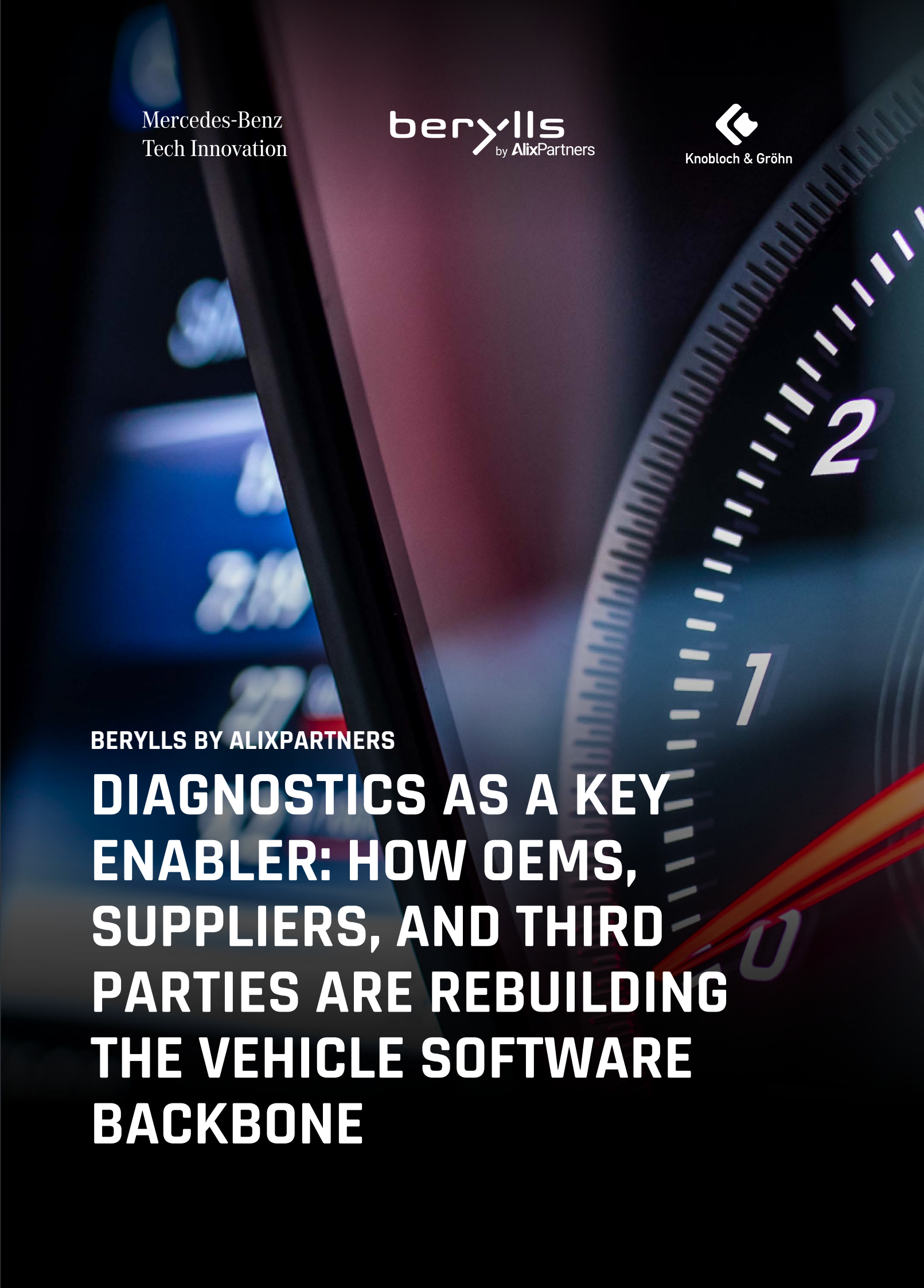


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DIAGNOSTICS AS A KEY ENABLER: HOW OEMS, SUPPLIERS, AND THIRD PARTIES ARE REBUILDING THE VEHICLE SOFTWARE BACKBONE

Executive Summary

Vehicle diagnostic function and architecture have evolved from an emission-driven, professional workshop-led utility to a client-backend coupled, lifecycle management infrastructure. Diagnostics serves an extensive range of functions for software-defined vehicles. The question is no longer which diagnostic tool to buy or use, but how do diagnostics fit into the overall vehicle software strategy, further supporting the SDV architecture and AI-DV trends.

The market is growing and shifting towards remote and connected services. We estimate that the global diagnostics software market will increase from ~EUR 14 billion in 2025 to reach ~EUR 34 billion by 2035 at approximately 9% CAGR. The underlying shift in where value is created will be important to decision-makers: embedded software falls from ~70% of the market to ~28%, while remote and connected services rise from ~8% to ~33%. The industry is moving from one-time software development and delivery to recurring lifecycle services: subscription and usage-based revenue grows from ~25% to ~70% of the market.

The diagnostic software stack has evolved into a two-layer architecture. UDS (ISO 14229) remains the transport-agnostic protocol used within ECUs and in-vehicle communications. SOVD (ISO 17978-3) sits above it as a service-oriented, REST-based API protocol designed for HPC and central computing architectures. It builds on OAuth 2.0/ OpenID Connect-based access control and uses a SOVD2UDS adapter to bridge legacy ECUs. SOVD complements existing infrastructure, enabling gradual and incremental adoption.

China is likely to develop a parallel diagnostic stack. Several Chinese OEMs are developing their own proprietary, vertically integrated platforms based on advanced architectures and in-house development capabilities. In the near term, widespread SOVD adoption is unlikely. However, compliance with export requirements, including UNECE R155/ R156 and Right to Repair regulations, will likely drive the adoption of dual-stack architectures for vehicles exported by Chinese OEMs by 2028-2030.

The role of public authorities in shaping automotive ecosystems is under-recognised. From CARB emissions monitoring to China's real-time monitoring of new energy vehicles since 2018, regulators have repeatedly reshaped vehicle software and connected functions, including diagnostics. The next wave is likely to focus on real-time safety monitoring of automated driving. OEMs and suppliers should engage with public authorities early as key ecosystem stakeholders in each jurisdiction and position themselves to benefit commercially from the standards they may mandate.

What Decision-Makers Should Do Now:

- **Embed Diagnostics Within Software Strategy.** Treat it as a lifecycle capability with a dedicated roadmap, revenue model and compliance strategy, not simply a software stack to be developed or procured.
- **Adopt a Two-Layer Architecture.** Use UDS at the ECU and in-vehicle level, with SOVD as the API surface for cloud, remote, and OTA, using SOVD2UDS to protect legacy investment. The architecture is well-defined and based on publicly available standards.
- **Plan for a Dual-Stack World.** Chinese OEMs should prepare for both global and China-specific compliance requirements within a single architecture through 2028–2030.
- **Capture Recurring Revenue Opportunities.** OEMs should prioritise remote and connected services before third parties do, adopting a service-oriented mindset.
- **Engage with Public Authorities and Prepare for Future Regulations.** OEMs can benefit from earlier and closer engagement, particularly regarding standards governing the monitoring of autonomous driving safety.

Berylls by AlixPartners helps OEMs and suppliers turn these considerations into actionable diagnostics and software strategies, translating business objectives into concrete architecture and product roadmaps, tailored to your unique software strategy, E/E architecture, and regulatory footprint.

Abstract

Vehicle diagnostic functions consist of software components, hardware interfaces, and protocols to support communication between ECUs, workshops, and cloud infrastructures. Vehicle diagnostic functions have evolved from emissions-driven fault detection to a lifecycle-integrated software infrastructure layer, driven by the convergence of SDV/AI enabled architecture, UNECE cybersecurity mandates, OTA lifecycle requirements, and increasing fleet-scale operational complexity and demands. Within the scope of automotive software, we estimate the global vehicle diagnostics software market at approximately EUR 14 billion in 2025 across the most relevant use cases, growing to EUR 34 billion by 2035 at a CAGR of approximately 9%. This is driven by a fundamental shift from a development-cost market to a recurring lifecycle-revenue market where software services dominate.

The industry diagnostic stack is converging around UDS (ISO 14229) as the ECU-resident application protocol. SOVD (ISO 17978-3:2026, published in March 2026) [4], as the service-oriented API layer for HPC-based, cloud-connected, and OTA-integrated environments, is gaining more attention in SDV/AI-DV oriented architectures. SOVD's REST/HTTP architecture, SOVD2UDS backward compatibility adapter, and OAuth 2.0/OpenID Connect-based security model provide solutions to the structural limitations of UDS in SDV-scale deployments, without requiring replacement of existing ECU infrastructure.

Some Chinese OEMs are adopting different strategies. They are building their own proprietary, vertically integrated diagnostic platforms. The solutions are also influenced by different national standards and requirements in China, such as MIIT data ownership requirements, GB/T regulatory frameworks, AI-first development models and relevant government strategic policies. Near-term domestic adoption of SOVD appears unlikely. Export compliance with UNECE R155/R156 and Right to Repair obligations is expected to necessitate a dual-stack diagnostic architecture across globally exporting Chinese OEMs by 2028 - 2030.

Future developments are trending toward AI-augmented diagnostics, cloud-edge inference architectures, and digital twin integration, with SOVD as the unified API surface for vehicle health management and software lifecycle governance. Vehicle diagnostic software and platform development strategy needs to be aligned with OEMs' overall software strategy, as diagnostic functions are increasingly standard functions, with OEM proprietary use cases often built on top.

Public authorities are often overlooked in the development, usage, and particularly the standardisation of diagnostics. The California Air Resources Board (CARB) requested a standardised format to monitor emissions and made an ensuing technical standard mandatory. Since 2018, Chinese authorities have required real-time monitoring (RTM) of new energy vehicles, with vehicle data reported in a defined and standardised format to authority servers. These legally mandated and enforced technical standards have had, and will continue to have, a significant impact on the future development of diagnostics. The next push in terms of standardisation will likely be the huge public interest in real-time monitoring of the safety and security of automated driving solutions. Given the dual-use nature of technical solutions for both commercial and public applications, OEMs and suppliers should seek close collaboration with the relevant public authorities, in order to benefit commercially from legally mandated diagnostics standards and formats.

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1 | Evolution of Vehicle Diagnostics

Over the last three decades, vehicle diagnostics has evolved from relying on technician expertise and intuition to a more stable and manageable tool-based, software-led approach. Early OBD standards have moved on to modern unified diagnostic protocols, with defined Diagnostic Trouble Codes (DTCs) and support for cross-brand diagnostic and repair tools. The development of modern diagnostic technology has been driven by several factors.

1.1 Key Drivers of Diagnostic Evolution and Industry Expectations

Vehicle diagnostics developments have been driven by a combination of technological, regulatory, commercial, and operational factors that have collectively elevated diagnostics from a workshop utility to a strategic function within the automotive value chain.

- **Vehicle Complexity and Cost Efficiency**

  Electrification of powertrains, expansion and of ADAS and autonomous driving functions, and transition to software-defined vehicle and zonal architectures have fundamentally expanded diagnostic scope. This new scope requires multi-domain fault detection across high-voltage systems, sensor fusion platforms, OTA management, and heterogeneous computing environments. For OEMs, early and accurate fault detection directly reduces warranty cost. For fleet operators or mobility service providers, predictive diagnostics can minimise vehicle downtime and optimise maintenance plans.

- **Safety and Reliability**

  Detecting safety-relevant faults before they result in functional failure is a fundamental requirement across the vehicle lifecycle. ISO 26262, as a functional safety standard, mandates systematic fault-detection functions[1]. Diagnostic functions can support fault assessment and safe-state management for safety-critical functions and systems. Diagnostics could also provide relevant mechanisms to continuously monitor and enforce these requirements throughout development, production, and aftersales.

- **Cybersecurity and Data Governance**

  Just as UNECE Regulations R155[11] and R156[12] mandate certified cybersecurity management systems and software update management systems for all newly type-approved vehicles, ISO/SAE 21434[9] defines the engineering requirements. These regulations require the interfaces to support secure access mechanisms and cryptographic authentication. For OTA functions, there must be full traceability of software update operations. New diagnostic functions and interfaces could potentially support these requirements.

- **Environmental Compliance**

  Emissions legislation, including Euro 6, Euro 7, and equivalent frameworks in other regions, mandates accurate, standardised fault reporting and real-time monitoring of in-vehicle emission-related systems. Diagnostic functions work as the major compliance mechanism to ensure deviations from accepted emission thresholds are detected, recorded, and reported according to relevant type-approval requirements.

- **Right to Repair**

  Regulations require OEMs to ensure independent workshops and aftermarket suppliers can access vehicle repair information via appropriate diagnostic interfaces[14]. Simply restricting ECU access through software controls may violate regulations. Standardised interfaces and platforms for specific operations will help OEMs fulfil regulatory requirements while maintaining security.

- **User Experience and Telematic Services**

  Customer expectations are increasing for real-time vehicle health monitoring, proactive service notifications and scheduling, and remote fault resolution. This has also elevated diagnostics beyond the workshop environment. Diagnostic functions could combine telematic services and use phone apps or OEM customer portals as touchpoints to make functions accessible to customers. This will become increasingly important to enhance product quality and brand loyalty.

Combined, these forces have repositioned diagnostics from a simple workshop tool to a strategic enabler of safety compliance, operational efficiency, regulatory conformity, and customer values, and something that is integral to the design, operation, and lifecycle management of modern vehicles.

1.2 Key Stakeholders in the Vehicle Diagnostic Ecosystem

The evolution of vehicle diagnostics has had substantive and differentiated implications across the automotive ecosystem. Each stakeholder group is affected by diagnostic functions in distinct ways and places specific demands on them in line with their operational priorities and compliance obligations.

- **OEMs**

  As well as delivering products, OEMs' priorities include achieving regulatory compliance, enhancing customer satisfaction, and lowering aftersales costs. Advanced diagnostic capabilities enable OEMs to design vehicles with embedded self-monitoring functions, supporting continuous quality assurance, accelerated software validation, and more efficient development cycles. OEMs must take responsibility for ensuring that diagnostic systems satisfy type approval requirements, cybersecurity, and lifecycle compliance.

- **Independent Service Networks and Authorised Workshops**

  For independent operators, access to standardised diagnostic data, which is reinforced by Right to Repair legislation, ensures equal participation in the vehicle service market, alongside authorised dealer networks.

- **Regulatory Authorities**

  Standardised diagnostic data provides regulatory authorities with a reliable and auditable mechanism for a range of oversight activities, for example, emissions compliance verification, cybersecurity incident monitoring, and enforcement of software update traceability requirements. Diagnostic standards further enable regulators to define manufacturer-neutral compliance frameworks.

- **Fleet Operators and Mobility Service Providers**

  Real-time access to diagnostic interfaces and relevant service data enables fleet operators to evolve maintenance routines from passive to predictive. This can reduce vehicle downtime and unscheduled maintenance, and also provide a reliable way for large mobility and logistic operators to reduce operational costs.

- **End Consumers**

  Standardised and connected diagnostic capabilities enable faster and easier issue detection and resolution. Vehicle health status can be seen more easily via vehicle apps. Remote diagnostic access also reduces the likelihood of having to make unscheduled workshop visits for repairs or breakdowns.

1.3 A Timeline of Diagnostic Technology Progression

The development of diagnostic standards reflects a progressive response to increasing vehicle complexity, regulatory requirements, and the transition to connected, software-defined vehicle architectures.

Before the introduction of OBD-II in 1996[33], diagnostic functions were entirely proprietary. OEMs were making their own solutions and tool chains. OBD-II established the first universal diagnostic framework with a standard connector (SAE J1962)[16], unified DTC definitions and communication protocols across all US passenger vehicles, followed by EOBD in Europe from 2001[34].

The consolidation of ECU-level diagnostic services into a single transport layer-independent standard was achieved with the introduction of UDS (ISO 14229-1) in 2006[3]. This defined structured services for fault memory (DTC code), session control, security access, data management, and ECU flashing. UDS remains widely implemented across OEMs and Tier 1 suppliers. As UDS is transport layer-independent, it operates outside of the underlying vehicle network architecture, whether CAN, FlexRay or automotive Ethernet. DoIP (ISO 13400)[5] extended UDS communication to Ethernet, addressing the bandwidth requirements of HPC-based architectures.

Remote diagnostics before SOVD: ISO 20080 (first published 2019, amended 2021)[10] defined general requirements, use cases, and scenarios for remote diagnostic support, building on the Extended Vehicle (ExVe) framework of ISO 20077/20078. Crucially, it standardised remote access while preserving the UDS service semantics underneath. That means the same fault-memory, routine-execution, and data-access operations a workshop tester would issue locally could now be invoked from a backend. Because it operated over the ExVe web interface rather than a point-to-point session, ISO 20080 already accommodated remote and effectively multi-client access before SOVD. It remains the conceptual reference point against which SOVD's remote use case should be understood.

The current development standard is SOVD (ASAM / ISO 17978-3), which was first released in 2022 and reached ISO publication in March 2026. SOVD introduces a service-oriented, REST/HTTP-based diagnostic interface for software-defined vehicles. SOVD offers self-describing APIs, cloud-native remote access, and lifecycle-integrated operations. When used together, SOVD complements UDS functions, with protocol adapters bridging SOVD service calls to underlying UDS-based ECU communications.

Table. Comparative Overview: OBD-II, UDS, and SOVD	**OBD-II (SAE J1979 / ISO 15031)**	**UDS (ISO 14229-1)**	**SOVD (ASAM / ISO 17978-3)**
Introduction	1996 (US mandatory)	2006	2022 (ASAM)[18]; March 2026 (ISO)[4]
Primary Purpose	Emissions compliance monitoring	ECU-level diagnostic services	SDV service-oriented diagnostics
Communication Model	Session-based, query-response	Session-based, point-to-point	Stateless REST/HTTP, self-describing
Transport Layer	CAN (ISO 15765), K-Line	CAN, CAN-FD, Ethernet/DoIP	Ethernet, 4G/5G, cloud
Data Format	Standardised DTCs, PIDs	Service identifiers (SIDs), ODX	JSON, OpenAPI
Security Model	None	Challenge-response (SID 0x27/0x29)	OAuth 2.0, certificate-based
Access Modes	Workshop only	Workshop, limited remote	Proximity, remote, in-vehicle, cloud
OTA Integration	None	Partial (ECU flashing 0x34–0x37)	Native - lifecycle-integrated
Regulatory Mandate	EPA/CARB (US), EOBD (EU)	Industry standard	ISO 17978-3; UNECE R155 / R156 aligned
Backward Compatibility	N/A	Replaces KWP2000	SOVD2UDS adapter bridges legacy ECUs

2 | Current Diagnostic Standard: UDS and Its Ecosystem

The Unified Diagnostic Services protocol (UDS, ISO 14229-1) is the global standard for ECU-level vehicle diagnostics, first published by the International Organization for Standardization in 2006[3], succeeding ISO 14229:1998, and last revised as ISO 14229-1:2026[2]. It defines an application-layer protocol that enables diagnostic clients to access and control functions in any compliant ECU, including both OEM-independent functions and specific proprietary implementations.

2.1 UDS Architecture and Service Model

UDS operates at the application layer of the OSI model, positioned above transport and network layers provided by ISO 15765-2 (DoCAN, covering classical CAN and CAN FD) or ISO 13400 (DoIP)[5]. This transport independence is a fundamental architectural property, which means the same UDS service request is valid whether transmitted over a legacy CAN bus or a gigabit automotive Ethernet link, allowing a single diagnostic application layer to span across different vehicle network topologies.

UDS organises its capabilities into functional groups, each covering a distinct area of vehicle interaction. Together they provide diagnostic tools with a complete set of instruments to inspect, configure, test, and update any compliant ECU.

2.2 Supporting Standards and Ecosystem

UDS does not operate in isolation. It is the central pillar of a broader diagnostic group of complementary standards that govern transport, data description, test execution, tool interoperability, and regulatory compliance.

Table. UDS Standard and Relevant Protocol

Standard	Full Name	Role
ISO 13400[5]	DoIP - Diagnostics over Internet Protocol	UDS messages transport over Ethernet; enables high-bandwidth, multi-ECU parallel diagnostics
ISO 22901[6] / ASAM MCD-2D	ODX - Open Diagnostic Data Exchange	XML-based format for describing diagnostic content (DIDs, DTCs, routines); decouples data from tool
ISO 13209[7]	OTX - Open Test Sequence Exchange	Standardised language for diagnostic test sequences and repair procedures
SAE J2534 [17]	Pass-Thru Programming Interface	Hardware-independent PC interface to vehicle; enables aftermarket tools to access UDS/OBD without OEM-proprietary hardware
ISO 27145	WWH-OBD[8] - World Wide Harmonized OBD	UDS-based extended OBD for heavy-duty vehicles; EU and UNECE mandated
SAE J1979-2[15]	OBDonUDS	Transition of OBD-II services from legacy SAE J1979 onto a UDS application layer; Required by CARB from MY2027 (light-, medium- and heavy-duty)[75]
ISO 14229-3/5/7	UDS on CAN / DoIP / LIN	Transport binding specifications per physical medium

UDS works together with other communication protocols in the vehicle system to ensure the modern diagnostic functions work for different tasks.

Figure 1 provides an overview of the diagnostic-relevant protocols in a layered approach mapping to the OSI reference model.

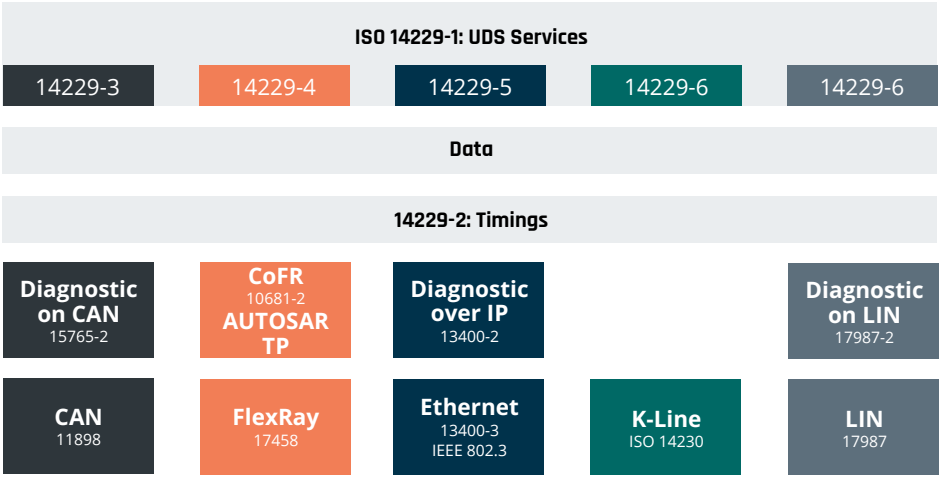


Figure 1. UDS Protocol with Other In-Vehicle Communication Standards

2.3 UDS Strengths and Limitations in the SDV/AI Enabled Context

UDS remains the uncontested global standard for ECU-level diagnostics and will continue to serve as the foundational in-vehicle communication layer for the foreseeable future. Together with its associated protocols, UDS supports most in-vehicle communication technologies used in modern vehicles. However, the shift toward software-defined vehicles, zonal and HPC-based architectures, continuous OTA operations, cloud-native service delivery, and increased demand for remote access, has exposed UDS' structural limitations.

Strengths

- **Universal Adoption:** Specified in ISO 14229 and implemented across virtually all OEMs and Tier 1 suppliers globally; many automotive diagnostic toolchains and EOL systems are built on UDS.
- **Transport-Agnostic:** A single application layer runs unchanged over CAN (ISO 15765), CAN-FD, LIN, FlexRay, and Ethernet/DoIP (ISO 13400), providing a consistent interface across all vehicle network types.
- **Regulatory Anchor:** Referenced or mandated by SAE J1979-2 (OBDonUDS, US), ISO 27145 (WWH-OBD, EU heavy-duty).
- **Mature, Standardised Toolchain:** Supported by a complete ecosystem of ODX (ISO 22901), OTX (ISO 13209), J2534 pass-thru hardware, and ASAM data formats, providing comprehensive development, validation, and service infrastructure.
- **Structured Security Model:** Security Access service and Authentication service[2] provide challenge-response and certificate-based controls for restricted diagnostic operations.

Limitations in the SDV Context

- **ECU-centric, Point-to-Point Model:** ISO 14229 was designed for a single tester communicating with a single ECU per session; it has no native concept of multi-domain, fleet-wide, or function-level diagnostic addressing, creating scalability constraints in HPC-based architectures where software functions span multiple compute domains.
- **Session-Based Communication:** The requirement to establish and actively maintain diagnostic sessions is structurally incompatible with stateless, cloud-native service models and creates fragility over intermittent cellular connections.
- **No Runtime Self-Description:** UDS clients depend entirely on offline ODX files to understand what a given ECU exposes; there is no mechanism for a tool to dynamically discover available diagnostic services or data at runtime.
- **OEM-Specific Extensions:** Despite ISO standardisation, manufacturers routinely define proprietary contents, security algorithms, and session behaviours, reducing interoperability and creating tool fragmentation across vehicle programmes.
- **Limited Cloud and Fleet Scalability:** The UDS session model, addressing scheme, and security mechanisms were not designed for concurrent multi-client, cloud-mediated access across large vehicle fleets.
- **No Native Lifecycle Integration:** UDS protocol contains no structured mechanisms for lifecycle-aware diagnostics, such as software version governance, OTA workflow validation, or tamper-proof audit logging aligned with UNECE R155/R156 cybersecurity obligations.

These limitations demonstrate that UDS is suitable for ECU-resident diagnostic services, governing all ECU-level diagnostic logics, while the emerging diagnostic standard, SOVD, provides the external-facing, service-oriented API layer above it to fulfil the new requirements.

3 | Diagnostics in SDV/AI Enabled Architecture

The development of Service-Oriented Vehicle Diagnostics (SOVD) is a direct response to the structural shift from distributed ECU networks toward software-defined vehicles (SDV). The mainstream vehicle architectures are built on high-performance computers, centralised computing architectures, zonal topology, and continuously updated software stacks enabled through over-the-air (OTA) updates. As defined by ASAM and standardised under ISO 17978, SOVD was explicitly created to address diagnostic gaps when traditional ECU-centric protocols are applied to HPC-based, service-oriented architectures.[18]

3.1 Diagnostics for the Software-Defined Vehicle

The transition to software-defined vehicle architecture introduced new requirements for diagnostic functions, spanning network topology, software design, cybersecurity, OTA software lifecycle management, regulatory compliance, and development processes. Each driver below directly links architecture or regulatory changes to the relevant diagnostic requirements.

Zonal Architecture Transition

As vehicles migrate from distributed, domain-based ECU networks to zonal or HPC-centric architectures, diagnostic functions need to shift from point-to-point, ECU-centric addressing to zone-aware, hierarchical topologies. Each zonal controller will have its own diagnostic endpoints, aggregated centrally via a diagnostic gateway or diagnostic manager. When cross-zone function increases, the implementations must support cross-zone fault correlation and dynamic service discovery. Static address-based (legacy UDS-over-CAN) routing cannot do this.

Networking and Connectivity (In-Car and Telematic Services)

The transition from CAN/CAN-FD to automotive Ethernet (IEEE 802.3 TCP/UDP for DoIP transport; IEEE 802.1AS / TSN for time-critical traffic) requires diagnostic implementations to manage significantly higher throughput, time-sensitive networking constraints, and parallel multi-ECU sessions, which replace the sequential, single-channel model of CAN-based UDS. Beyond the vehicle boundary, telematics-integrated diagnostics must operate over mobile network and cloud interfaces, supporting real-time remote diagnostics and fault analysis, while maintaining end-to-end encryption across all connectivity layers.

Software Architecture

SDV software platform design requires diagnostic functions to be implemented as modular, independently deployable software components. These components should support separate update and validation cycles. Implementations should specify standardised REST/OpenAPI interfaces with semantic versioning and backward compatibility guarantees as best practice to ensure workshop tools, cloud backends, and mobile applications remain functional across platform and ECU software generations.

Cybersecurity

In compliance with UNECE R155[11] and ISO/SAE 21434[9] which require OEMs to implement cybersecurity measures to detect and respond to attacks, certain capabilities are needed to protect against unauthorised access and support forensic data investigations. To fulfil the requirements, a zero-trust access model which requires authentication and authorisation for every request is recommended for diagnostic session implementations regardless of client type (workshop tester, OEM backend, or in-vehicle service). Diagnostic operations involving security-relevant access, data modification, software transfer, or remote sessions should generate an audit log, traceable across the full vehicle lifecycle. The audit log as required by UNECE R155 is necessary to support, for example, incident response, regulatory audits, and post-market cybersecurity surveillance obligations.

OTA and Lifecycle Management

Diagnostic functions should be integrated with OTA update workflows, providing pre-update health verification, real-time progress monitoring, post-update software version validation, and secure rollback processes where technically possible. Across the full vehicle lifecycle, from end-of-line testing through end-of-life decommissioning, the implementations must maintain continuous, structured lifecycle records covering software version histories and fault logs.

Regulation and Homologation for Different Regions

Diagnostic implementations must simultaneously satisfy divergent regional regulatory frameworks for a unified global rollout of the product.

Table. Overview of Regulatory Frameworks

Region	Framework	Key Requirement
Europe & adopting countries	UNECE WP.29 R155/R156	Cybersecurity management; OTA traceability
United States	SAE J1979-2 (OBDonUDS)	Required by CARB from MY2027; OBD services over UDS layer
EU heavy-duty	ISO 27145 (WWH-OBD)	UDS-based extended emissions diagnostics
China	MIIT / GB-T standards	Data sovereignty; OEM-specific reporting formats
L3/L4 autonomous platforms	UNECE R157; EU Delegated Acts	Structured reporting of safety-critical fault events for type approval

This necessitates a configurable, region-aware diagnostic compliance layer that activates or restricts services, data formats, and access permissions based on the vehicle's homologation region.

Development Process

Agile and CI/CD-based SDV development requires diagnostic functions to be integrated into automated build, test, and validation pipelines, with virtual ECU (vECU, including vHPC) environments enabling diagnostic interface testing early in the development cycle. This can reduce hardware dependency and support parallel development across distributed teams. Under ASPICE, every diagnostic use case must be systematically specified, implemented, and validated with full requirements-to-test traceability. ISO 26262 demands additional traceability obligations for safety relevant diagnostic functions. ISO/SAE 21434 requires equivalent traceability for security-relevant diagnostic work products. These frameworks represent a substantially more rigorous process than legacy diagnostic development. Dedicated diagnostic architects embedded throughout the development lifecycle will help to solve this challenge.

3.2 What Makes SOVD Different?

SOVD defines diagnostics as a set of modular, service-based APIs. It enables secure, on-demand access to diagnostic data across ECUs, HPCs, and backend systems. The standard was designed to address new requirements for the next generation of connected and autonomous vehicles.

SOVD introduces a modern, web-based diagnostic architecture built on proven IT technologies like HTTP/REST and JSON, with OAuth 2.0/OpenID Connect as the reference approach for authentication and authorisation. It can build upon capabilities within previous diagnostic stacks, like UDS, with flexible, service-oriented APIs that support diagnostics across the entire vehicle lifecycle.

Key Features of SOVD

- **Service-Oriented Architecture**

  Diagnostics are exposed as modular services. SOVD can enable dynamic access, task and capability management, and integration with backend systems.

- **Cross-Domain Compatibility**

  SOVD can work across legacy ECUs and modern high-performance computers (HPCs), bridging traditional UDS-based systems and new platforms, and translating API requests into UDS commands when required.

- **Offline and Remote Access**

  Offline diagnostics are typically performed in a workshop, with the tester connected to the vehicle via Wi-Fi or Ethernet, without cloud dependency. SOVD also supports diagnostics via Wi-Fi, 4G/5G, and cloud platforms, enabling proximity, in-vehicle, and remote use cases.

- **Tracing Capability**

  SOVD supports data streaming and event subscription capabilities. SOVD uses WebSocket or server sent events (SSE) extensions for data streaming and event handling. These capabilities enable continuous signal monitoring, fault event notification, and diagnostic trace collection during vehicle operation or development validation, without requiring a physical data logging device connected to the OBD port. These streaming capabilities may reduce reliance on dedicated data loggers for specific development and in-service monitoring use cases, though full functional equivalence with dedicated logging hardware remains a future development trajectory.

- **Security by Design**

  Built-in authentication, authorisation, and encrypted communication meet cybersecurity mandates like UNECE R155[11].

- **Scalability**

  SOVD supports different vehicle platforms, amid increasing architectural complexity. It supports modular deployment, with standard interfaces based on mature network application technologies, like RESTful, JSON, and OAuth 2.0.

- **The Standardised Data Access Layer**

  As vehicular computational power increases, and use cases become data-driven, SOVD may in the future provide a unified, interoperable data layer that powers cloud-edge hybrid AI use cases.

SOVD standard is designed to support the entire vehicle lifecycle with the following key tasks.

- **Component Validation**

  SOVD interfaces allow suppliers to validate and log component health (e.g. battery modules and ECUs) both at the component level prior to vehicle integration, and at the system level after integration into the vehicle – using standardised RESTful service calls to verify functional readiness and capture baseline health data for traceability and quality records.

- **Vehicle Assembly**

  During build, SOVD enables automated system checks, configuration validation, and fault logging across distributed systems.

- **End-of-Line Testing**

  Final diagnostics are run via SOVD services to ensure vehicle readiness and baseline health data capture.

- **In-Use Operation**

  Real-time diagnostics via SOVD enables the retrieval of relevant vehicle health data for real-time monitoring and supports additional services like predictive maintenance and remote fault resolution. In addition, SOVD's authorisation model governs who may issue a request, not whether the vehicle and occupant are in a state where executing it is safe. This in-vehicle consent and state-gating logic sits above the diagnostic standard to ensure a safe remote operation of diagnostic access. HMI engineers should work closely with diagnostic experts to define appropriate user interaction and consent concepts. These considerations are often overlooked due to separate development workstreams.

- **After-sales and Workshop Service**

  Workshops access standardised diagnostic services across brands and platforms, improving efficiency and reducing training overheads.

- **Fleet and Mobility Management**

  Cloud-based SOVD implementations enable centralised health monitoring, usage analytics, and lifecycle optimisation.

- **Vehicle Disposal and Recycling**

  At end of life, SOVD interfaces can provide authorised dismantlers and recyclers with structured access to component health data, including battery degradation state, software version records, and system deactivation status, which could support reusability assessments, second-life battery qualification, and safe high-voltage system decommissioning.

This end-to-end applicability makes SOVD a strategic enabler and not just a technical upgrade.

The complete modern diagnostic function and SOVD architecture adopts a component-based and layered approach inspired by the AUTOSAR Adaptive Platform.

Layer 1 - SOVD Gateway

The SOVD Gateway is the single, vehicle-resident entry point for all diagnostic requests. It acts as an HTTP reverse proxy, receiving REST requests from any client type[21] – workshop tester, cloud backend, mobile application, or in-vehicle service – and routing them to the appropriate internal component. Each vehicle hosts a single SOVD Gateway instance as defined by the AUTOSAR Adaptive reference architecture.

Layer 2 - Diagnostic Manager

The Diagnostic Manager implements diagnostic services within the vehicle software platform – covering fault memory access, session control, routine execution, and data reading and writing. Depending on the platform architecture, this role may be fulfilled by different components: the DCM in AUTOSAR Classic environments, the ara::diag-based stack in AUTOSAR Adaptive, or a containerised diagnostic service in Linux-based SDV platforms.

Layer 3 - SOVD2UDS Adapter (Classic Diagnostic Adapter)

The SOVD2UDS Adapter provides backward compatibility with UDS-based ECUs on the vehicle network[21]. It translates SOVD REST service calls into ISO 14229-compliant UDS requests, forwarding them over DoIP or CAN-FD to the target ECU and converting the UDS response back into a JSON/REST format for the SOVD client[21]. This adapter is the critical bridge that enables full SOVD deployment without replacing any existing ECU infrastructure.

Besides the three architectural layers, backend and connectivity capabilities are important for enabling remote SOVD access through different communication technologies. SOVD requests from OEM backends and fleet management systems can be routed to the SOVD Gateway via HTTP forwarding. How different connectivity solutions are implemented is left to OEMs to decide, ensuring autonomy of backend infrastructure across the industry.

3.3 Integration into Modern E/E Architectures

SOVD is designed to fit into modern E/E architecture such as zonal or centralised computing with different HPCs. Leading OEM platforms (MB.OS, BMW Neue Klasse, VW SSP, Stellantis STLA Brain, Toyota Arene) are migrating from domain to zonal/HPC architectures between 2024 and 2029, while older programmes will remain domain-based for years to come. SOVD will provide a range of benefits for modern architectures.

- **Zonal Architecture**

  SOVD service components can be deployed on zonal controllers, enabling localised diagnostics and reducing wiring complexity. Each zone can expose its own diagnostic endpoints, managed centrally via the SOVD Gateway.

- **Centralised HPC Architecture**

  In SDVs, diagnostics are consolidated on HPCs. SOVD integrates directly into these platforms, supporting dynamic service discovery, real-time fault analysis, and secure OTA updates.

- **Cloud-Connected System**

  SOVD's stateless, RESTful design enables native integration with backend systems, supporting predictive diagnostics, remote servicing, and compliance reporting. Remote diagnostic functions and capabilities are necessary enablers when the connected vehicle penetration rate is high.

This architectural flexibility ensures SOVD can scale with evolving vehicle platforms, fulfil regulatory requirements, and enable new business models.

3.4 How SOVD Could Support OEMs with Software-Defined Vehicles

As OEMs begin to implement software-defined vehicle systems and use cases, SOVD delivers tangible benefits across the vehicle lifecycle.

- **Reduced Interface Fragmentation**

  One standard interface replaces multiple proprietary protocols, simplifying integration and tool development with external devices while allowing underlying devices, especially legacy devices, to remain unchanged.

- **Faster Development and Testing**

  Modular diagnostics with clearly defined interfaces can enable parallel development and easier validation across platforms, quickening overall development and integration.

- **Improved Serviceability**

  Remote diagnostics and OTA capabilities reduce workshop visits and enable proactive maintenance, with measurable downstream effects on warranty cost and NPS at OEMs that have deployed both (e.g. BMW Remote Software Upgrade, Mercedes-Benz Online Services).

- **Lifecycle Efficiency**

  SOVD provides a single diagnostic interface from vehicle production, through aftersales, to end-of-life processing. It replaces phase-specific proprietary tools and reduces fragmentation. Software updates and fault resolution can be performed via a unified service-call interface at every stage.

- **Regulatory Readiness**

  Built-in support for cybersecurity and data transparency aligns with emerging global regulations.

3.5 SOVD Roadmap: From Concept to Compliance

The evolution of SOVD reflects the industry's response to increasing regulatory demands, software complexity, and the need for lifecycle-integrated diagnostics. As the standard matures, its roadmap is shaped by both technological innovation and alignment with global mandates such as UNECE WP.29[11], ISO 21434[9], and Right to Repair legislation.

SOVD has evolved through three development phases. SOVD 1.0[18], was released by ASAM in 2022, followed by AUTOSAR Adaptive integration guidance in releases R22-11 and R23-11. Together, these specifications established the core architectural principles of SOVD: HTTP/REST, JSON, OAuth 2.0, self-describing APIs, and stateless communication, while maintaining compatibility with UDS through backward-compatible adapters.

SOVD 1.1[19] expands the standard with trigger-based and cyclic data queries, execution of diagnostic scripts, and the foundation for legislative diagnostic applications, which extend SOVD's applicability across the full vehicle lifecycle from development through legal and technical inspection. These SOVD features support OEM compliance efforts to meet R155/R156 audit-logging and OTA-traceability.[64]

SOVD 1.2.0[20], currently under development with a planned release in 2028, targets enhanced multi-core HPC and zonal architecture support, dynamic diagnostic content discovery, and deeper OTA and backend analytics integration. It is being developed through open ASAM workshops with synchronised ISO WG2 alignment.

Standardisation Outlook: Integration into ISO 17978

The development of SOVD within ASAM and ISO is closely coordinated. ISO 17978-3 reached FDIS status in October 2025 and was released in March 2026[4]. ISO 17978-3 incorporates the content developed as ASAM SOVD v1.1[19]; as of October 2026, the standalone ASAM v1.1.0 release is still pending. The ISO 17978 series covers the full SOVD scope, including remote, proximity, and in-vehicle use cases, using HTTP/REST, OpenAPI, and OAuth 2.0 within the Extended Vehicle (ExVe) framework defined by ISO 20077. This ensures alignment with the broader ISO vehicle connectivity ecosystem.

Work on ASAM SOVD v1.2.0 launched in November 2025. It is due for release in March 2028, and will deliver enhanced support for multi-core HPCs, zonal architecture, dynamic diagnostic content discovery, and expanded OTA integration. ASAM is also extending the OTX (Open Test Sequence eXchange, ISO 13209) standard with an SOVD execution profile, enabling diagnostic test logic to be written and executed against the SOVD API without any automotive-specific stack on the client side.

4 | Diagnostic Use Cases and the Standards That Support Them

4.1 Use Cases Across the Whole Vehicle Value Chain

Historically, vehicle diagnostics has been treated as a vehicle-programme expense with costs justified and recovered as part of each new platform's development budget. The diagnostic stack now serves as a strategic interface between OEMs and their vehicle fleets, shifting value from one-time embedded software licences toward continuous, parc-driven services.

Berylls by AlixPartners estimates that the total addressable market (TAM) will grow from roughly EUR 14 billion in 2025 to roughly EUR 34 billion in 2035, at about 9 percent CAGR. The headline increase matters less than the shift in value sitting behind it. Embedded diagnostics software is projected to fall from 70 percent of TAM to 28 percent. Remote and connected services will rise from 8 percent to 33 percent over the same period. Two of the seven value-chain domains (In-Use Monitoring & Analytics, and Remote & Connected Services) account for most of the net growth. Diagnostics is becoming a vehicle-parc business, with value derived from services delivered across the fleet.

4.2 Three Business Models Drive the Diagnostics Market

Diagnostic markets are typically segmented in three ways: by pricing model (one-time licence vs. subscription), by deployment (on-board vs. off-board), and by customer (OEM vs. workshop vs. Tier 1 and tool providers).

The market comprises seven domains, which together cover 30 named use cases.

Value-Chain Domain	Representative use cases	2025 to 2035 TAM (CAGR)
1. Engineering & Development	ECU validation software Remote debug tooling SOVD test clients CI/CD diagnostic integration HIL/SIL bench orchestration VirtualECU diagnostic testing	EUR 180 M to 224 M (~2%)
2. Manufacturing & End-of-Line	EOL flashing software Configuration validation MES-integrated diagnostic services Pass/fail diagnostic logging	EUR 568 M to 722 M (~2.4%)
3. Aftersales & Service	OEM-authorised dealer diagnostic platforms Independent multi-brand workshop software OBD diagnostic reader / consumer apps Guided diagnostics and service workflow software	EUR 1.3 B to 2.7 B (~7.5%)
4. In-Use Monitoring & Analytics	Warranty analytics Predictive quality models Fleet health / predictive maintenance Use based Insurance Battery state-of-health analytics	EUR 595 M to 7.0 B (~28%)
5. Compliance & Validation	Type approval diagnostic validation OBD compliance testing software R155 / R156 diagnostic audit logging and validation	EUR 454 M to 2.6 B (~19%)
6. Remote & Connected Diagnostic Services	Remote ECU coding Feature-on-demand activation via diagnostic APIs OTA pre/post-update diagnostic validation Rollback orchestration / post-update health checks Diagnostic security monitoring	EUR 1.1 B to 11.1 B (~26%)
7. Embedded Diagnostic Software	Embedded diagnostic communication / runtime stacks Secure boot / ECU health diagnostic software BMS diagnostic software	EUR 9.8 B to 9.3 B (~ –0.5%)

4.3 Domain Deep Dive

4.3.1 Engineering & Development

Engineering and development tooling represents a relatively small market in absolute terms. It scales with programme and developer counts, not with the vehicle parc, and headline growth is therefore muted. Diagnostics is increasingly being integrated into the CI/CD pipeline rather than being deferred to late-cycle bench validation.

The mechanism is SOVD plus OTX. SOVD (defined by ASAM and standardised in ISO 17978-1/-2/-3) exposes diagnostic services through a REST/HTTP/JSON API and removes the dependency on offline ODX (ISO 22901) files during early development. The OTX SOVD execution profile (ISO 13209) lets diagnostic test sequences run against SOVD interfaces without an automotive-specific stack on the client side. Combined with virtual ECU and virtual HPC environments, this allows earlier and geographically distributed validation.

Within the segment, SOVD-native test clients will grow from a near-zero base to roughly EUR 8 million by 2035 (around 54 percent CAGR). Classical HIL/SIL bench orchestration is expected to remain relatively flat as virtual testing offsets growth in physical test-bench deployments.

The standardised API surface lowers the technical barrier to entry. Certification depth, integration with the vehicle programme, and tool-chain breadth still favour the incumbents (Vector, ETAS, dSPACE, Elektrobit, KPIT). New entrants compete most strongly in the SOVD test-client niche, where work is greenfield.

4.3.2 Manufacturing & End-of-Line (EOL)

EOL diagnostics has traditionally been a pass/fail flashing activity: confirmation that wiring, calibration, and configuration are correct on a vehicle-by-vehicle basis. Three pressures are evolving the market:

- **Software-Defined Configuration Complexity.** Every vehicle leaving the line is effectively unique.
- **Electrification.** Battery-pack attestation, high-voltage validation, and BMS calibration are now EOL-critical activities.
- **Evidentiary Obligations.** UN R155 and the EU battery passport (Reg. 2023/1542) require EOL records to be audit-grade across the lifecycle, not a stamp at end-of-line.

The standards mechanism replaces vehicle-specific UDS (ISO 14229) sequences with MES-integrated SOVD API calls. The same diagnostic logic is executed programmatically through a uniform REST API, with end-to-end traceability. The growth rate of traditional EOL flashing (around EUR 300 million today) tracks vehicle production at low single digits. MES-integrated diagnostic services and configuration validation are predicted to grow at roughly 10 percent and 3 percent CAGR respectively, as variant complexity and attestation requirements expand.

Standalone EOL-flasher providers face commoditisation. Vendors that combine SOVD-compliant logic with native MES integration can build a defensible position. The EOL output ceases to be a stamp and becomes the foundational data layer for warranty analytics, field quality, and lifecycle compliance.

4.3.3 Aftersales & Service

Aftersales is the steady middle of the market, accounting for around 9 percent of TAM in 2025, and forecast for around 8 percent by 2035. OEM-authorised dealer platforms remain a mature segment of around EUR 540 million, growing at a rate under 1 percent. Independent multi-brand workshop software is growing steadily at around 5 percent. Consumer-grade OBD app software will reach around EUR 800 million by 2035 as connected-vehicle ARPU scales.

The underlying driver of these developments is regulation. EU Regulation 2018/858 requires OEMs to provide non-discriminatory access to vehicle repair and maintenance information. The Massachusetts Right to Repair law (Question 1, 2020) and the proposed federal REPAIR Act define equivalent requirements in the US. SOVD provides the standardised API surface through which this access can be delivered.

One outstanding question is how the cybersecurity gating – mandated by R155 (credential issuance, session security, vehicle access management) – interacts in practice with the right of independent operators to access diagnostic data. This boundary will be determined through implementing acts and case law in the coming years, not through standards alone.

For established providers (Bosch, Autel, Launch, and Snap-on), the substrate change matters more than the protocol change. A standardised REST API means multi-brand diagnostic functions can be delivered through browser or mobile interfaces without proprietary scan-tool hardware. Whoever holds the diagnostic interface holds the warranty analytics pipeline, the feature activation rights, and the customer relationship across the vehicle's life. The fight for SOVD access governance is therefore more consequential.

Meanwhile, guided diagnostics will play a more important role in the aftersales process, supporting the investigation and resolution of issues identified through predictive analytics. For example, a diagnostic signature might indicate a fault lies with part A in roughly 80 percent of cases and part B in 15 percent, with the remainder undetermined. Remote diagnostics will direct the workshop to run a specific local test to confirm the root cause. For parts producers, the steps are recorded and status is transferred to backend for analysis and stock optimisation.

4.3.4 In-Use Monitoring & Analytics

This is the first of two domains where diagnostics meets OEM P&L directly. Four subsegments drive the growth: battery state-of-health analytics (EUR 270 million to ~EUR 3.3 billion at ~28% CAGR); predictive quality models (EUR 80 million to ~EUR 2.2 billion at ~39% CAGR); fleet health and predictive maintenance (~EUR 200 million to ~EUR 1.4 billion at ~22% CAGR); and warranty analytics (smaller in absolute terms, but operationally well-established).

The technical enabler is SOVD's bulk-data and streaming surface, including the WebSocket and Server-Sent Events extensions defined in ISO 17978-3. Continuous DTC and signal streaming from vehicles in the field to backend analytics replaces the older pattern of fault-log collection at scheduled service visits and compresses the feedback loop from field event to engineering action.

Berylls research shows that credible battery health data has become a key input for the residual value of EVs. Berylls estimates that the global connected passenger-car parc will grow almost threefold, from around 450 million vehicles in 2025 to around 1.3 billion by 2035 (Berylls estimate; see Market Sizing Methodology). The binding constraint at most OEMs in this domain is not technical; field data exists but does not consistently reach the engineers who could act on it.

4.3.5 Compliance & Validation

Compliance and validation are expected to grow from EUR 454 million in 2025 to EUR 2.6 billion by 2035, a 19% CAGR. This is one of the quickest growth rates seen, even though nothing in this domain differentiates one OEM from another. The driver is a regulatory floor that keeps rising, and growth is concentrated in a single subsegment.

Type approval diagnostic validation grows to EUR 227 million at 2% CAGR, tracking the rate for new vehicle programmes. Euro 7 (Regulation (EU) 2024/1257), adopted in 2024, largely retains the Euro 6 exhaust limits for cars and vans but adds a requirement for on-board monitoring (OBM), which must be demonstrated at type approval[76]. OBD compliance testing software will stay small at EUR 7 million, anchored to programme counts, and is where the emissions protocols land. SAE J1979-2 (OBDonUDS) is required by CARB from the 2027 model year for light-, medium- and heavy-duty vehicles[75], while WWH-OBD (ISO 27145) covers heavy-duty vehicles in the EU. EPA's federal rule adopts the CARB requirements for light- and medium-duty vehicles, although a May 2026 EPA proposal would defer them to MY2029[77]. The growth is in R155/R156 diagnostic audit logging and validation, which will expand from EUR 268 million to EUR 2.4 billion at 24% CAGR, to become the dominant subsegment by 2035. R155 and R156 are not emissions rules; they demand lifecycle evidence of cybersecurity and software-update management (logs, test records, audit trails) produced by tooling that is itself auditable. That evidence must be generated with every vehicle programme and every OTA update. Automated driving adds another layer: the new UN Regulation on Automated Driving Systems (ADS), adopted at WP.29 in June 2026 and expected to enter into force in early 2027, requires a data storage system for automated driving (DSSAD) and continuous in-service monitoring and reporting.[78]

Two forces are pulling the market in opposite directions. Consolidation is one: as the tooling matures, OEMs will fold compliance into the engineering toolchains they already license, and standalone compliance specialists face margin compression. Regional divergence is the other. China operates a parallel regulatory regime, based on the mandatory national standards GB 44495-2024 (vehicle cybersecurity)[73] and GB 44496-2024 (software update)[74], in force for new type approvals from January 2026. These standards sit above the earlier GB/T recommended standards, which are reinforced by the 2025 MIIT/SAMR restrictions on over-the-air updates and the 2026 MIIT/CAC cross-border data transfer guidelines. That is a separate architecture with its own tests, evidence formats and data localisation rules, not a variant of the UN model. A compliance toolchain built for a single global market cannot serve a US, EU and China split, which is the structural reason the subsegment keeps growing even as individual tools commoditise.

4.3.6 Remote & Connected Diagnostic Services

By 2034, Remote & Connected Diagnostic Services (~EUR 9.6 billion) will overtake Embedded Software (~EUR 9.4 billion), becoming the largest single domain contributor. OTA pre/post-update diagnostic validation will reach around EUR 4.3 billion by 2035 (~23% CAGR), as every R156-compliant update must be preceded and followed by diagnostic validation. Remote ECU coding will reach around EUR 2.9 billion (~25% CAGR), and rollback orchestration and post-update health checks around EUR 1.5 billion (~31% CAGR). Diagnostic security monitoring is expected to grow fastest in this domain, at around 43% CAGR to reach EUR 1.6 billion, the highest growth rate of any use case exceeding EUR 1 billion by 2035. Feature-on-demand activation via diagnostic APIs will reach around EUR 900 million.

The technical substrate is SOVD's remote use case as defined in ISO 17978-2/-3: backend access via HTTPS with OAuth 2.0 authentication, with an authorisation model that permits fine-grained service exposure. This is what allows a diagnostic session to occur without physical or proximity connection.

Diagnostic security monitoring increasingly feeds DTCs into the same Security Information and Event Management (SIEM) platforms that process intrusion-detection events. Growth in this segment reflects R155 evidentiary obligations and the absorption of vehicle SOC-style monitoring into the diagnostic stack. Feature-on-demand (FoD) shifts diagnostics from fault management to revenue-generating service delivery. The FoD use cases that monetise reliably at scale are those tied to software-created value, for example driver-assist function bundles, navigation services, and OTA-deliverable convenience or personalisation features.

AWS for Automotive, Microsoft MCVP, and Google Automotive Services are the dominant backend providers across many OEMs. They reach the diagnostic data plane through three vectors: managed connected-vehicle platforms; telemetry and streaming infrastructure (IoT Core, Greengrass, Pub/Sub); and AI/ML services for predictive analytics. The strategic question is not whether OEMs use a hyperscaler but how much of the diagnostic data plane they cede to a managed service versus retaining in OEM-owned infrastructure. The pattern at scale is hybrid (hyperscaler underneath, OEM-owned models and data governance on top), but the partition line moves with each renegotiation.

4.3.7 Embedded Diagnostic Software

The largest domain in 2025 (around 70 percent of TAM), Embedded Diagnostic Software will contract to around 28 percent by 2035. The headline flat growth rate conceals a sharp internal rotation. Embedded diagnostic communication and runtime stacks will decline from about EUR 7.7 billion to EUR 4.9 billion (~ –4% CAGR) as ECU counts fall with HPC consolidation. Secure boot and ECU health diagnostic software will grow from about EUR 1.9 billion to EUR 3.3 billion (~5% CAGR), driven by R155 adoption. BMS diagnostic software will expand from about EUR 252 million to EUR 1.1 billion (~16% CAGR), based on EV production growth.

The architectural inflection plays out across three implementation paths, which are not mutually exclusive:

- **Traditional OEM-and-Vendor.** For example, providers such as Vector, ETAS, Softing, Elektrobit and KPIT. Pre-integrated, standards-compliant components are delivered as a stack. This approach remains dominant.
- **OEM In-House.** The diagnostic stack is treated as a strategic asset. Mercedes-Benz MB.OS is a mature production example. Several other OEMs are at platform pilot stage.
- **Open-Source.** Typically combined with one of the first two paths rather than replacing them. Eclipse OpenSOVD (Eclipse Foundation, launched 2025) is an open-source exemplar implementation aligned with ISO 17978. Eclipse S-CORE (first release October 2025) is the broader safety-oriented middleware base.

BMS diagnostic software is increasingly OEM-owned rather than vendor-licensed. Battery IP is commercially integral to every EV-producing OEM, and second-life and warranty-reserve economics depend on the OEM controlling the state-of-health (SoH) model. Secure boot and ECU health diagnostics are being absorbed into the cybersecurity surface defined by R155. They are now baseline capabilities, rather than optional add-ons.

The vendors with the strongest forward position are those offering HPC grade diagnostic frameworks with SOVD compliant gateways, safety certified stacks for ASIL-D components, and cybersecurity integrated offerings, not those defending the traditional per-ECU Classic AUTOSAR diagnostic stack.

5 | Diagnostic Software Stack Implementation

5.1 Implementation Approaches

OEMs and Tier 1 suppliers are increasingly treating diagnostics as a core software capability in the SDV/AI-DV era. Across the industry, implementation of SOVD-based diagnostic stacks can be characterised by three distinct approaches, each reflecting different levels of ownership, development philosophy, and reliance on external partners. In practice, most programmes combine elements of all three; which approach is dominant is shaped by an organisation's digital maturity, platform architecture, and strategic priorities around diagnostic IP, cybersecurity governance, and lifecycle data ownership.

5.1.1 Traditional OEM and Vendor Approach

In the most widely adopted model, OEMs define diagnostic use cases, functional requirements, and compliance targets – including UNECE R155/R156 and regional homologation obligations – while Tier 1 suppliers and specialised software vendors carry primary responsibility for implementation and integration. OEMs focus on high-level specification and lifecycle coverage expectations. Tier 1 suppliers integrate SOVD services, protocol adapters, and backend connectivity modules from established vendors into ECUs, HPCs, and zonal controllers. Diagnostic software specialists, for example Vector, ETAS, Softing Automotive, and Elektrobit, supply pre-integrated, standards-compliant components such as SOVD gateways, diagnostic managers, and SOVD2UDS adapters.

For OEMs, this approach offers direct integration, proven regulatory compliance, and scalability across broad vehicle portfolios without requiring deep internal diagnostic engineering capability. For Tier 1 suppliers, it positions diagnostics as an integrated deliverable within broader ECU or HPC platform supply. The primary trade-off for both parties is reduced ownership of diagnostic IP and longer iteration cycles when adapting to new use cases or regulatory changes. Each new use case adaptation may lead to a change request process, which could extend the development time. Maintaining the rapid iteration cycles required by a DevOps operating model is particularly challenging within this traditional vendor-integration structure.

5.1.2 OEM In-House Development

An increasing number of OEMs, particularly those investing in proprietary SDV platforms and centralised HPC architectures, now consider diagnostic software components a strategic enabler for the future. They are taking direct ownership of diagnostic software development, retaining full control over architecture design, service definition, cybersecurity mechanisms, and lifecycle data governance. Integrating SOVD natively into HPC platforms, these OEMs develop diagnostic use cases in-house and treat the diagnostic stack as an important software asset. Vendors may contribute reference implementations, compliance validation tooling, and targeted third-party components such as cloud connectors and OTA interfaces. Tier 1 suppliers shift to the role of system integrators or hardware abstraction providers, with diagnostic logic and components, including cloud services, remaining on the OEM side.

For Tier 1 suppliers, the implication is a shift toward providing hardware platform and system integration services rather than acting as diagnostic stack providers. This will require investment in open interfaces, standardised abstraction layers, and the ability to integrate OEM-defined diagnostic services cleanly into supplied hardware. For OEMs, this strategy enables faster iteration cycles, tighter alignment between diagnostic functions and vehicle software architecture, and direct ownership of diagnostic data. It offers advantages that are strategically significant in cases where diagnostics enable connected services, predictive maintenance, and after-sales differentiation. The trade-off is substantially higher internal engineering investment and the need for dedicated diagnostic architects embedded across the full development lifecycle.

5.1.3 Open-Source Adoption

A third approach with open-source solutions, frequently adopted in combination with the models above, is also gaining traction across both OEMs and Tier 1 suppliers. This approach involves contributing to, and building upon, open-source foundations for vehicle software diagnostics.

The most notable open-source solution in vehicle diagnostics is the Eclipse OpenSOVD project[39], which provides a reference implementation of the SOVD standard including RESTful APIs, Classic Diagnostic Adapters (CDA), and protocol test tools. OEMs can use these frameworks to prototype and validate SOVD interfaces early in the development cycle, giving ASAM working groups implementation experience and accelerating the development of new SOVD features[39]. Tier 1 suppliers can leverage open-source foundations to reduce per-platform development effort, standardise interfaces across OEM programmes, and simplify cross-supply-chain collaboration, particularly for Tier 1s supplying HPCs or zonal controllers across multiple OEM architectures simultaneously.

For both OEMs and Tier 1s, open-source co-development reduces vendor lock-in, lowers the barrier to SOVD adoption on heterogeneous platforms and architectures, and improves interoperability across the supply chain. It is most effective when used as a shared foundation layer beneath OEM or supplier-specific extensions. It serves not as a complete replacement for vendor toolchains or in-house development but as an accelerator and interoperability baseline that all parties can contribute to and validate against, especially with common functions and use cases.

5.1.4 Strategic Implications

The choice of primary implementation strategy has direct consequences across four dimensions that determine programme outcomes.

Table. Comparison of Different Implementation Strategies

Dimension	Traditional Vendor Approach	OEM In-House	Open-Source Adoption
Time-to-Market	Fastest - proven stacks	Slower - internal build	Medium - shared foundation
Regulatory Flexibility	Vendor-dependent	Highest - direct control	Medium - community-driven
Platform Scalability	High across portfolio	Platform-specific	High - interoperable base
Diagnostic IP Ownership	Supplier-held	OEM-owned	Shared in community, OEM partially

As vehicles become more connected, electrified, and software-driven, a combination of factors is collectively pushing OEMs toward greater in-house capability, supported by open-source foundations and targeted vendor partnerships rather than being fully delegated to the supply chain. This includes cybersecurity obligations under UNECE R155 and R156, access to vehicle data and right to repair frameworks [14], and the strategic value of lifecycle diagnostic data. For Tier 1 suppliers, this means the competitive differentiation in diagnostics is moving from stack ownership to integration depth, hardware platform quality, and the ability to operate within OEM-defined, service-oriented architectures across different domains and platforms.

5.2 Real-World Implementations

5.2.1 OEM SOVD Adoption Status

Our research shows significant variations in the maturity of SOVD adoption across OEMs. Several OEMs and suppliers are already piloting or deploying SOVD-based solutions while others are adopting different strategies.

Volkswagen, with its software subsidiary company CARIAD[49], is pursuing the software-defined vehicle (SDV) strategy, combining in-house software development with selected supplier/vendor solutions. It also participates in SOVD standardisation through ASAM. Across the whole Volkswagen Group, standardised diagnostic APIs are expected to appear on the SSP platform from 2029, supported by AUTOSAR-aligned SOVD components from vendors. Volkswagen can be said to have a medium level of SOVD maturity.

BMW follows a mixed model, with internal development and partnership with external companies like Vector[50]. BMW is also actively involved in ASAM standardisation and Eclipse community activities[40], and also has a medium level of SOVD maturity.

Mercedes-Benz has established MB.OS[51] as an in-house, cloud-connected operating system, supported by vendors such as ETAS[53]. The diagnostic stack supporting both SOVD and UDS interfaces became available in 2025/2026. In parallel, Mercedes-Benz, through its software subsidiary Mercedes-Benz Tech Innovation GmbH, is the main driver of Eclipse OpenSOVD and leads the CDA workstream. Mercedes-Benz is therefore considered to have a high level of SOVD maturity.

Ford primarily leverages third party providers such as Vector[50] and participates in ASAM led standardisation instead of developing a complete SOVD stack internally. Following its decision in 2025 to merge its next-generation FNV4 architecture into the evolved FNV3.X platform, Ford's SOVD adoption is expected to be gradual, indicating a medium SOVD maturity level.[52]

Toyota is experimenting with SOVD in open-source proofs-of-concept (PoCs)[54] that combine Automotive Grade Linux and AECC cloud/edge architectures, where each AGL instance runs an SOVD server to access and control vehicle data. These PoCs put Toyota at a medium SOVD maturity level in the prototype phase, with deployment of similar SOVD-based architectures expected from 2027 onward.

Tata Motors recently announced its new Tata Sierra model, which uses Excelfore's eSync platform[55] to provide full vehicle OTA and service-oriented remote diagnostics. This makes Tata an early adopter of REST/HTTP-based remote diagnostics that align architecturally with SOVD in the Indian market.

Tesla operates a vertically integrated, OEM-controlled diagnostic architecture, built on a hybrid UDS stack over DoCAN and DoIP with mature remote access functionalities. Rather than a fully closed ecosystem, it pursues "openness under supervision". Tesla provides free service manuals and theory-of-operation documentation, a free on-screen Service Mode, the purchasable browser-based Toolbox 3 (unlocking Service Mode Plus, ODIN routines, and Autodiag), and support for independent third-party tools[56][57]. Tesla has publicly committed to the standardised OBD-II J1962/ISO 15031 connector with UDS-over-DoIP on vehicles built from April 2024 onward. DoIP is consolidated onto that single connector, whereas earlier vehicles supported it via a separate, dedicated port[57][58][61]. A recent 76% reduction in Toolbox 3's annual subscription (USD 3,000 to USD 700) may reflect requirements to open access as per right to repair regulations.[62]

Li Auto operates a proprietary SDV stack[47] with strong in house software and rapid iteration on ADAS and cockpit features. Diagnostics is handled through Li's own vehicle and cloud platform. SOVD maturity is considered low.

NIO, with its SkyOS[42] full stack vehicle OS and the Service Guardian[43] remote diagnostics platform, integrates its vehicle, app and service ecosystems. Vehicle data is integrated vertically across the NIO app, battery-swap network, and aftersales operations. The diagnostic stack to fulfil such information is currently proprietary; however, NIO's export ambitions and SDV development indicate a medium level of SOVD maturity. The introduction of an SOVD-compatible interface layer for exported vehicles appears likely.

Geely's GEA/GEEA architectures[48] and the Smart Geely 2025 strategy provide a highly structured E/E architecture foundation, with centralised controllers and domain-wide AI capabilities. The platform supports OTA and connected services; however, diagnostics are still largely proprietary and cloud-specific, so SOVD maturity is low–medium. Nonetheless, Geely's global ambitions and structured platforms make SOVD-compatible interfaces on unified architectures a realistic scenario beyond 2027.

BYD is pursuing vertical integration through a proprietary software stack. The DiPilot and God's Eye driving system [44] are built on top of e-Platform 3.0[45], with diagnostic and health-monitoring data routed to BYD's own backend. BYD currently shows a low-medium level of SOVD maturity. Export ambitions will necessitate the adoption of SOVD-compatible or UDS-based standard interfaces to satisfy regulatory and interoperability requirements in Europe and other markets.

5.2.2 Third-Party Solution Providers

Vector demonstrates SOVD in action with use cases such as ECU quick checks, fault memory access, and diagnostic sequences, all via service-based interfaces.

Softing Automotive is extending its Smart Diagnostic Engine (SDE) – a function-oriented diagnostic runtime deployed across engineering, manufacturing, and aftermarket environments – with a REST API layer aligned to the SOVD standard.[65][66]

ETAS offers modular SOVD components as part of its AUTOSAR Adaptive platform portfolio, targeting integration with OEM SDV development and validation workflows.[53]

KPIT offers SOVD integration services as part of broader AUTOSAR Adaptive and SDV platform engagements. KPIT integrates SOVD capabilities within its AUTOSAR Adaptive platform (KSAR Adaptive), supporting cloud-native development and virtual ECU validation on AWS.[69][70]

Elektrobit delivers SOVD support within its EB corbos AUTOSAR Adaptive platform, enabling diagnostic service deployment on HPC-based vehicle architectures. [71][72]

Excelfore provides a production-ready SOVD implementation integrated with its eSync™ OTA platform, combining SOVD with secure, standards-based OTA software lifecycle management. [55][68]

Eclipse OpenSOVD offers an open-source implementation of the SOVD standard, allowing OEMs and developers to build and test compliant solutions with REST APIs and protocol adapters for legacy systems.

DSA's PRODIS.SOVD provides a unified diagnostic interface for production, aftersales, and fleet management, with cloud bridges for secure remote access and lifecycle integration.[67]

6 | Global Diagnostic Standards and China's Proprietary Diagnostic Strategy

The global automotive industry is converging on a standardised, interoperable diagnostic framework centered on UDS (ISO 14229), SOVD (ASAM / ISO 17978), and AUTOSAR-based implementation stacks. Simultaneously, China's leading OEMs (e.g. NIO, BYD, Li Auto, Xpeng, and Geely) have built deeply proprietary, vertically integrated diagnostic and connected vehicle platforms that operate largely independently of these international standards. This section analyses the technical, regulatory, and strategic dimensions of this divergence, and assesses the conditions under which partial convergence is likely to occur.

6.1 Global Standard Diagnostic Architecture

The international diagnostic framework rests on a layered, interoperable stack developed through ASAM, ISO, AUTOSAR, and SAE standardisation bodies, built on principles of vendor neutrality, multi-brand interoperability, regulatory traceability, and lifecycle coverage.

Layer	Standard	Function
Application	UDS (ISO 14229)	ECU-level diagnostic services
Transport	DoIP (ISO 13400)	UDS over Ethernet
Data Description	ODX (ISO 22901)	Diagnostic database format

Layer	Standard	Function
Test Sequencing	OTX (ISO 13209)	Diagnostic test sequence exchange
Service Interface	SOVD (ASAM / ISO 17978)	REST-based SDV diagnostic API
Security	OAuth 2.0, ISO/SAE 21434	Authentication and cybersecurity
OTA Mandate	UNECE R156	Software update management
Emissions Compliance	OBDonUDS (SAE J1979-2)	US OBD transition, required by CARB from MY2027

This architecture theoretically enables any compliant diagnostic tool from any supplier to interact (to a limited extent) with any compliant vehicle. In principle, this may change the diagnostic setup between OEMs and other stakeholders.

6.2 China's Parallel Regulatory Framework

China has developed a comprehensive, domestically specific regulatory framework for vehicle diagnostics, cybersecurity, and data governance that diverges significantly from the UNECE/ISO model.

Regulation	Authority	Key Requirement
GB/T 40861-2021[23]	SAC	General technical requirements for vehicle cybersecurity - covers in-vehicle communication, access control, anomaly detection
GB/T 41590-2022[24] [26]	SAC	K-Line based diagnostic communication standard
GB/T 42193-2022[28]	SAC/MIIT	Emission-related diagnostic communication requirements
MIIT ADS Regulations (2025)[29]	MIIT/SAMR	Mandatory reporting of ADAS/ADS malfunctions; L3/L4 type approval requirements
MIIT OTA Regulations (2025)[29]	MIIT/SAMR	Safety-critical OTA updates classified as recalls; SAMR approval required before deployment
Automotive Data Cross-Border Transfer Guidelines (2026)[31]	MIIT/CAC	Data localisation requirements; cross-border transfer subject to security assessment

6.3 Critical Divergences from Global Standards

Data Localisation. China's Personal Information Protection Law (PIPL), Data Security Law (DSL), and 2026 MIIT/CAC Automotive Data Guidelines, require vehicle data collected in China to be stored domestically, with cross-border transfers subject to security assessment. This regulation also covers diagnostic data collected from vehicles. This conflicts structurally with SOVD's cloud-native, globally connected architecture and the Extended Vehicle (ExVe) framework defined in ISO 20077, making a single unified rollout across all markets challenging.[31]

OTA Restrictions. MIIT regulations classify safety-critical OTA updates as product recalls, require SAMR approval before deployment, and prohibit public beta testing programmes. This is a more restrictive framework than UNECE R156's traceable update management model. Companies issuing frequent OTA updates are subject to targeted regulatory inspections.[29]

Diagnostic Reporting Mandate. Manufacturers must report all system malfunctions, failures, and accidents related to ADAS and autonomous driving functions to MIIT and SAMR through designated government platforms. China's mandate includes malfunctions and failures beyond crashes, unlike NHTSA's Standing General Order on crash reporting for ADS/ADAS vehicles (SGO 2021-01). It has created China-specific compliance requirements for which global diagnostic standards do not have direct coverage.[32][36]

Cross-Border Exemptions. The 2026 MIIT/CAC Guidelines provide limited exemptions for security vulnerability remediation, incident response, and recall-related data transfers – representing a partial easing of regulations, but within a tightly controlled framework.[31]

6.4 Strategic Comparison

Dimension	Global Standard (SOVD / UDS)	China Proprietary Approach
Architecture	Layered, interoperable, vendor-neutral	Vertically integrated, OEM-specific
Interface	REST/HTTP, OAuth 2.0, OpenAPI	Proprietary APIs, OEM-specific protocols
Data Governance	UNECE/ISO-aligned, internationally open	China-localised, MIIT/CAC regulated
OTA Framework	UNECE R156, traceable update management	MIIT recall classification, SAMR approval required
Cybersecurity	ISO/SAE 21434[9], UNECE R155 [11]	GB/T 40861-2021, MIIT cybersecurity regulations
Standardisation Body	ASAM, ISO, AUTOSAR, SAE	SAC, MIIT, CATARC, CAICV
Aftermarket Access	Right to Repair mandated	No equivalent mandate currently
Competitive Advantage	Interoperability, compliance, multi-brand	Speed, ecosystem depth, AI integration
Export Applicability	Global - all major markets	Domestic-optimised; standards-compliant interfaces required for export

6.5 Why Chinese OEMs Are Not Actively Adopting SOVD

As described in the previous chapter, some OEMs, especially Chinese, are not actively progressing SOVD adoption. Six primary factors explain the current reluctance:

No Domestic Regulatory Mandate: China's GB/T and MIIT frameworks do not require SOVD, removing the primary driver seen in Western OEM adoption, i.e. a regulatory mandate.

Data Sovereignty Constraints: SOVD's cloud-native design conflicts with China's strict data localisation requirements under PIPL and the 2026 MIIT/CAC Guidelines.

Proprietary Ecosystems as Competitive Moats: Connected service platforms are positioned as premium consumer differentiators, not commodity infrastructure.

Speed Advantage of Proprietary Development: Chinese OEM iteration cycles move faster than international standards bodies can ratify changes.

Limited Influence Over ASAM: Chinese OEMs have limited influence over ASAM working-group agendas, so SOVD features evolve around use cases that European OEMs prioritise.

Different Innovation Model: Some Chinese OEMs follow a consumer electronics-inspired development model that emphasises fast iteration, AI-first product development, and ecosystem integration. In parallel, automotive engineering disciplines such as process rigour, certification, and standards compliance, are treated primarily as regulatory necessities, rather than differentiators.

6.6 Convergence Scenarios

Despite current divergence, several factors are likely to drive partial convergence toward international standards by 2028–2030.

Export market requirements are the strongest near-term driver. Chinese OEMs exporting to Europe must comply with UNECE R155/R156 and Right to Repair regulations, creating a dual-stack necessity where a standards-compliant (increasingly SOVD-compatible) interface is implemented for export models, while domestic platforms remain proprietary.

ISO 17978's international standing gives it more regulatory legitimacy in China than an ASAM proprietary standard. Chinese participation in ISO working groups is growing, and the publication of ISO 17978-3 [4] increases its relevance in bilateral standards discussions.

China's own OTA restrictions paradoxically push Chinese OEMs toward structured, traceable update management – a core SOVD capability – potentially increasing domestic demand for SOVD-aligned approaches as MIIT compliance requirements mature.

Regulatory maturation post-2026 may drive increasing alignment between China's domestic connected vehicle frameworks and international standards, particularly in cybersecurity and data interoperability, as China deepens participation in international standards bodies and bilateral trade frameworks.

The most realistic outcome by 2028–2030 is a dual-stack architecture across Chinese OEMs exporting globally: proprietary, AI-integrated platforms for domestic vehicles operating under China's regulatory framework, with a SOVD-compatible interface layer for export vehicles requiring international standard compliance.

7 | A “hybrid” Automotive Ecosystems View on Diagnostics – Where Business and Public Interests Meet

Technology is always use-case agnostic and can support various use cases from different domains or stakeholders. Automotive diagnostics technology is no exception. It continues to support use cases for public authorities and business partners alike across the automotive value chain.

This chapter analyses selected dependencies and relationships between the public ecosystem, responsible for public interests such as road safety, cybersecurity and safe autonomous driving, and the commercial ecosystem. In the latter, diagnostics technology is a key enabler for new business models but also a key control point for the highly profitable parts and service business segment.

7.1 The Dimensions of the Hybrid Ecosystem

The “hybrid” ecosystem view features four dimensions needed for successful digital ecosystems:

a.) The legal dimension – rights and responsibilities of stakeholders in the system.

b.) The commercial dimension – incentives and business models in the system.

c.) The technical dimension – technology that limits or fosters new business models.

d.) Data, functions and processes dimension – the operating model that defines how human and IT actors interact in the system.

The four dimensions are highly interlinked, and developments in one dimension often influence outcomes in others. This interlinking relationship effectively creates a 4D-Space for successful digitalization. Automotive stakeholders in the value chain must closely monitor trends and developments across all four dimensions to determine their optimal business strategy.

7.2 Example: The 4D-effect of the ECJ Ruling on Restricted OBD Access

A clear example of how these dimensions are interlinked can be seen in a 2023 European Court of Justice ruling on access to vehicle diagnostic information[37]. The case addressed whether OEMs could restrict access to OBD data on cybersecurity grounds, ultimately ruling in favour of independent repairers and reinforcing the EU principle of unrestricted, non-discriminatory access to repair and maintenance information. This illustrates how legal, technical, commercial, and operational considerations can become tightly intertwined within the automotive ecosystem.

In parallel with the court proceedings, affected stakeholder groups, represented by their associations, engaged with the European Commission to determine how to revise and update the legislation so that required cybersecurity measures would not undermine legally protected access rights. The result was the Delegated Act (DA) C(2026) 1811, which was published in March 2026[38].

Key implications of the Delegated Act for vehicle diagnostics include the following:

a.) The Act explicitly extends the technology options in scope beyond the OBD-port to cover new onboard as well as offboard capabilities (Annex X, point 2.9). This creates opportunities for new diagnostics business models and may lower barriers to entry for smaller independent providers, for example in remote diagnostics. **Note:** while access to the OBD data stream via the OBD connector remains free of charge in the legislation, OEMs are entitled to claim fees if the technically new remote access option is chosen (Appendix 4, 3.8).

b.) Cybersecurity risks are addressed not only through technical controls but also process and governance measures. OEMs may require independent partners to obtain costly certifications such as TISAX or ISO 27001-compliant alternatives (Appendix 4, 6.1.1). Together with mandated insurance coverage (Appendix 4, 8.1.a), these technical security requirements could reduce the number of smaller start-ups willing to enter the diagnostics market.

c.) The potentially greatest commercial impact is related to a change in the operating model for approving diagnostic tools. As shown in Appendix 4, 6.4, vehicle manufacturers are entitled to test and verify diagnostic tools before granting approval. Although this is primarily intended to support compliance with UN Regulations R155 and R156, it has broader implications. Diagnostic tools also have to be integrated in the CSMS/SUMS to work over their lifetime. With software in vehicle components constantly evolving, and bearing in mind that future diagnostics solutions might rely at least to some extent on an in-vehicle component running on an HPC, this establishes a paradigm shift for the commercial automotive ecosystem. The software-defined vehicle (SDV) is also part of a software-controlled ecosystem (SCES), where the OEM is potentially in total control of all parts, tools and services developed for, and provisioned to, its vehicle fleet.

In summary, technological change and cybersecurity requirements have driven both legal challenges and regulatory reform. The resulting Delegated Act does more than address technical access requirements; it also reshapes the competitive dynamics of the diagnostics market and introduces new operating models for OEMs, service providers, and independent operators.

7.3 The Process Dimension: The Relationship Between Diagnostics and the Parts Business

Diagnostics has always been the entry point, or even a gatekeeper, for the vehicle parts business. Parts is becoming an increasingly important revenue stream for OEMs, amid declining revenues from new car sales. OEMs have therefore sought ways to protect or expand their market position in parts. Higher fees for access to legally mandated RMI information, as well as restrictions that made it more difficult to identify or select spare parts, were intended to slow down the development of independent diagnostics tools and limit the adoption of independent replacement parts. In an "open ecosystem", where access to the necessary information was sufficient to develop competing tools and alternative parts, these were effective competitive countermeasures.

Technical evolution has changed this paradigm. The car and the car market are increasingly becoming closed-loop systems, making previous countermeasures against competition increasingly obsolete. As controllers of the ecosystem around the modern SDV/AI-DV, OEMs can exert significant control over how services, software functions, and replacement components are deployed throughout the vehicle lifecycle. In-vehicle sensors can detect "intelligent" replacement components, such as adaptive headlights, that must communicate correctly with the vehicle's software environment. Even for comparatively simple components, such as brake pads, digital service records might require the "certified and authorised" operator in a workshop to enter the unique ID associated with the part. This allows the vehicle to resume proper operation after a component change is detected, e.g. a change in braking performance.

The legal right with respect to spare parts can also be found in the Annex X revision within Appendix 4, point 5, "Traceability requirements". Point 5.5 is of particular interest:

"5.5. Cases of access referred to in point 5.4. shall include such repair and maintenance operations as pairing an original replacement part (including software and hardware compatible (as defined by the vehicle manufacturer) remanufactured or re-used part) or a vehicle manufacturer-authorised replacement part to a vehicle by using an independent diagnostic tool and reprogramming a module by using original equipment vehicle software and original equipment programming software in accordance with the vehicle manufacturer's instructions. It shall also include cases of decoupling or deregistering a part from a vehicle."

The cases from 5.4 mentioned in 5.5 are defined as: "5.4...change of the vehicle software or its configuration/its parameters consisting in reprogramming of the vehicle software code, resulting in alteration of the intended behaviour of the vehicle and persisting beyond the repair and maintenance operation, so that it can only be reversed or overwritten by the performance of an equivalent operation...".

For a modern SDV/AI-DV, made up of onboard as well as backend software components, the above definition essentially covers all possible service provisions to the SDV/AI-DV, from registering an oil change, to updates to apps or ECUs, as well as registering new spare parts in the digital service record and within the CSMS/SUMS for "intelligent parts".

Business models are likely to change significantly. In the future, RMI and even the use of OEM diagnostics could be offered for free to tool developers, parts producers and workshops alike, since revenue is predominantly generated for OEMs by authorising parts, integrating them in their CSMS/SUMS and receiving revenue shares for every installed part.

In this future scenario, success will be determined by who can offer the best technical support and the most attractive commercial model for the legally mandated coexistence of OEMs, independent parts producers, and OEM-authorised suppliers.

Legal annotation: Since Annex X only mentions the term "vehicle manufacturer authorised parts" once, further details for the required cooperation are yet to be discussed and defined. Two options are possible. The EC could decide to refine the details in a similar format as seen in the ECJ-ruling exercise, resulting in another delegated act, or the issue will become a key subject in the upcoming revision of the MVBER for 2028.

Summary: The technical evolution of diagnostics has made its use as an enabler or blocker in the market of competing "classical" diagnostic tools or replacement parts increasingly obsolete. For diagnostic software developers and OEMs, the key question is how to build secure, high-performance software platforms in the SDV/AI-DV and at the OE backends, so that different and innovative solutions for parts, apps or other services can be easily and quickly tested, integrated and offered to consumers.

For diagnostics software developers in particular, the task will likely shift from developing OE specific software solutions alongside a standard like SOVD, to tasks around SOVD, e.g. implementing SOVD for an OEM or creating SOVD adapters.

7.4 Authorities as Creators of Digital Ecosystems

When technical solutions and standards are referenced by legislation and their use is mandated by public authorities, commercial ecosystems are created. The need for emission control and reduction resulted in the development of data standards and processes underpinning eOBD and the OBD-port. The technology was later used extensively for commercial diagnostics purposes. The need for in-service monitoring of solutions for automated driving will very likely lead to a similar development.

Firstly, standards around automated driving will have to be created, not only to compare different automated driving solutions but also to verify that the performance of these systems is as good as or better than a human driver, as required in current EU provisions for automated driving.

The reporting will likely be carried out continuously and in real time to authority-operated backends. While this level of oversight, with authorities acting as controllers of the public ecosystem for safe traffic, and OEMs as the controllers of their vehicle ecosystems, might not always be welcomed, it has significant long-term advantages. The overall system can approve and launch new solutions for automated driving more quickly and can respond to reported issues in a swift and coordinated manner across OEMs.

Lastly, this approach has a commercial incentive for participants. Authorities wishing to support players in their markets can encourage the development and use of standardised supporting technology without risking disturbing market behaviour, because the standard is mandatory for all participants.

8 | Outlook: The Future of Vehicle Diagnostics, SDV to AI-DV

The diagnostic function is undergoing a structural transformation from a workshop tool to a continuous, AI-augmented software intelligence platform embedded across the vehicle, fleet backend, and cloud services. The following three subsections trace the technology, regulatory, and software stack trajectories that will define vehicle diagnostics through 2030 and beyond.

8.1 Technology Outlook: From the Base of SDV to the Future of AI-DV

Diagnostic systems are shifting the operating model from fault detection after failure toward continuous prediction, live data acquisition, issue prevention, and remote and autonomous repair. Certain new technologies are beginning to have real, practical applications:

Cloud-Edge Diagnostic Architecture

The emergence of cloud-edge hybrid architecture, where inference and time-critical diagnostic processing occur at the vehicle edge while aggregation, analytics, and fleet intelligence operate in the cloud, is resolving the latency and connectivity constraints that limited earlier remote diagnostic models. In this architecture, SOVD's stateless REST interface operates at both layers: the vehicle-resident SOVD Gateway handles local, real-time diagnostic queries and event logging at the edge, while the backend connectivity layer channels aggregates health data, OTA triggers, and compliance reporting upstream to cloud platforms over 4G/5G. Advances in 5G network capabilities will further lower latency floors, enabling near-real-time remote diagnostic interactions at fleet scale without the session stability constraints that limit UDS-over-cellular deployments.

Digital Twin Integration

Vehicle digital twins can provide software models that continuously mirror the real-time state of a physical vehicle. This technology helps the engineering team change the traditional work method from static engineering simulation tools toward intelligent, AI-driven operational platforms. Digital twin modelling provides consistent health monitoring across the vehicle lifecycle. SOVD provides self-describing REST API, which enables digital twin platforms to discover available diagnostic entities, query real-time signal values, and push configuration changes to the vehicle through a standardised interface used for all other diagnostic clients. In the future, the fault resolution pattern will begin with first diagnosing the twin, then validating the remediation path virtually. Only at that stage will the physical vehicle be engaged, with the support of remote diagnostic technologies. By adopting a virtual-first workflow, OEMs can reduce unnecessary workshop interventions and accelerate fault resolution for connected fleet operations.

AI-Augmented Diagnostics

In the AI-defined vehicle, diagnostics evolves into a distributed intelligence function spanning onboard compute, edge gateways, and cloud analytics. AI-based models can process cross-domain telemetry, software-state data, and fleet-level operating patterns to detect weak signals, classify anomalies, and predict functional degradation before conventional threshold-based diagnostics or DTC logic are triggered. When integrated with in-vehicle agentic AI and service-oriented diagnostic interfaces, this enables continuous health assessment, context-aware fault isolation, and data-driven initiation of remediation actions such as recalibration, software updates, or targeted service intervention.

8.2 Regulatory Outlook - Global Harmonisation and Autonomous Driving Type Approval

The regulatory landscape for vehicle diagnostics is entering a period of accelerating complexity – driven simultaneously by the expansion of cybersecurity mandates, the emergence of autonomous driving type approval frameworks, and the ongoing tension between global harmonisation and regional regulatory divergence.

UNECE WP.29 - Expanding Diagnostic Obligations

UNECE R155[11] cybersecurity and R156[12] OTA software updates, both in force for new vehicle type approvals since July 2022, have established diagnostic traceability as regulatory requirements. This is not merely engineering best practice. Post-market surveillance obligations under R155 require manufacturers to continuously monitor the vehicle status, have capabilities to detect cybersecurity incidents, and respond to these across the full vehicle lifecycle. R156 mandates that every OTA update is traceable, reversible, and validated, making diagnostic functions inseparable from every software update lifecycle step. As WP.29 expands adoption beyond the current contracting parties, these requirements will progressively become global baselines, applying progressively to the entire new vehicle fleet over the next type approval cycles.

L3/L4 Autonomous Driving Type Approval

The type approval of SAE L3/L4 autonomous driving systems is creating an entirely new category of diagnostic obligation. Under the UNECE WP.29 Framework Document on Automated/Autonomous Vehicles and the UN Regulation on Automated Driving Systems (ADS), adopted in June 2026 and expected to enter into force in early 2027[78], manufacturers must demonstrate that ADS-equipped vehicles can safely manage failure modes across nominal, critical, and failure scenarios throughout the complete vehicle lifecycle. This requires diagnostic functions to provide structured, automated reporting of safety-critical fault events, system availability states, and Operational Design Domain (ODD) boundary violations to regulatory authorities, both for initial type approval certification and ongoing in-service surveillance. SOVD's self-describing API, standardised log access and remote access model, combined with tamper-proof audit logging implemented at platform level, can provide a suitable architectural foundation for meeting these requirements. SOVD can therefore provide a framework to fulfil the continuous, cross-domain, lifecycle-integrated reporting obligations that L3/L4 type approval demands with reduced implementation efforts.

Global Harmonisation vs. Regional Divergence

While UNECE R155/R156 and ISO 17978-3 are establishing a de facto international standard baseline, regional divergence remains a structural challenge. CARB's OBDonUDS requirement (SAE J1979-2[15], from model year 2027[35] [75]) aligns US emissions diagnostics with the UDS application layer for the first time – a significant convergence step. China's GB/T framework, data localisation requirements, and MIIT OTA restrictions continue to diverge from the international model, requiring Chinese OEMs and global OEMs operating in China to maintain region-specific diagnostic compliance layers. The most realistic near-term outcome is a layered compliance architecture, a single SOVD-based diagnostic API core, with region-configurable compliance modules that activate or restrict services, data reporting formats, and access permissions per homologation market.

8.3 Software Stack Development Outlook - SOVD, OTA Convergence, and Open-Source Maturity

SOVD and OTA Convergence

The most significant near-term architectural development is the deepening integration between SOVD diagnostic services and OTA update orchestration platforms. ASAM SOVD v1.2.0[20], is currently under development with a planned release in March 2028. It targets enhanced support for multi-core HPCs, zonal architectures, and dynamic diagnostic content discovery, alongside expanded OTA workflow integration. The practical result will be a unified software lifecycle management interface where pre-update health verification, update execution monitoring, post-update validation, and rollback orchestration are all invoked through the same standardised SOVD REST API. It eliminates the proprietary update agent interfaces that currently fragment OTA implementations across vehicle programmes. ASAM is simultaneously extending the OTX (ISO 13209) standard with an SOVD execution profile, enabling diagnostic test logic to be written and executed against the SOVD API without any automotive-specific stack on the client side – further weakening the boundary between diagnostic testing and software lifecycle management.

Open-Source Maturity and Ecosystem Growth

Eclipse OpenSOVD[39] launched as a formal Eclipse Foundation project in 2025. The open-source ecosystem is maturing rapidly from a reference implementation into a production-relevant foundation that OEMs and Tier 1 suppliers are actively integrating into SDV platform programmes. Its integration with the Eclipse S-CORE project[40] ensures that SOVD diagnostic capabilities are natively supported within broader SDV software architectures, which enables developers and OEMs to build standard compliant diagnostic stacks without starting from scratch on proprietary foundations. The growing contributor community spans OEMs, Tier 1 suppliers, tool vendors, and independent developers.

Diagnostic Stack Architecture in 2028–2030

By 2028–2030, the diagnostic software stack in leading SDV programmes is expected to exhibit the following characteristics:

- **Unified API Surface:** A single SOVD REST interface serving workshop, remote, in-vehicle, and cloud clients, with UDS retained as the ECU-resident service layer accessed primarily through the SOVD2UDS adapter.
- **AI-native Anomaly Detection:** On-board edge inference for real-time DTC prediction, complemented by cloud-side fleet analytics for population-level pattern recognition.
- **Lifecycle-Integrated OTA:** Diagnostic and update functions fully merged into a single service-oriented lifecycle management platform, with every update step traced through audit logs accessible via SOVD.
- **Open-Source Foundation:** Eclipse OpenSOVD and related Eclipse SDV projects providing the interoperability baseline, with commercial vendors adding production hardening, OEM support structures, and certified compliance tooling above it.
- **Region-Aware Compliance Layer:** A configurable module within the SOVD stack that manages market-specific regulatory obligations – UNECE R155/R156, OBDonUDS, WWH-OBD, GB/T – without requiring separate diagnostic architectures for each region.

The net result is a diagnostic function that has completed its transition from a workshop repair tool to a continuous software intelligence platform, serving as the operational backbone for safety assurance, regulatory compliance, lifecycle management, and connected service delivery. The implementation of these new standards will also support the shift from an SDV era focused primarily on vehicle architecture and technical foundations, to a more use-case-driven AI-DV era.

8.4 What Does This Mean for Stakeholders?

For OEMs: Diagnostic software transitions from a development expense to a lifecycle revenue stream. The strategic decision is build vs. buy for the diagnostic software stack, and more critically, whether to own or cede the diagnostic data layer. OEMs that continue to treat diagnostics as a cost line risk losing control of aftersales value; those that treat it as a platform opportunity can capture recurring revenue across the vehicle lifecycle. As recurring revenue (subscription, SaaS and usage-based fees across aftersales, in-use monitoring, compliance and remote services) grows from around 25% to around 70% of the diagnostic software market by 2035, OEMs that treat diagnostics as a platform investment, owning the data layer, controlling the API surface, and monetising downstream services, will improve margin compared with those that continue to outsource diagnostics as a commodity function within vehicle development programmes. The critical decision is not technical but commercial: whether to retain ownership of the diagnostic data layer and its downstream monetisation potential in aftersales, fleet, and digital services, or to cede that position to suppliers and third-party platform providers.

For Tier 1 Suppliers: The traditional role of embedding diagnostics logic in ECU software is under pressure as OEMs bring development in-house and HPCs centralise functions. The defensible position is in middleware, toolchains, and systems integration expertise, in particular when bridging legacy UDS systems with SOVD. The direct software value-add of Tier 1 suppliers in diagnostics is narrowing. As OEMs in-source diagnostic logic onto centralised HPCs, and SOVD abstracts away ECU-level protocol complexity, the traditional role of embedding proprietary diagnostic software at the ECU level is becoming less prominent. Tier 1s sit at the interface between OEM requirements and ECU implementation, translating platform-level diagnostic specifications into embedded software across different vehicle controllers. This integrator role spans multiple use cases (engineering, manufacturing, testing, aftersales) and is particularly valuable for OEMs that lack the internal software maturity to manage the SOVD transition themselves. The strategic imperative is to extend proven legacy diagnostic solutions toward SOVD compatibility and serve OEMs that prefer turnkey diagnostic integration rather than building their own proprietary stack. The margin may be compressed, but the volume of integration work across the global OEM landscape ensures a durable value pool for players who execute reliably.

For Diagnostic Software Vendors: The market growth represents a generational opportunity. The transition from ODX/UDS to SOVD creates a product cycle scenario where incumbents must rebuild and new entrants can compete. Vendors that establish SaaS-based pricing models, contribute to open-source credibility, and build cross-OEM cloud platforms will benefit. The transition from proprietary UDS/ODX toolchains to SOVD-based architecture means the installed base of legacy diagnostic tools must be replaced or bridged, and no single OEM will build everything in-house. The winning strategy is to build a unified, SOVD-native diagnostic platform that operates as close to plug-and-play as possible. This can minimise per-OEM adaptation effort and maximise cross-platform reusability. This prospect is particularly compelling for OEMs that do not plan to develop proprietary diagnostic stacks: volume brands, commercial vehicle manufacturers, and OEMs entering new markets (notably Chinese exporters facing UNECE compliance requirements for the first time). For these OEMs, a configurable, standards-compliant diagnostic platform from a trusted vendor is not a compromise; it is the fastest path to market.

Conclusion: Diagnostics as a Strategic Enabler with Future Vehicle Architecture

Vehicle diagnostics has moved from a regulatory compliance mechanism to a foundational enabler of SDV operations and connected services. Relevant functions cover the whole vehicle lifecycle and could generate continuous value for stakeholders across engineering, production, aftersales, fleet management, vehicle recyclers and regulatory authorities.

SOVD introduced a service-oriented, REST-based diagnostic API that resolves the structural limitations of UDS at SDV scale. Global diagnostic standards are no longer optional for OEMs with international ambitions. Chinese OEMs exporting to Europe and North America must comply with UNECE R155 and R156, Right to Repair requirements, and OBDonUDS mandates. Standards-based interfaces, increasingly SOVD, become a prerequisite for market access, not a strategic choice. At the same time, Chinese OEMs continue to develop proprietary diagnostic solutions to support fast go-to-market for AI-integrated and consumer-facing use-cases that domestic competition rewards.

Open-source initiatives, which are mainly led by Eclipse OpenSOVD within the broader Eclipse SDV community, will play an increasing role in the future. By providing a shared, vendor-neutral reference implementation that any OEM, Tier 1, or tool vendor can build on, open-source foundations lower barriers to adoption and reduce fragmentation.

OEMs need to decide how to implement the new diagnostic software based on their own vision and strategy. Implementation needs to be cost-effective while maintaining sufficient flexibility and agility across different platforms and ECU configurations, based on a shared core architecture and HPCs. At this point, OEMs need to plan not only the implementation of the diagnostic software stack but also the use case roadmap that will deliver recurring value across the vehicle lifecycle.

9 | How Berylls by AlixPartners Can Help

The decisions made between 2026 and 2028 will define each OEM's diagnostic position through 2035. The window is narrow, and the choices are no longer purely technical.

9.1 Five Dimensions of Change OEMs Are Navigating

Organisational: In-house diagnostic engineering, DevOps-cycle delivery, and ownership of diagnostic data require capabilities that most OEMs have historically outsourced. Tier 1 relationships are being renegotiated at the same time.

Architectural: Zonal and HPC consolidation, the migration from session-based UDS toward an SOVD service layer, and the integration of diagnostics into OTA orchestration are reshaping the in-vehicle software backbone.

Commercial: Revenue is rotating from one-time embedded licences to parc-driven services across the vehicle lifecycle (see §4.1 and §4.2 for the TAM split). The highest-value lever is monetisation of the diagnostic data layer: predictive maintenance, warranty analytics, battery state-of-health, and feature-on-demand all depend on owning it.

Regulatory: UNECE R155 and R156, OBDonUDS in 2027, Right to Repair, and L3/L4 type approval are turning diagnostic traceability into a permanent lifecycle obligation rather than a homologation milestone.

Geopolitical: China's data localisation requirements, MIIT OTA classification rules, and the GB/T framework are creating a dual-stack reality for globally exporting brands.

The pain points we observe across OEM engagements follow a recurring pattern: unclear ownership of the diagnostic data layer; legacy ODX and UDS toolchains that do not scale to HPC and zonal architectures; investment cases for SOVD migration competing with platform programmes already under cost pressure; regulatory readiness work running in parallel silos; and aftersales organisations not yet wired to capture the value the new stack creates.



9.2 How We Support Our Clients

Our priority offerings address the structural decisions that determine OEMs' and suppliers' positions in 2030:

1. **Diagnostic Strategy and Target Picture:** build-versus-buy, in-house versus vendor-led, and the commercial logic of owning the diagnostic data layer as a strategic asset rather than a programme cost.
2. **SOVD and SDV/AI Enabled Architecture Roadmap:** sequencing the migration across vehicle programmes, HPC platforms, and backend connectivity, aligned with the OEM's broader software strategy.
3. **Sourcing and Partner Model:** defining the operating model and division of responsibility across Tier 1 suppliers, diagnostic software vendors, and open-source components; structuring the commercial and IP terms that keep the OEM in control of the data layer while drawing on external capability.
4. **Diagnostic Data-Layer Monetisation:** business cases for feature-on-demand, predictive maintenance, warranty analytics, and battery health services.
5. **Regulatory Readiness:** gap assessment against R155 and R156, Right to Repair, Revision Annex X/858, and the China-specific GB/T and MIIT frameworks, as well as an outlook on the upcoming working groups on coded parts and the planned Motor Vehicle Block Exemption Regulation (MVBER).

The diagnostic stack is no longer a line item in a vehicle programme. It is the operating layer of the connected, software-defined fleet. Decisions taken now will determine which OEMs hold the customer relationship, the warranty pipeline, and the recurring-revenue position through 2035.

To discuss your diagnostic strategy, contact your Berylls by AlixPartners team for in-depth assistance.

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Disclaimer

Certain detailed data points and roadmap elements reflect the best available information at the time of writing and may be refined during the progress of technology, standards, and different product development activities.

Appendix

Abbreviation	Full Form
ADAS	Advanced Driver Assistance Systems
ADS	Automated Driving System
AECC	Automotive Edge Computing Consortium
AGL	Automotive Grade Linux
AI	Artificial Intelligence
AI-DV	AI-Defined Vehicle
ASAM	Association for Standardization of Automation and Measuring Systems
AUTOSAR	Automotive Open System Architecture
CAC	Cyberspace Administration of China
CAGR	Compound Annual Growth Rate
CAN	Controller Area Network
CAN-FD	Controller Area Network – Flexible Data-rate
CARB	California Air Resources Board
CI / CD	Continuous Integration / Continuous Delivery
DoIP	Diagnostics over Internet Protocol
DSA	Daten- und Systemtechnik GmbH
DTC	Diagnostic Trouble Code
E/E	Electrical/Electronic
ECU	Electronic Control Unit
EOBD	European On-Board Diagnostics
EOL	End-of-Line
EPA	Environmental Protection Agency
ETAS	Engineering and Tool Architecture Systems
EV	Electric Vehicle
GEA	Geely Electric Architecture
GEEA	Geely Evolved Electrical Architecture
HIL	Hardware-in-the-Loop
HPC	High-Performance Computer
HTTP	Hypertext Transfer Protocol
ICV	Intelligent Connected Vehicle
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
JSON	JavaScript Object Notation

Abbreviation	Full Form
KWP2000	Keyword Protocol 2000
L3 / L4	SAE Level 3 / Level 4 Automated Driving
LEEA	Li Auto Electric and Electronic Architecture
LIN	Local Interconnect Network
MB.OS	Mercedes-Benz Operating System
MCD-2D	Measurement, Calibration and Diagnostic Data
MIIT	Ministry of Industry and Information Technology
OBD / OBD-II	On-Board Diagnostics / Second Generation
ODX	Open Diagnostic Data Exchange
OEM	Original Equipment Manufacturer
OS	Operating System
OSI	Open Systems Interconnection
OTA	Over-the-Air
OTX	Open Test sequence eXchange
PIPL	Personal Information Protection Law
PRODIS	Professional Diagnostics
QNX	QNX Neutrino Real-Time OS
R155	UNECE Regulation No. 155
R156	UNECE Regulation No. 156
REST	Representational State Transfer
SAC	Standardization Administration of China
SAE	Society of Automotive Engineers
SAMR	State Administration for Market Regulation
SDV	Software-Defined Vehicle
SID	Service Identifier
SIL	Software-in-the-Loop
SkyOS	NIO full-stack vehicle OS
SOVD	Service-Oriented Vehicle Diagnostics
SOVD2UDS	SOVD-to-UDS backward compatibility adapter
SSP	Scalable Systems Platform
TOPS	Tera Operations Per Second
UDS	Unified Diagnostic Services
UNECE	United Nations Economic Commission for Europe
WP.29	World Forum for Harmonization of Vehicle Regulations
WWH-OBD	World-Wide Harmonized On-Board Diagnostics
XML	Extensible Markup Language
XNGP	XPENG Navigation Guided Pilot

Reference and Source List

Market Sizing Methodology

Each use case is sized bottom-up using the formula TAM = volume driver × unit price × adoption rate. Volume drivers are anchored to independent external data and expert interviews. Unit prices reflect the diagnostics-only portion of each use case where platforms are bundled. Adoption rates interpolate linearly between 2025 and 2035 anchor points; stated CAGRs are 2025-2035 endpoint rates, and annual growth is front-loaded.

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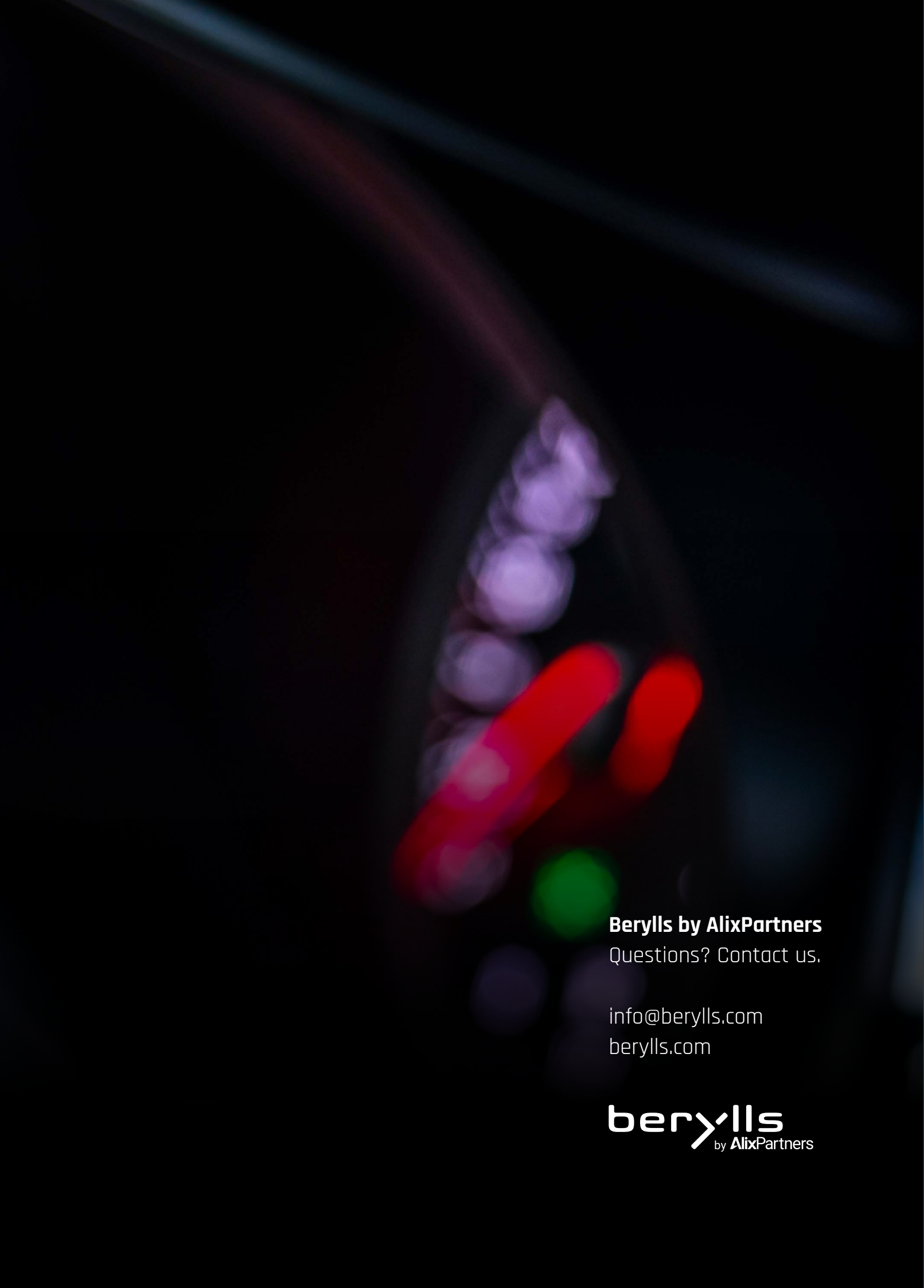
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