastructure. The fully autonomous vehicle will also depend on internal vehicle sensing technology, much of which exists today but is being deployed in new applications and combined with other sensor functionalities requiring, in some cases, even greater levels of functional safety and accuracy.

Today multiple ADAS related applications such as Electronic Stabilization Control (ESC) and Anti-Lock Braking System (ABS) are enabled by precise sensor-generated information. The following use cases describe examples of the expanded and increased significance of sensors in fully autonomous vehicles.

### Reactive Body Position Control for Collision Protection

A key driver of ADAS and autonomous driving is the industry's goal to increase safety and eliminate road fatalities. There are already numerous advanced features that utilize sensor-based technology to monitor, detect, and respond to driving hazards and risks.

Another advanced feature is adaptive body height control in advance of side impacts. This feature uses lateral motion sensors to detect an imminent side collision and work with the suspension system which leverages position sensors to increase body height ride by as much as 10 centimeters or more to expose a more robust part of the chassis to the likely impact zone.

### Predictive Stabilization for Greater Control and Comfort

In addition to safety considerations, autonomous driving also provides greater levels of comfort for passengers. One example is predictive suspension technology, where data from stereo cameras or LIDAR works with chassis position sensors and the suspension system. Cameras or LIDAR can scan the road surface ahead up to 15 meters away in real-time and measure obstacles within three millimeters of accuracy and up to 130 kilometers per hour.

*Figure 6. TE's chassis height sensors*

The measurement data is then passed to the suspension system whereby position sensors actively adjust ride height in advance of meeting obstacles. This enables the vehicle to ride smoothly over obstacles and reduces vibration and oscillation for maximum comfort.

A similar example is cross-wind stabilization. By monitoring data coming from existing vehicle sensors in the suspension system, power steering, and ESP vehicles can automatically compensate for the effects of strong winds. When winds are detected, the stabilization system triggers the application of brakes on one side of the vehicle to help smoothly maintain the driver's position.

These types of features are already available in selected passenger vehicles. In the future, they will be an essential component of fully autonomous vehicles..

### Braking Control in Adverse Weather Conditions

Sensors measuring temperature and humidity are currently used within clearly defined use cases. For example, the temperature level triggers a warning to the driver if there is a risk of icy roads, and HVAC control needs to know about the level of humidity to avoid windshield fogging.

In a fully autonomous vehicle, however, data on temperature and humidity can also be used to classify a road condition that is not visible to the naked eye, such as black ice. When the road is wet or snowy, there will be less grip. Thus, an autonomous vehicle would need to apply the brakes earlier to prevent skidding or a collision.

### New Sensor Data Business Models

As mentioned earlier, data from rain sensors, combined with telematic modules, is already being used for weather forecasting. Enhanced driving condition intelligence as described above could be collected in real-time from vehicles and made available commercially as an in-vehicle application.

*Figure 7. TE's humidity sensors with digital outputs*

### SENSOR REQUIREMENTS

All the above use case examples describe the deployment of sensors in safety-relevant applications. However, as the vehicle becomes increasingly autonomous and assumes greater responsibility for the security of its passengers, the safety relevance of some of the most basic sensor operations also increases.

Sensors are classified under Automotive Safety Integration Level (ASIL) standards, which assesses the risk of potential hazards by analyzing the severity, exposure, and controllability of the vehicle operating scenario. There are four ASIL standards, A to D, with ASIL D carrying the highest requirement levels and generally reserved for potentially life-threatening or severe injury risks in the event of the automobile's malfunction.

Fully automated or driverless vehicles will require the highest possible levels of robustness and reliability to ensure continuous operation and safety. For example, sensor-enabled technology will divert a car to a workshop for maintenance or repairs well within reliability safety margins to ensure fail-operational behavior.

As one of the largest sensor companies in the world, TE's innovative solutions have become an integral part in many modern vehicle nervous systems, integrating innovative sensors in demanding applications, such as engines, brake systems, and the chassis of cars.

## 8 | CO-CREATING THE FUTURE OF MOBILITY WITH TE CONNECTIVITY

Autonomous driving is changing the way we view vehicles and mobility. Ever since the crimp was invented, we have been partnering with automotive manufacturers to co-create leading connectivity solutions that set industry standards. Today, autonomous driving trends and technologies are presenting new challenges that will drive transformation of the entire automotive industry. We continue to engage with customers early in the development process and serve as true partners in the co-creation of solutions that enable vehicles to be smarter and safer.

### Fast Collaborative Design Process

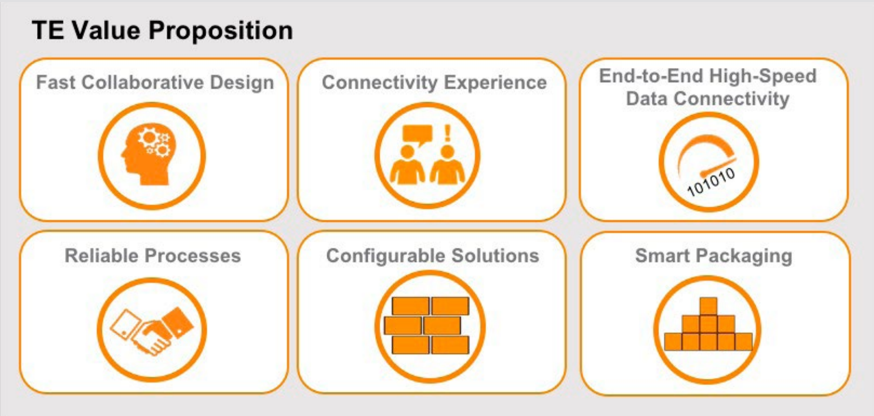
Our digitally enabled collaborative design process incorporates powerful methods to model and simulate complete systems, from the RF characteristics of the mechanical design to tool and process simulations. This capability ensures that TE creates highly accurate system models at an early stage and produces a near-final serial design at the first iteration, including electrical, mechanical, and manufacturing tolerance evaluations.

### Automotive Experience

Another key factor in TE's success is the company's vast experience and deep understanding of the automotive world, other industries, and adjacent technologies. TE has extensive experience across a wide range of industries that demand precision engineering for difficult and complex operational conditions. For example, TE is able to draw on its expertise designing and building automotive-grade systems and the work it has done creating modern hyperscale data centers to develop highly robust, high-speed connectivity solutions for the automotive ecosystems of tomorrow.

### End-to-End Automotive Data Connectivity Technology

No matter which technology path the automotive industry takes, we can provide solutions for safe and reliable systems and processes for high-speed data, leveraging our decades of experience producing reliable connectivity, antenna, and sensor systems. Our technology portfolio is being developed to support end-to-end automotive connectivity addressing all the physical layer challenges of today and the increasing demands of autonomous driving as the industry develops These challenges include the ability to transmit large amounts of data in real-time; the flexibility required to integrate heterogeneous devices and chip protocols; and ever-increasing industry requirements for miniaturization, flexible packaging, and automotive grade robustness for safety-critical applications.




Our technology and competence within the areas of sensors and antennas means TE is equipped to offer a truly holistic solution to meet the connectivity demands of autonomous driving within the vehicle and beyond.

In addition to enabling high-speed data, TE collaborates with large industry leaders and is actively involved in developing standards. We perform benchmarks on different technologies and develop advanced concepts to increase high-speed performance using conventional physical layers, while exploring new research areas.

### Processes

TE creates systems that are built to withstand the harshest environments while simultaneously developing scalable production processes that follow a holistic approach. In particular, our semi- and fully-automated production capabilities can be scaled according to the volume scenarios of each customer's requirements. Sophisticated test and control measures ensure that TE provides the quality needed to meet the industry's highest safety standards.

### Configurable Solutions

Building customized connector solutions according to each customer's needs and requirements is a central goal on the path to providing an extraordinary customer experience. TE's modular and scalable product family offers full design flexibility to create customized systems combining data, signal, and power for various applications and numerous configurations.

### Packaging

The increasing number of functions running on high-performance computers and the large quantity of links connected to these devices is contributing to an increasing port density and the need to miniaturize connectivity. TE is able to design and produce systems with improved packaging and ever-smaller connector systems.

## 9 | SUMMARY

An entire industry is inspired by the market's vision of self-driving vehicles. New vehicle concepts, business models, and services are likely to reshape the mobility world as we know it. As the market evolves, TE helps its partners enable technologies that will drive innovation and change mobility behavior. Existing TE solutions are meet the requirements of the upcoming vehicles that are more complex and have a higher degree of automation. Future connectivity solutions will have to meet even higher requirements. We engage with our customers early in the design process to accelerate innovation and co-create solutions that enable future vehicles to become smarter and safer.

## SOURCES

1) Connected Car Media Deck, Bearing Point Institute
(https://www.tns-sofres.com/sites/default/files/2016.05.24-connectedcar.pdf)

## ABOUT TE CONNECTIVITY

TE Connectivity (TE) Ltd. (NYSE: TEL) is a $13 billion global technology and manufacturing leader creating a safer, sustainable, productive, and connected future.

For more than 75 years, our connectivity and sensor solutions, proven in the harshest environments, have enabled advancements in transportation, industrial applications, medical technology, energy, data communications, and the home.

With 78,000 employees, including more than 7,000 engineers, working alongside customers in nearly 150 countries, TE ensures that EVERY CONNECTION COUNTS. Learn more at www.te.com and on LinkedIn, Facebook, WeChat and Twitter.

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