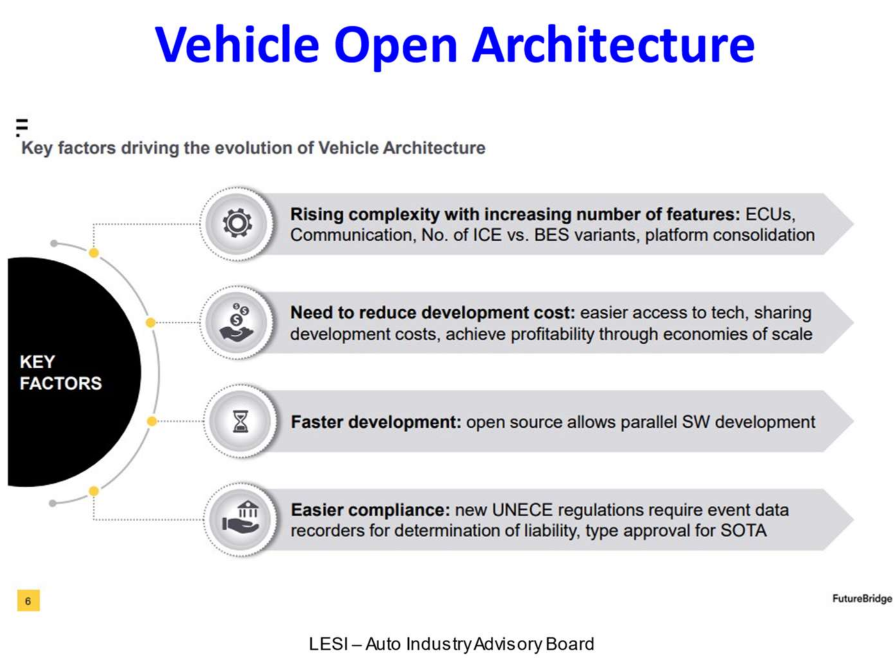
LESI - Automotive Industry Advisory Board
Open Vehicle Architecture
Summary of Session Held June 29, 2022

Background:

As consumers, we all enjoy the convenience and a host of useful applications we access through smart phones as part of our personal digital network. As our vehicles become increasingly connected, the car is set to be the next major element of that network. To fulfill this promise, vehicle systems will need to adapt and expand. Traditionally, vehicle control systems and the software that directs them, has been the private domain of vehicle producers and key Tier 1 suppliers. Under the “old order” for vehicle design and manufacture, installing updates to vehicle software frequently involved a trip a dealer via slow and costly vehicle “recalls” from the manufacturer. New entrants to the market like Tesla are challenging this “old order” for companies that design and manufacture vehicles and their key suppliers by providing software-defined features that are frequently updated and offering new applications over the life of the vehicle.

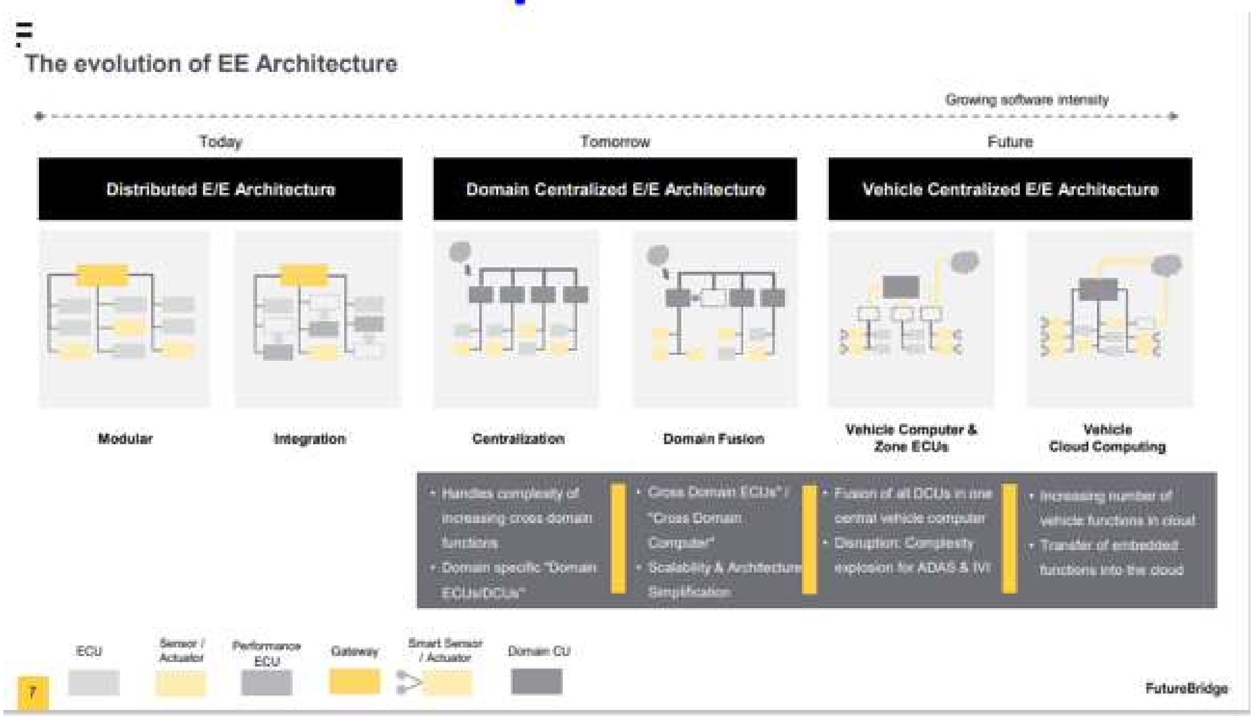
What allows vehicle controls systems to be “open?” Connecting vehicles to the “Internet of Things” through V2X (Vehicle to Everything) and Open Vehicle Architectures will enable the next wave of technology to change how we use our vehicles. Open Vehicle Architectures create an operating and controls system that allows ongoing software updates, new applications, and works with software applications from a broad variety of software/systems developers. For vehicles, this is a significant change from vehicle architectures that included dozens of small independent control systems which operate everything from engine and powertrain controls; vehicle comfort and convenience systems, including powered seats, windows, and sunroofs; safety systems, like airbags, and automatic emergency braking systems, and entertainment systems. Other key drivers supporting Open Vehicle Architectures are include:



Since automobiles came into broad use in the last 120 years, vehicles were defined by styling and mechanical systems with unique features that helped create brand identity. In the past 45 years, those mechanical systems added electronic controls that optimized performance of everything from engine combustion to suspension and braking. These system controls came independently over time and often did not communicate with other vehicle control systems.

Today's vehicles contain up to 150 small electronic control units (ECUs) which generally operate independently to monitor and manage individual systems.

Vehicle Open Architecture



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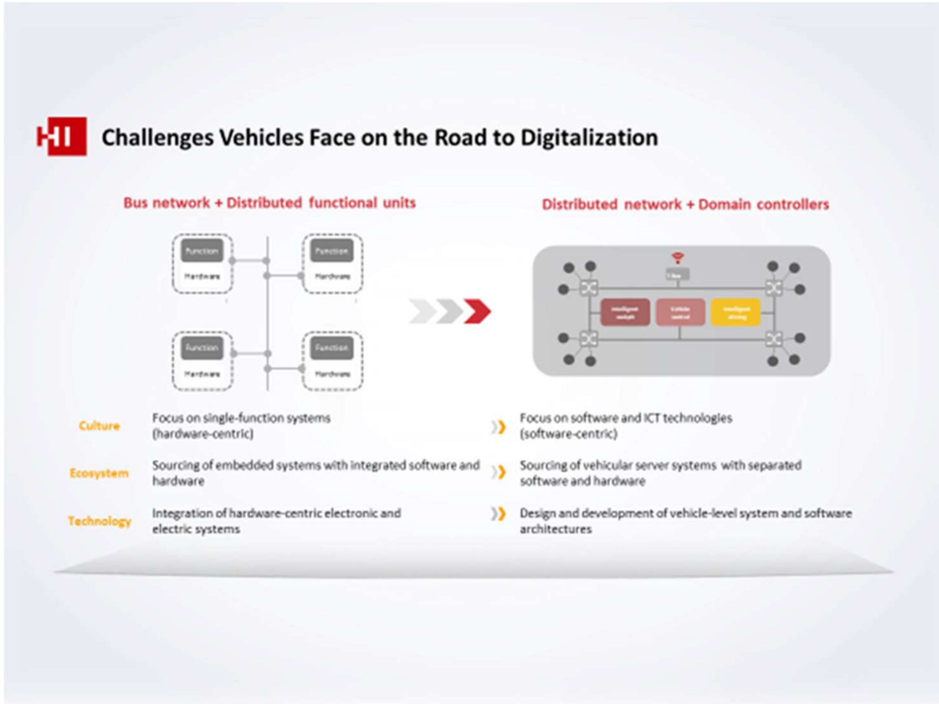
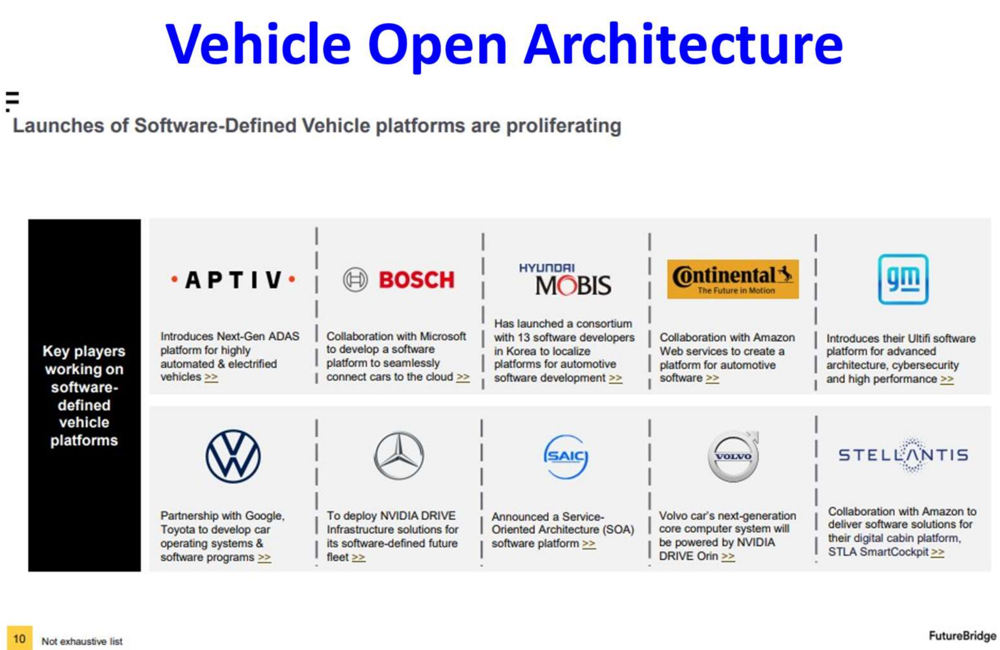
Industry observers believe that the current systems that provide functional control of the vehicle will migrate from software contained in individual ECUs to domain controllers that contain a variety of software control algorithms, thus supporting multiple systems. These new domain controllers (DCUs – or Zone Controllers) will host software from a variety of vehicle systems and will be partitioned based on the risk associated with the systems they control.

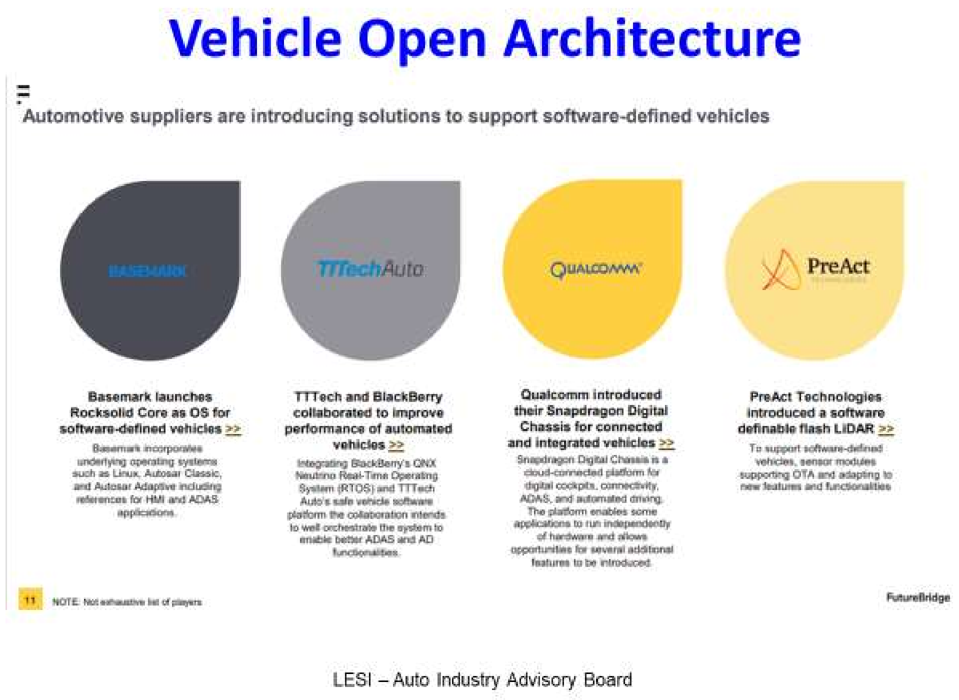


Software Defined Vehicles

Vehicle OEMs looking for a market advantage are also increasingly using software to create innovative performance, custom features, and unique vehicle identity. This trend is being embraced by the supply community, in cooperation with key vehicle manufacturers, as illustrated here:



Open systems will also help enable what automakers are calling “software defined vehicles.” Software defined vehicles can be customized based on individual consumer preferences after the initial sale “over the air” with new applications sold to consumers or made available on a pay-per-use basis. With software defined vehicles, vehicle manufacturers will no longer be restricted to defining vehicle features either in the original design or during “mid-cycle enhancements” later in the vehicle’s production life.

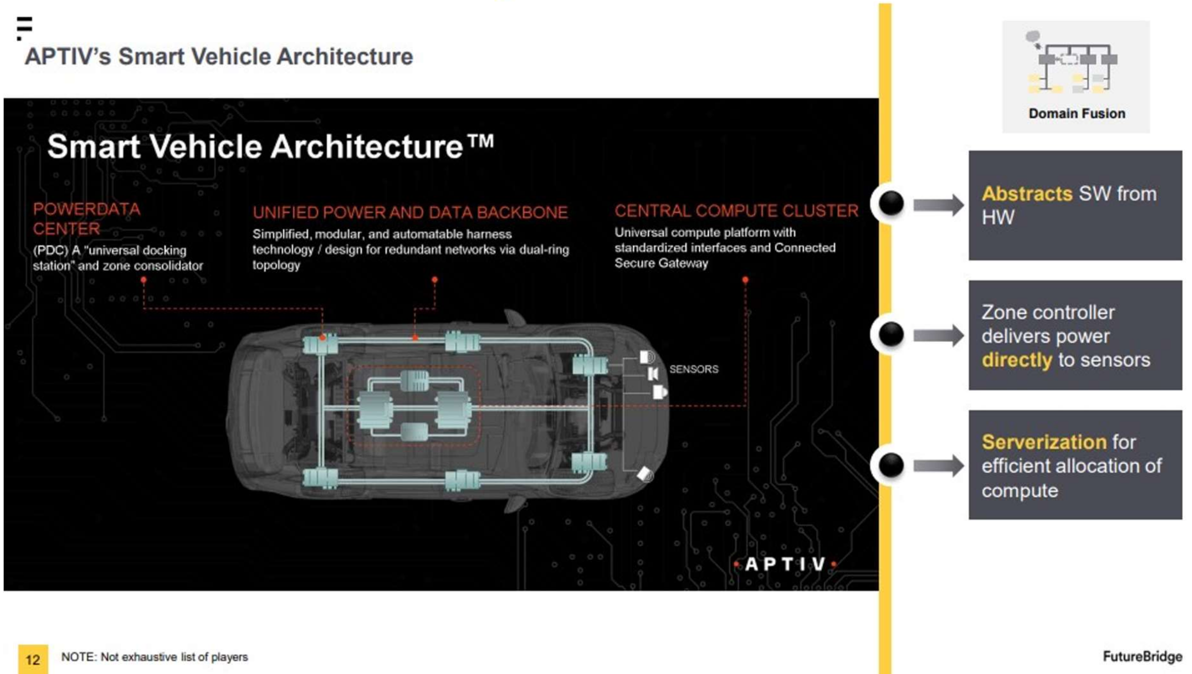


An open vehicle operating system creates a continuous path for new software-defined applications, through over the air (OTA) updates. New software and updates can flow seamlessly to the vehicle OTA, allowing vehicle manufacturers and suppliers of approved applications to update vehicle features and functions over the entire life of the vehicle. The tech industry has taken notice of this opportunity.

<u>What Is Happening: Enabling Technologies - Open Vehicle Architecture</u>

Reconfiguring vehicle electrical/electronic architecture: One of the key enablers is the need for a signal and power distribution network inside the vehicle aligned with the domain control computing architecture. An example of such a power and signal backbone is illustrated here with a system offered by Aptiv:

Vehicle Open Architecture



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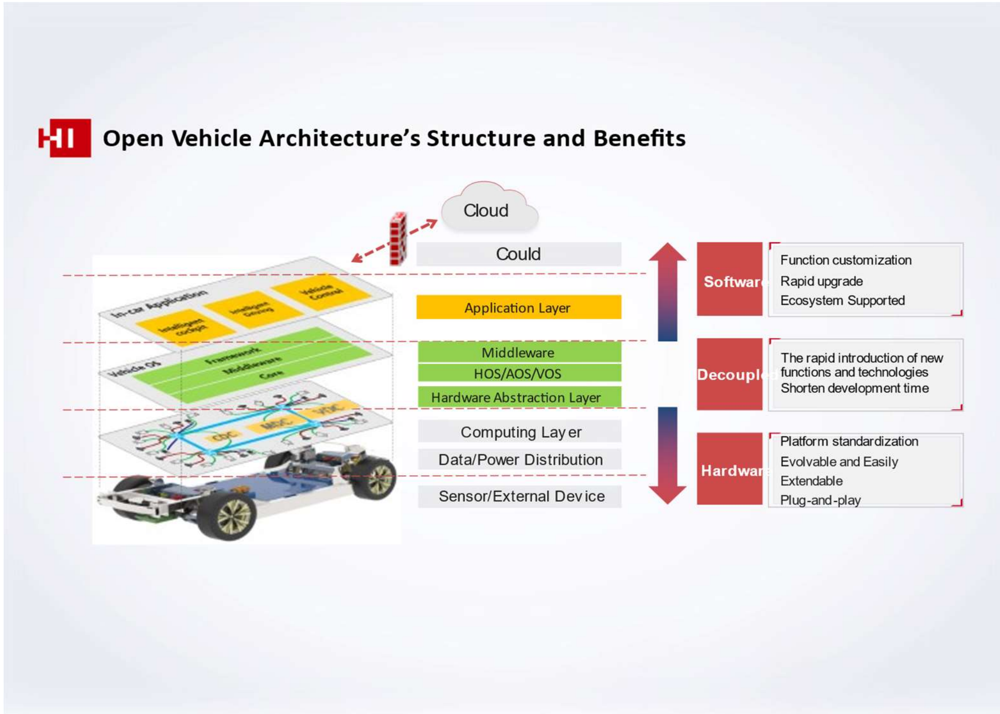
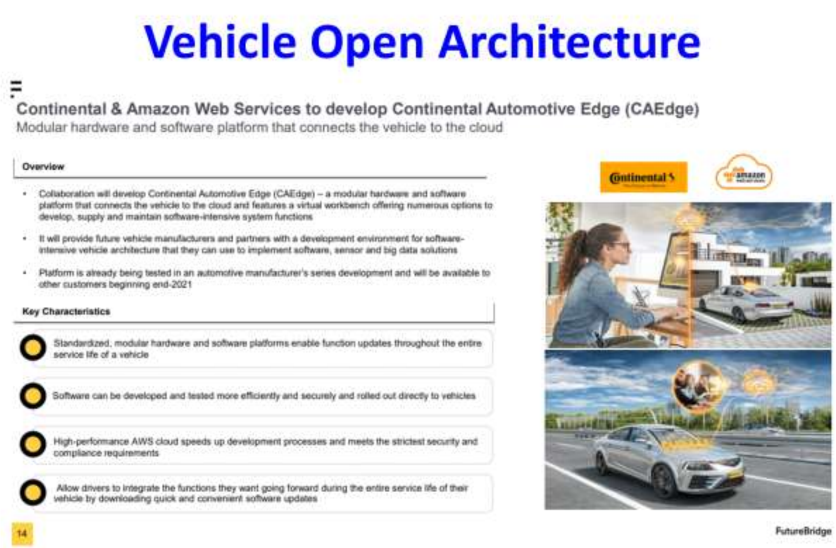
While this may seem like a simple change, moving software contained to local ECUs into zone controllers has an important consequence. Software moved into zone controllers becomes available for OTA updates. This has huge potential for ongoing updates to sell consumers additional functionality though apps or vehicle service subscriptions. This also requires the software to be separated from the hardware system sold by Tier 1 suppliers, which has significant impact on their revenue stream. Tier 1 suppliers would need to provide software separately from the hardware they sell, eliminating the ECU from their product offering.

Enabling Technologies - **Vehicle Operating Systems** - Suppliers of vehicle connectivity and operating systems are also active in supporting open architecture based on domain control units, as seen in the example from Huawei:



Under this scenario presented by Huawei, vehicle control and computing is centralized in domain/zone controllers, supported by power data centers that collect and process data and power sensors. Other more traditional Tier 1 automotive suppliers are teaming with the IT community to deliver a variety of cloud-based vehicle services:



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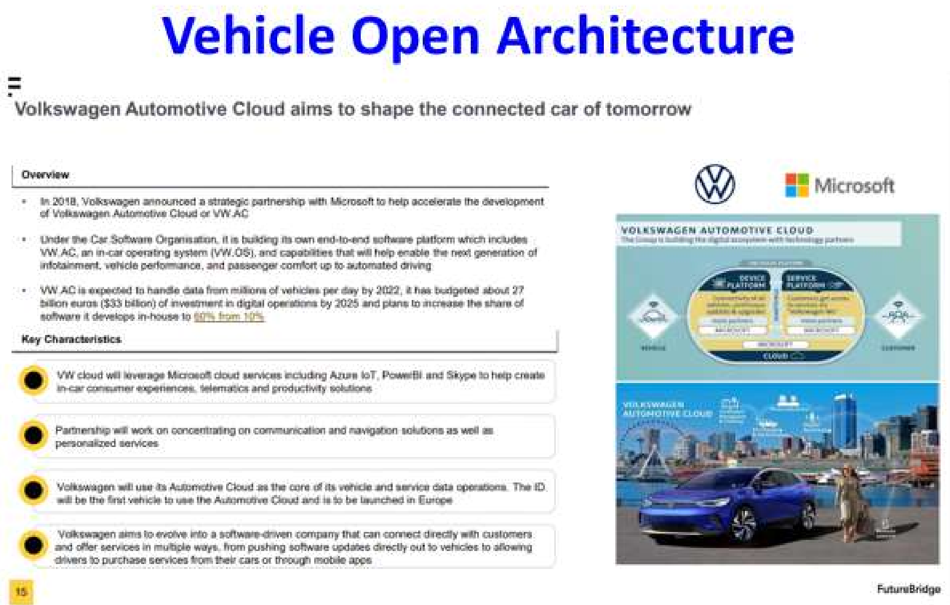
Connecting vehicles to the worldwide web and the cloud can enable local processing of sensory information, as the vehicle assumes the role of edge computing devices. As an edge device, the connected car becomes an important element of the automotive Internet of Things/cloud network, providing initial processing of data captured by the vehicle and then shared via the cloud. Vehicle OEMs are driving the industry direction toward connected open vehicle architectures with the help of their partners, as seen in the VW example:



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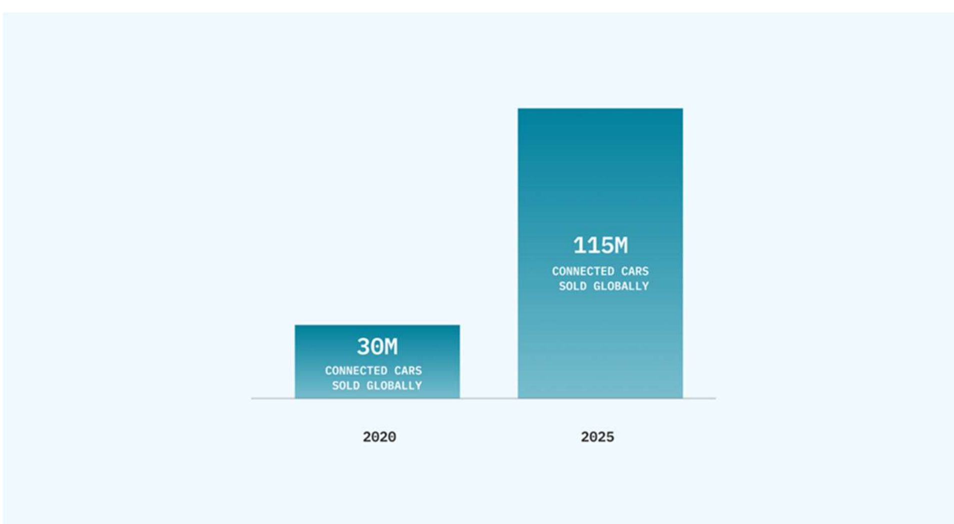
Enabling Technologies – V2X Deployment/Creating the Connection

A secure connection from and to the vehicle is increasingly becoming standard equipment for new vehicles produced today. The following illustration shows the progress toward making new vehicles part of the worldwide web:

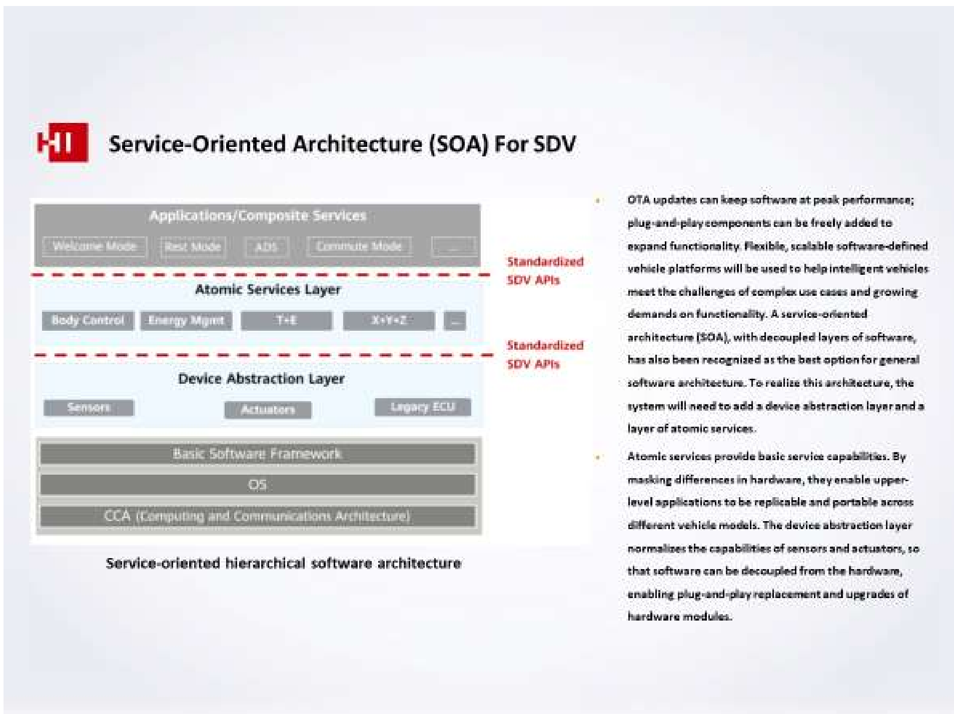
Connected Vehicles Built in 2020 and 2025 projections



Sales of connected cars are expected to increase more than four-fold in the next five years. (Source: ABI Research). In the US, over 13 million connected cars were produced in 2020; 91% of new cars sold were connected cars. (Sources: ABI Research, Marklines)

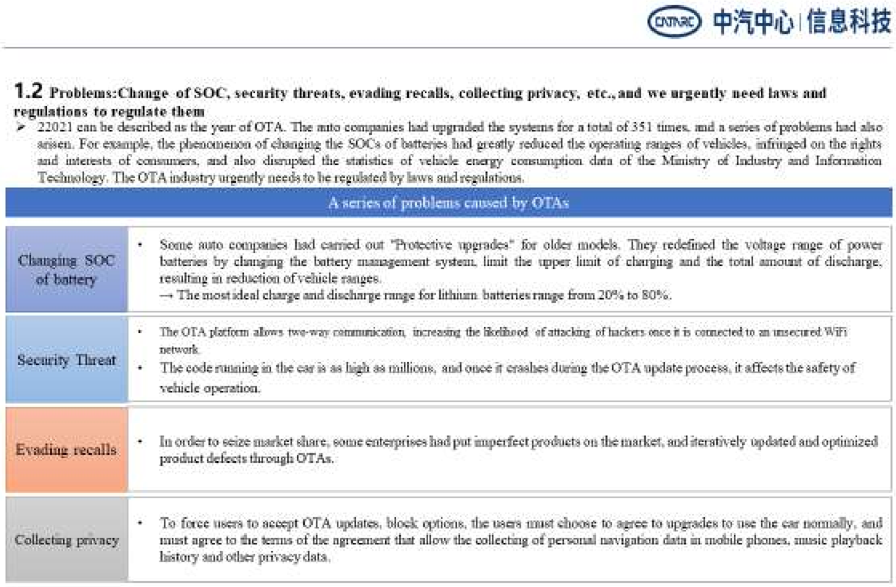
The world vehicle fleet changes slowly as vehicle useful life can extend to 20 years or more. Scott McCormick, President of the Connected Vehicle Trade Association, believes "If all new vehicles sold were to start being connected tomorrow, it would take 15 years for the entire fleet to be enabled."

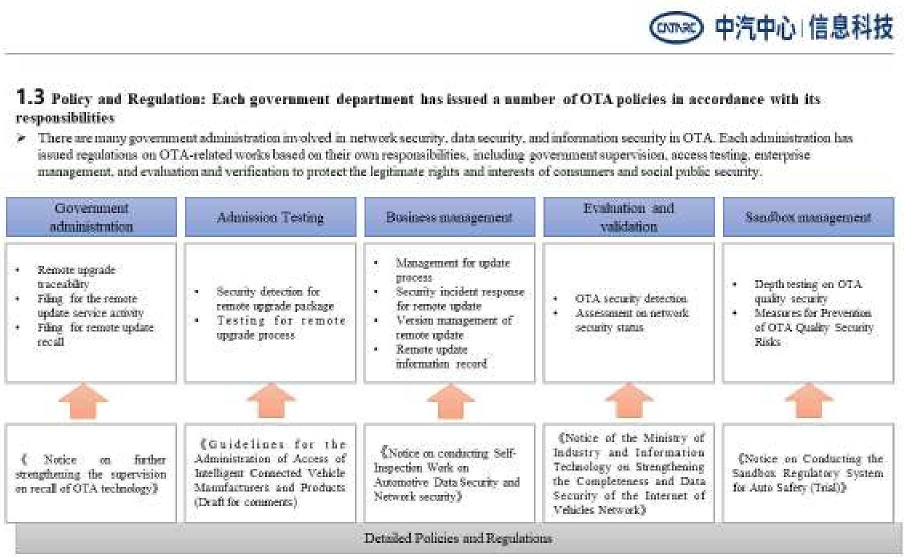
These connections position vehicles to provide their owners and other data users with critical informtion to enable additional services:



Avoiding the expense and inconvenience of taking (and generally leaving) a car at a dealership for service appeals to vehicle OEMs and owners.

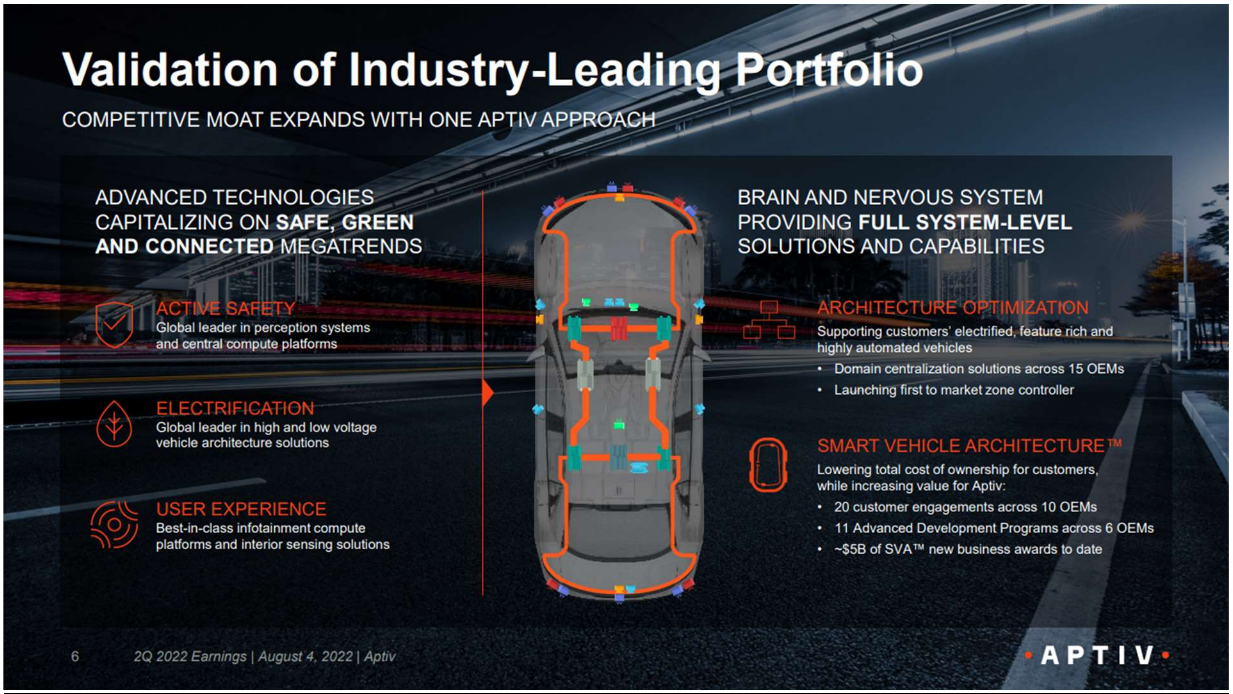
Governments also are aware of the growing demand for the efficiency and convenience of OTA systems, and are responding with regulations to govern their roll out and use - as well as the challenges - as seen in the case of the China market:



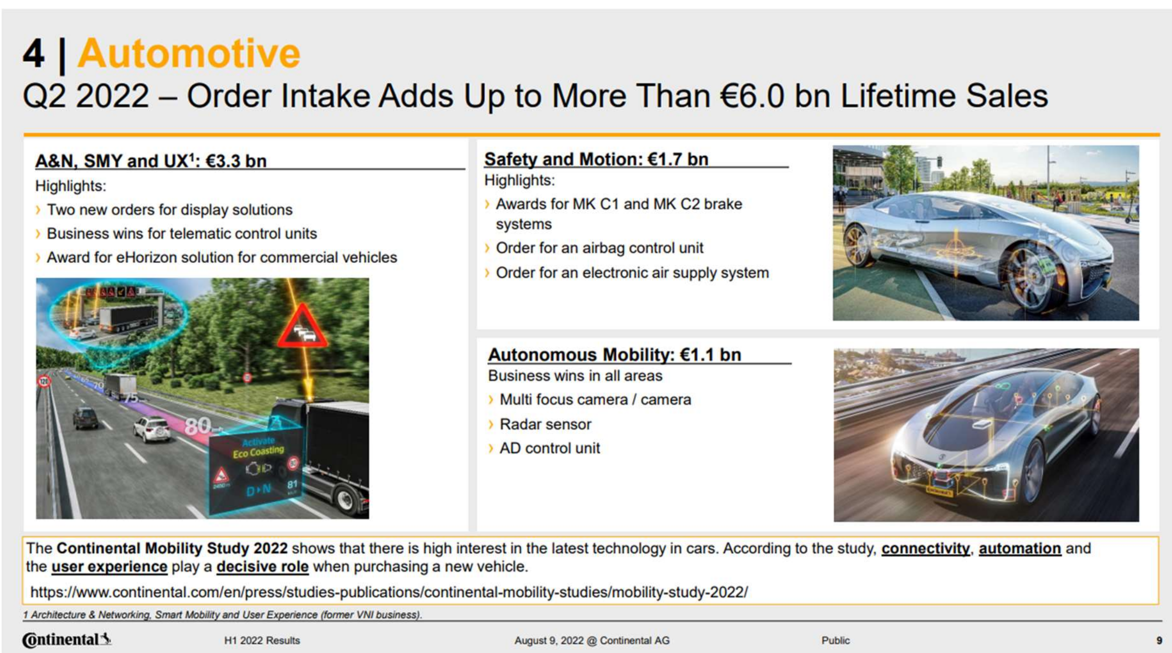


Vehicle Roll Out – Key Enablers

Key to enabling these technologies are actual vehicle programs to build these communication systems into the vehicles being manufactured and sold. So, are these key vehicle communication building blocks being installed in vehicles being designed today? We can see indicators in product announcements included in investor packages issued by key suppliers:



In the management discussions for the first two quarters of 2022, Aptiv is reporting progress on domain architecture centralization and Smart Vehicle Architecture in their recent communications to investors.

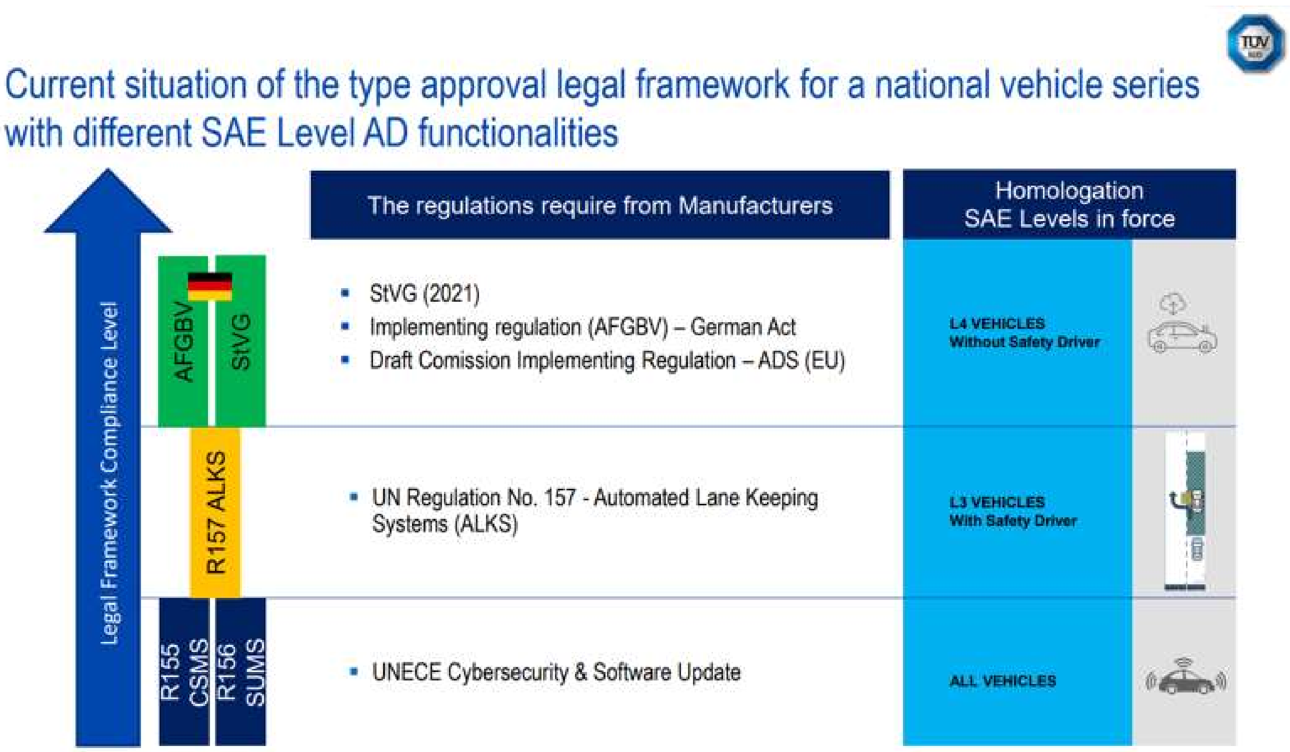


In that same period, Continental is reporting new orders for Telematic Control Units (TCUs) that enable advanced vehicle connectivity and control systems in their recent investor communications.

Summary and Conclusions

What Remains to be Done?

Compliance - Providing systems to assure the updates to software comply with regulations and are effectively implemented remains a challenge, given the rapid advance of software-defined vehicle systems, as seen in this autonomous vehicle software illustration:



Continue to Build a Fleet of Connected Vehicles – Global Markets

While new cars are increasingly equipped with TCUs (electronics that enable vehicles to send and receive more sophisticated data), fully rolling this technology out to the global fleet will require about 15 years. Concurrently, cellular systems (5G and beyond) will be capable partners with the connected car universe.

Compliance: Over the Air Updates – Managing for the Long Term

Manufacturers will need to support the local requirements for OTA updates. This will take a different form in various world markets, as illustrated in the case of China.

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1.5 Challenges: Massive data maintenance, information security, and other huge challenges

- OTA faces a series of challenges in the policy and regulatory, and technical files. On the policy filed, it is necessary to find a combination of strengthening management and encouraging innovation; on the technical field, it faces challenges such as maintaining massive data, ensuring information security, and preventing malicious intrusions.

Main challenges to auto OTA

In the Area of Policy Administration	The Challenges in the Technology Area
There is a lack of a set of processes to support vehicle manufacturers from OTA design and development to functional application in China	Massive date maintenance, building a data center
Lack of technical specifications for electrical and electronic architecture, automotive software version management, after-sales software services and Big data application capabilities	Network communication security to ensure a safe and smooth update process
Once the OTA with new autonomous driving function is strictly controlled, it may restrict the development of technological innovation	Hackers maliciously invade the system, steal customer privacy, and even tamper with self-driving programs
It is lack of a systematic OTA management system, each government department conducts supervision according to the existing functional location	How to open OTA functions in the areas such as autonomous driving, body control, chassis, and battery power consumption, etc. and meet the demands of auto safety.

These challenges require solutions from the vehicle manufacturers working with regulators in world markets. Compliance will be essential to enjoy the many benefits of OTA updates.

What IP Is Involved & How Can the IP Profession Assist in Managing IP Rights?

Standard Essential Patents – Industry Standards for smart cars and cities will continue to generate new standards building on CV2X (Cellular Vehicle to Everything) and WiFi based protocols. While the momentum for CV2X is strong, riding on the coattails of the worldwide smartphone rollout, 5G penetration will roll out first in major metropolitan markets. Established protocols, like Wi-Fi/DSRC, will continue to play a role for the foreseeable future. While there is debate on which 5G patents are essential, the following leaders will no doubt play a role in licensing rights for vehicles and the supporting data infrastructure:

Figure 2. Top 6 Companies' share in core 5G patent families

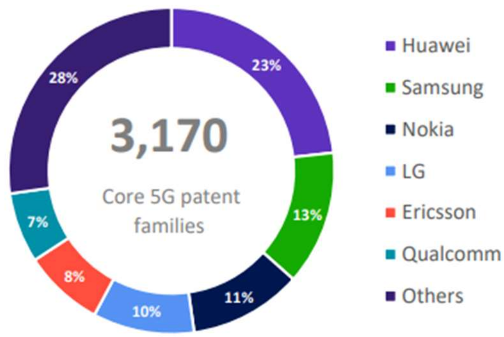

Table 1. Distribution of core 5G patent families across top six patent assignees

Entity	# Declared families	# Analyzed families with ≥ 1 granted patent (A)	# Core 5G patent families (B)	Internal % (B/A)
Huawei	4845	2752	736	27%
Samsung	3042	2101	423	20%
Nokia	2243	1698	355	21%
LG	2091	1493	319	21%
Ericsson	2187	1064	253	24%
Qualcomm	2076	1203	221	18 %
Others	10630	4031	863	21%
Grand Total	27114	14342	3170	22%

Clarivate- Derwent ™ - Demystifying the 5G standard essential patent landscape published on August 17, 2020.

While the final roll out of 5G and actual configuration of the communication technology in the vehicle will determine the rights required, the rights will come from these key IP owners.

Moving Control Software to Zone Controllers - Separating (extracting) software from the hardware systems they control will also pose an important challenge to Tier 1 system suppliers. Vehicle OEMs will need access to software to load into zone controllers. This Tier 1 software should be made available under license to control how and where the code is used by the vehicle OEM. Tier 1 suppliers have developed these control algorithms over decades and this code is a key IP asset. Our profession can support clients through creating durable licenses with terms that protect the owners of the software as Zone Control becomes the basic vehicle architecture.

Software Development & Protection – Vehicle Applications - Apps

Once vehicles become capable of accepting authorized software, creating special applications will provide a multitude of opportunities for software developers to work with OEMS to make their software available to vehicle owners.

One key opportunity for small-to-medium-sized firms and start-ups will involve new applications, which these open vehicle architectures will support. Approval and release of these car-based apps will need to follow the smartphone model and be controlled through an approved source, like the vehicle OEMs. These products may be rolled out as software as a service, with features enabled by vehicle OEMS, for extended vehicle range (Tesla example), or additional horsepower (Polestar). The market for enhanced performance features will be strong, creating an almost limitless market for new user-defined applications for the vehicle. These software-defined features can extend the working life of the vehicle and create huge markets for software and connected vehicle enabled services.

Concluding Thoughts:

The IP profession can benefit from work with software programmers and small-to-medium sized businesses that will create these software-defined vehicles and new connected vehicle applications. The evolution of smartphone applications created a new "apps" industry. Connected vehicles with open vehicle systems have the potential to take the apps development industry to the next important level. IP will be at the center of this industry and protecting it will create value for IP owners and developers as these industries develop and mature. Speed to market will be essential for optimal deployment of this new software, but managing and retaining IP rights to the software in an open-source world is a daunting task. This need will create opportunities for the IP profession to work with software professionals and their firms to create and protect proprietary software-based IP rights.

John Carney
Chair – Automotive Industry Advisory Board
Licensing Executive Society International
September 5, 2022

Other Reading

Automotive Pay per Use

https://getjerry.com/insights/volkswagen-plans-implement-pay-per-use-car-technology

https://www.vice.com/en/article/epxzya/car-companies-want-you-to-keep-paying-for-features-you-already-have

Software Defined Vehicles

https://www.bosch-mobility-solutions.com/en/solutions/software-and-services/open-technology-platform-for-software-defined-vehicles/

Standards

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/936211/BSI-Future-of-Transport-system-interoperability-and-standards-report-accessible.pdf

https://www.bsigroup.com/globalassets/localfiles/en-gb/cav/cav-standards-roadmap/cav-standards-roadmap-2022.pdf

<u>Standards Involved – Connected and Autonomous Vehicles</u>

BSI CAV Standards Roadmap 2022

A summary of key standards related to CAVs and priority areas for future development to support the safe testing, trialling and future deployments of CAVs.

Standards

	Recently Published	In Development	Priority Gaps
Safety & Assurance	**PD/ISO PAS 21448:2019** Road vehicles – Safety of the intended functionality **PAS 1881:2020** Assuring the operational safety of automated vehicles – Specification **SAE J3016** Taxonomy & definitions for terms related to driving automation systems for on-road motor vehicles **UL 4600** Evaluation of autonomous products **BS ISO 26262:2018** Functional safety **BS ISO 22737:2021** LSAD systems for predefined routes – Performance requirements, system requirements & performance test procedures **ASAM OpenDRIVE®**	**ISO/AWI 23793-1** MRM for automated driving – Framework, straight stop and in-lane stop **ISO 34501** Road vehicles - Terms and definitions for test scenarios for ADS **ISO 34502** Road vehicles - Scenario-based safety evaluation framework for ADS **ISO/WD 34503** ODD taxonomy **SAE J3259** Taxonomy & definitions for ODD **ISO/AWI TS 5083** Safety for ADS – Design, verification and validation	Standard behaviours in response to emergency vehicles (incl. high priority messages) Library of scenarios/test cases for testing & type approval of CAVs & systems (may include by simulation) Guidance on how to apply SOTIF ISO 21448 Minimal risk manoeuvre & conditions for ADS failures & other malfunctions HMI standards for handover & takeback/fallback functionality includes monitoring of safety driver & training
Perception, Decision Making & AI	**PAS 1883:2020** ODD taxonomy for an automated driving system – Specification **BS ISO 22735:2021** Road vehicles – Test method to evaluate the performance of lane-keeping assistance systems **PD ISO/SAE PAS 22736:2021** Taxonomy & definitions for terms related to driving automation systems for on-road motor vehicles	**ISO/AWI PAS 8800** Road vehicles – Safety and artificial intelligence **ISO/AWI 39003** Road traffic safety (RTS) – Guidance on safety ethical considerations for autonomous vehicles	Verification & validation of machine learning models, systems, & results suitable for safety cases Verification & validation of systems by simulation suitable for safety cases, to match real-world ground truth Performance metrics for perception including sensor integrity & calibration & data fusion
Data	**PAS 1882:2021** Data collection and management for AV trials for the purposes of incident investigation – Specification **ITU FGAI4AD-02** Automated driving safety data protocol – Ethical and legal considerations of continual monitoring **ISO/TS 5255-1:2022** ITS – Low-speed automated driving system (LSADS) service – Part 1: Role and functional model **BS ISO 20524-2:2020** ITS – Geographic data files (GDF) GDF5.1 – Map data used in automated driving systems, Cooperative ITS, and multimodal transport	**ISO/PWI 7856** ITS – Remote support for LSAD - Performance requirements and test procedures	Benchmarking safety performance of manual & automated vehicles Teleoperation system specifications Real-time monitoring of AVs (including performance of ADS) for safety Using Off-Vehicle Data from C-ITS V2X including perception & situational awareness for safe driving decisions External communications for other road users & public that self-driving mode is active and includes standardized behaviour
Security	**BS ISO/SAE 21434:2021** Road vehicles – Cybersecurity engineering **ISO/PAS 5112:2022** Road vehicles – Guidelines for auditing cybersecurity engineering	**BS ISO 24089** Software update engineering **GB/T 204-13** Software upgrades **GB/T 204-14** Telematics service/management **GB/T 204-16** Emergency response	
Digital Infrastructure	**ASAM OpenSCENARIO®** **ASAM OpenLABEL®**	**ISO/PWI 7856** ITS – Remote support for LSAD – Performance requirements and test procedures **ISO/WD 34503** ODD taxonomy	
Human Factors	**PAS 1884:2021** Safety operators in automated vehicle testing & trialling – Guide **PD ISO/TR 21959-1:2020** Road vehicles – Human performance and state in the context of automated driving – Common underlying concepts **PD ISO/TR 21959-2:2020** Road vehicles – Human performance and state in the context of automated driving – Considerations in designing experiments to investigate transition process	**ISO/AWI TS 5283** Road vehicles – Ergonomic aspects of driver monitoring and system interventions in the context of automated driving **BS ISO 39003** Road traffic safety (RTS) – Guidance on safety ethical considerations for autonomous vehicles **PD ISO/PAS 11585** Road vehicles – Partial driving automation – Technical characteristics of conditional hands-free driving systems	Teleoperation human factors / training, testing and operator license Requirements for interior design for new vehicles without steering wheels / pedals etc. Internal communications to AV occupants to explain AV actions to gain trust (includes monitoring occupants for safety)

Key:

Live BSI research projects

Urgent priority gaps as voted by industry experts during BSI's CAV roadmap workshops

Standards – Data Exchange and Interoperability

3.4 Core data exchange standards for transport systems

Whilst it is agreed FoT is a broad topic, debate on the standards landscape sought to ascertain what can be considered the core data exchange standards for transport systems. An analysis of this is presented in Annex 5. This is a complex picture and a simplified view of this is presented below in *Figure 13 – Simple view of core data exchange standards for transport systems.*

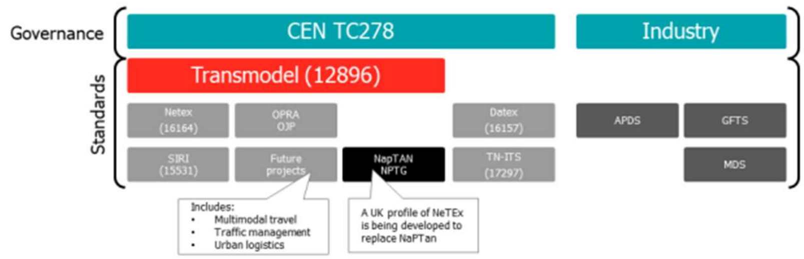

Figure 13 – Simple view of core data exchange standards for transport systems

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Most of the core standards are developed through the international committee ISO TC 204 (Intelligent Transport Systems) and the European standardisation committee CEN TC 278 (Intelligent Transport Systems). There is common working between these two committees but CEN TC 278 is not a mirror committee of ISO TC204. Key points to note on developments are:

- Many, but importantly not all, of the implementation-level standards developed by CEN TC 278 are based on the Transmodel reference ontology. This defines a common set of concepts and relationships (See *Figure 14 – CEN Transmodel project for public transport data exchange*).
- The current UK core standards for bus transport are based on the Transmodel reference. These currently being migrated to a UK profile of NeTEx.
- Although the DATEX II and TN-ITS standards are not formally based on Transmodel there are attempts to ensure they align.
- APDS is an industry standard for parking data definitions but uses concepts from DATEX II and TN-ITS and is proposed to ISO TC204 as a new standard.
- Future projects under the Transmodel framework include urban logistics, traffic management and multimodal journeys.
- A formal mapping between GFTS and NeTEx has been completed (see *Figure 31 – Example NeTEx and GFTS mapping*).

These standards are largely segmented and designed by the function (for example 'real time messaging') they specify and so it is not evident which standards should be used for a given activity; for example, 'micro-mobility'. Any activity will encompass typically the same functions, but from a different viewpoint and so it is important that any standard that considers data exchange from an activity ensures functional aspects are consistent with existing standards to ensure interoperability.

Standards – Communication

Under development – SAE (Society of Automotive Engineers – US)

Vehicle Architecture for Data Communications Standards

Works in Progress			
Project	**Title**	**Sponsor**	**Date**
J1850	Class B Data Communications Network Interface	Mark Zachos	May 19, 2022
J2056/3	Selection of Transmission Media	Mark Zachos	May 19, 2022
J2057/1	Class A Application/Definition	Mark Zachos	May 19, 2022
J2057/2	Class A Multiplexing Actuators	Mark Zachos	May 19, 2022
J2057/3	Class A Multiplexing Sensors	Mark Zachos	May 19, 2022
J2057/4	Class A Multiplexing Architecture Strategies	Mark Zachos	May 19, 2022
J2284/3	High-Speed CAN (HSC) for Vehicle Applications at 500 KBPS	Ajeya Y. Gupta	Apr 27, 2022
J2284/4	High-Speed CAN (HSC) for Vehicle Applications at 500 kbps with CAN FD Data at 2 Mbps	Natalie Wienckowski	Dec 17, 2021
J2284/5	High-Speed CAN (HSC) for Vehicle Applications at 500 kbps with CAN FD Data at 5 Mbps	Natalie Wienckowski	Dec 17, 2021
J2411	Single Wire Can Network for Vehicle Applications	Mark Zachos	May 19, 2022

J2716	SENT - Single Edge Nibble Transmission for Automotive Applications	Vincent M. Hiligsmann	May 11, 2022
J2962-2	Communication Transceivers Qualification Requirements - CAN	Doug Oliver	Nov 15, 2021
J2962-3	Communication Transceivers Qualification Requirements - Ethernet	Doug Oliver	Oct 29, 2021
J2962/1	Communication Transceivers Qualification Requirements - LIN	Doug Oliver	Oct 29, 2021
J3076	Clock Extension Peripheral Interface (CXPI)	Mark Zachos	May 19, 2022
J3076-1	SAE J3076-1 Clock Extension Peripheral Interface (CXPI)	Gangolf Feiter	Feb 10, 2017