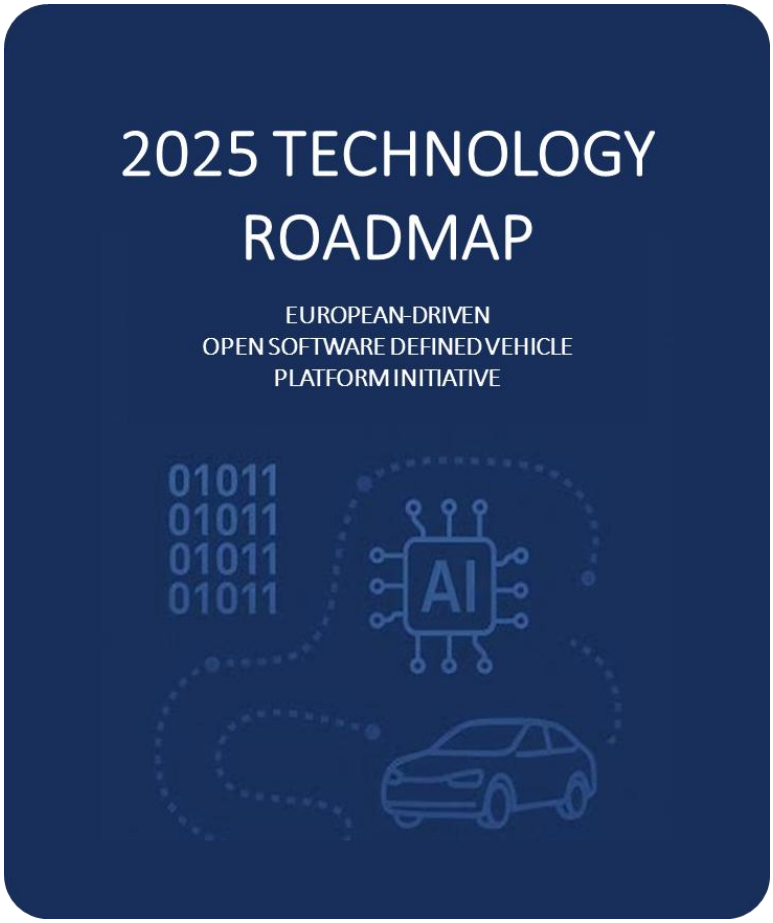

Version: 1.0

This report is the product of a collaborative effort of the European SDV technical working group.
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Document creation used AI technology.

Executive Summary

The European automotive industry is undergoing a **profound transformation**. As vehicles become increasingly **autonomous, electric, connected**, and **service-oriented**, **software** has emerged as the **key driver of innovation**, **safety**, and **value creation**. In response, in 2023 the European Commission launched the European-driven Software Defined Vehicle (SDV) software platform initiative, as part of the broader Digital Vehicle initiative[1], to strengthen Europe's leadership in next-generation mobility. In August 2025, the European Commission opened applications for the European Connected and Autonomous Vehicle Alliance (ECAVA)[2] to take the next step in providing strategic guidance and advice for technological developments and cooperation between automotive stakeholders in both European and global markets.

The Digital Vehicle initiative aims to build a robust and collaborative ecosystem among European OEMs and suppliers and open-source initiatives, focusing on shared open-source software building blocks rather than proprietary solutions. This system-level approach supports EU goals for digital sovereignty, zero-emission mobility, and industrial competitiveness. Publicly funded projects focus on a **common strategic imperative**: working towards the integration of project results into automotive series development by 2030. It addresses growing global competition, particularly from East Asian and U.S. companies that benefit from a "digital native" business model, early adoption, state aid, and the ability to invest massively into software and technology. Without coordinated actions, Europe risks falling behind in one of its most strategic sectors.

The European driven SDV platform initiative combines two complementary technical approaches:

- **Bottom-Up Integration**: OEMs assemble tailored software stacks from foundational open-source software building blocks like communication protocols and security modules.
- **Top-Down Middleware Development**: A standardized, automotive-grade middleware layer ensures safe, reliable communication between hardware and software applications. Reference SDV software stacks are built from the foundational open-source software, integrated and tested as platforms for specific automotive domains like automated driving, infotainment, body and chassis or powertrain.

[1] https://digital-strategy.ec.europa.eu/en/policies/digital-vehicle-ecosystem

[2] https://digital-strategy.ec.europa.eu/en/policies/vehicle-alliance

The development unfolds in four layers:

- **Hardware/Software Abstraction**: enabling flexible integration across platforms.
- **Middleware & API Framework**: providing essential services and standardized interfaces.
- **Applications**: domain specific, non-differentiating SW (outside SDV collaboration)
- **Automated DevOps Toolchain**: streamlining development, testing, and updates (AI – powered).

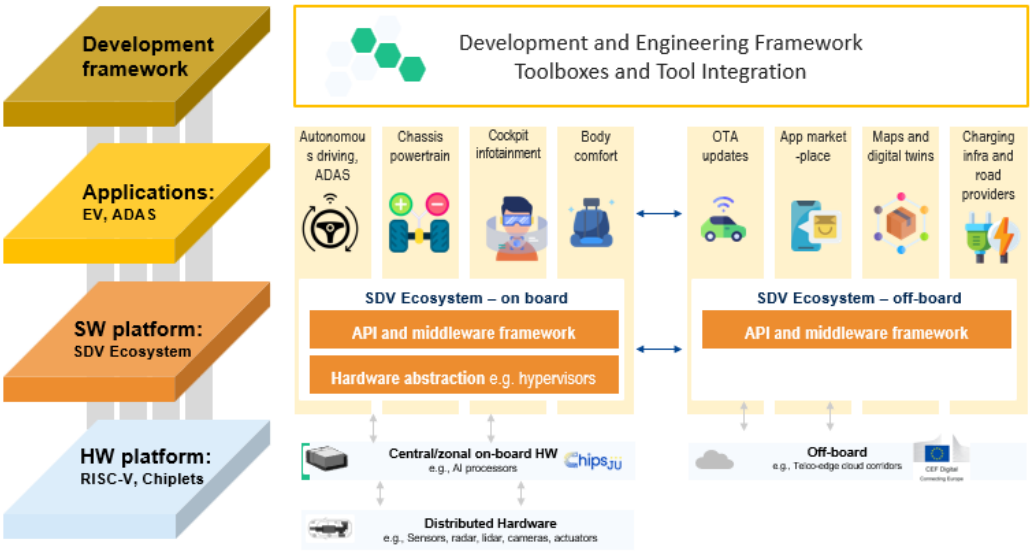

Figure 1: Overview of European Digital Vehicle Ecosystem

Europe's automotive sector is advancing toward this unified, modular software-defined vehicle (SDV) platform by leveraging open-source foundations and, member-state driven and pan-European collaboration. Legal and contractual barriers have been overcome, enabling OEMs and suppliers to co-develop non-differentiating software layers, significantly reducing costs and time to market. Key open-source initiatives—including ECLIPSE SDV, ECLIPSE-SDV S-CORE, COVESA, AUTOSAR, SOAFEE, Android Automotive Open source (AAOS), and Service-Oriented Vehicle Diagnostics (SOVD) - bring process expertise and broaden the development community.

This effort is uniquely focused on the automotive domain, aligning outputs from multiple EU-funded projects under one shared vision. The Chips Joint Undertaking ensures a scalable rollout across EU projects and national initiatives, while a streamlined contribution model feeds results into open-source repositories, promoting alignment, reducing redundancy, and accelerating adoption. Governance is reinforced through industry associations (VDA, PFA, ANFIA), open-source leaders, and the FEDERATE support action. The European Connected

and Autonomous Vehicle Alliance will build the next level of collaboration with broadened technology scope that ensures agility, strategic alignment, and legal clarity for cross-partner collaboration.

A technology roadmap combines the results from EU-projects following the clear research and innovation roadmap and the results from open-source initiatives, and has broad support by European OEMs and suppliers.

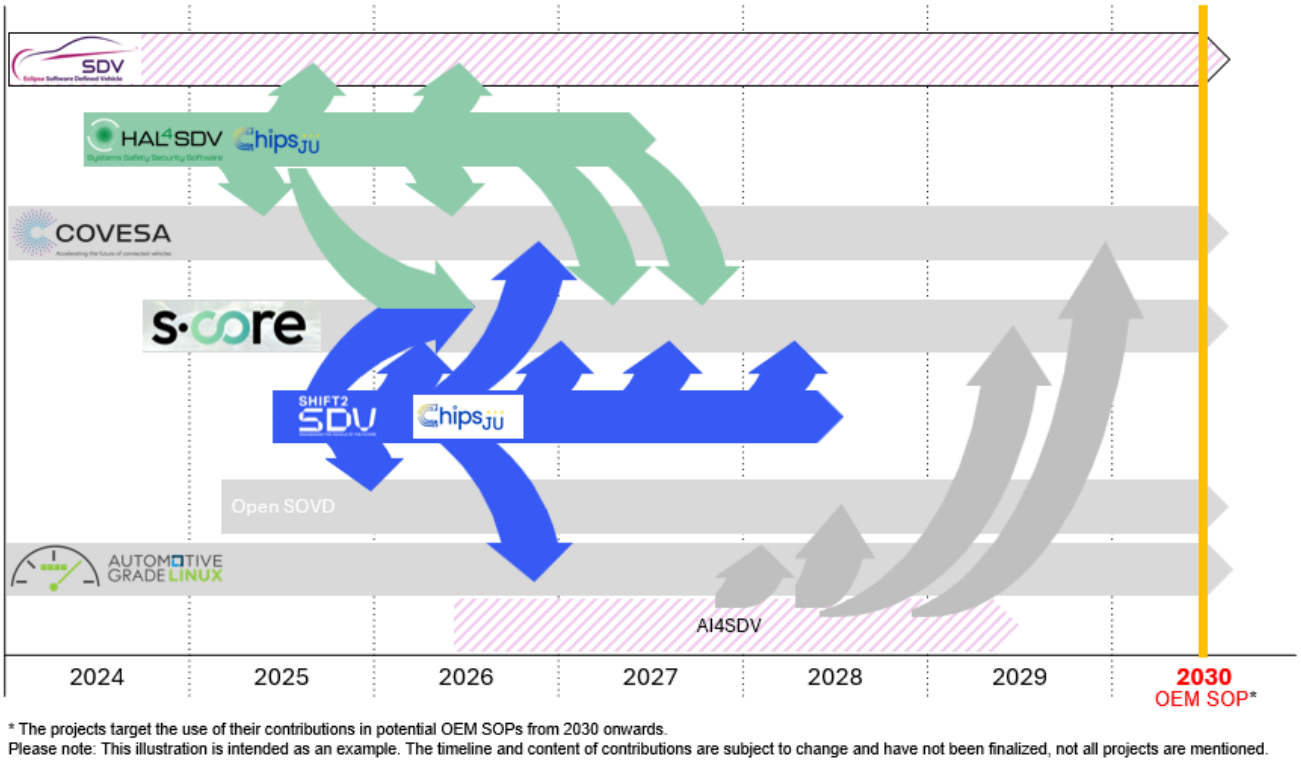

Figure 2: Overview of project timelines for intended collaboration until series production (SOP) 2030

This report aims to set the stage toward accelerating and deepening European collaboration on connected and autonomous vehicles under ECAVA. It is a working document, intended to be hardened before the first ECAVA Steering Committee meeting. Future ECAVA roadmaps, such as on autonomous computing hardware and autonomous driving, may build upon the outputs of this paper. With decisive action, Europe can be at the forefront of digital vehicle innovation considering its solid manufacturing and engineering assets.

To accelerate the adoption of Software-Defined Vehicles (SDVs) and ensure readiness for series production by 2030 or earlier, the European Commission should continue its strategic dialogue with industry stakeholders and actively leverage the ECAVA initiative. This includes fostering an SDV ecosystem built around open-source building blocks and software stacks, with ECAVA Working Groups aligning their efforts to support these integration goals.

A critical enabler of this transition is the establishment of a dedicated software management body, which would serve to coordinate and strengthen the SDV ecosystem. The Commission can play a catalytic role by providing initial funding and facilitating collaboration among industry players, open-source communities, and associations within a virtual organizational framework.

To further support innovation and agility, funding processes should be streamlined—reducing public-private partnership proposal writing and project execution timelines to six months, limiting participant numbers, focusing investments on tangible deliverables such as open-source software, and lowering entry barriers for startups and SMEs. These measures will help create a dynamic, inclusive, and results-driven environment for SDV development across Europe.

Policymakers are encouraged to **support the European driven open SDV software platform initiative** through targeted investment, regulatory harmonization, and the establishment of robust public-private partnerships. With such strategic engagement, Europe can assert a leading role in shaping the future of mobility.

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Framework for the collaboration

Challenges in the automotive industry

The development of a robust European Software-Defined Vehicle (SDV) ecosystem faces several critical challenges (see Figure 3) that must be addressed to ensure global competitiveness and technological sovereignty. At the core the SDV software stack—particularly operating systems and middleware—remains fragmented across OEMs. The effort to integrate will stay high, turnaround times continue to be long, and standardization focused on an SDV ecosystem will not happen.

SDV Stack (OS/MW)	• Inconsistent OS/MW building blocks and stacks across OEMS • High effort for configuration, integration leading to long turnaround times • Missing SW Management organization focused on enabling an SDV ecosystem
SW Toolchain & Process	• Lack in toolchain automation and cohesiveness from spec over code to integration towards validation and verification • Significant non-value creating effort in quality related processes (ASPICE, Safety, Security etc.)
Regulatory impediments	• Regulatory lag in type approval • Fragmented cybersecurity regulation • Restrictive data protection laws • Burdensome AI regulation • Homologation and safety certification does currently not incremental certification
Lacking technology leadership	• Slow and complicated innovation funding • Lack of European leadership in efficient SDV standardization • Semiconductor dependency from other markets, missing European Silicon ecosystems
Other/Expertise	• Missing expertise in creation of scalable ecosystems and digital business models (create “fly-wheel effect”) • Foreseeable shortage of skilled automotive software developers in Europe

Figure 3: Pain points of automotive industry in SDV development

Toolchain inefficiencies further increase the challenges, with limited automation and cohesion along the development pipeline across suppliers —from specification to validation. Quality assurance processes, including ASPICE, safety, and security compliance, demand significant additional resources.

Regulatory barriers also pose a major obstacle. Delays in type approval, fragmented cybersecurity regulations, restrictive data protection laws, and burdensome homologation procedures hinder innovation:

– **Regulatory Lag in Type Approval**: European type approval law must be able to handle software speed. This is because the SDV and its ecosystem are defined by continuous and fast updates of applications and

functions – they are a decisive differentiating and quality feature for the SDV. A new approach to type approval is therefore needed that rebalances entrepreneurial freedom and security, considering approval-relevant updates of software and hardware over the entire life cycle, establishing uniform and harmonized procedures, e.g. through digital vehicle files.

- **Fragmented Cybersecurity Regulation:** The multitude of EU cyber legislation leads to a patchwork of regulations (e.g. NIS 2.0, UN R155, CRA, among others). Therefore, it is necessary to systematize and structure IT security law and reform computer criminal law to enable innovation.
- **Restrictive Data Protection Laws:** We observe highly restrictive, unbalanced and innovation-inhibiting interpretations of the data protection supervisory authorities for the European General Data Protection Regulation (GDPR). Therefore, a comprehensive review and adaptation of the regulations is necessary, or its national implementation rules, incl. for the cross-sectoral, legally compliant exchange of vehicle-generated data.
- **AI Regulation:** The current legal framework, in particular the reporting obligations of the 'EU AI Act', makes rapid vehicle development more difficult due to high additional costs. Therefore, we require facilitations for AI-supported vehicle-specific development systems, such as protected experimental spaces as well as regulatory relief in the Code of Practice. In particular, a focus should be to rapidly **leverage the ready-to-use legal provisions of the AI Act** to launch regulatory sandboxes for controlled experimentation and testing; and real-world-testing.
- **Homologation and safety certification does not currently support incremental SW updates**: Homologation and safety certification should support incremental certification originating from software updates.

There is an urgent need for regulatory frameworks that support incremental safety certification and agile development cycles.

Europe's technology leadership in automotive electronics and software is at risk due to cyclical and rather static innovation funding mechanisms, limited standardization influence, and continued dependency on non-European semiconductor supply chains. Compounding this is a growing shortage of skilled automotive software developers and a lack of expertise in building scalable digital ecosystems and business models capable of generating network effects.

Addressing these pain points requires coordinated action across industry and government, with targeted investment in open-source collaboration, regulatory modernization, and workforce development to unlock the full potential of SDV innovation in Europe.

Roadmap for SOP ready SDV software platform by 2030

To accelerate the development of a competitive and sovereign SDV ecosystem in Europe, a coordinated focus on key technology building blocks is essential. Five key priorities have emerged as critical enablers for industry-wide transformation (see Figure 4).

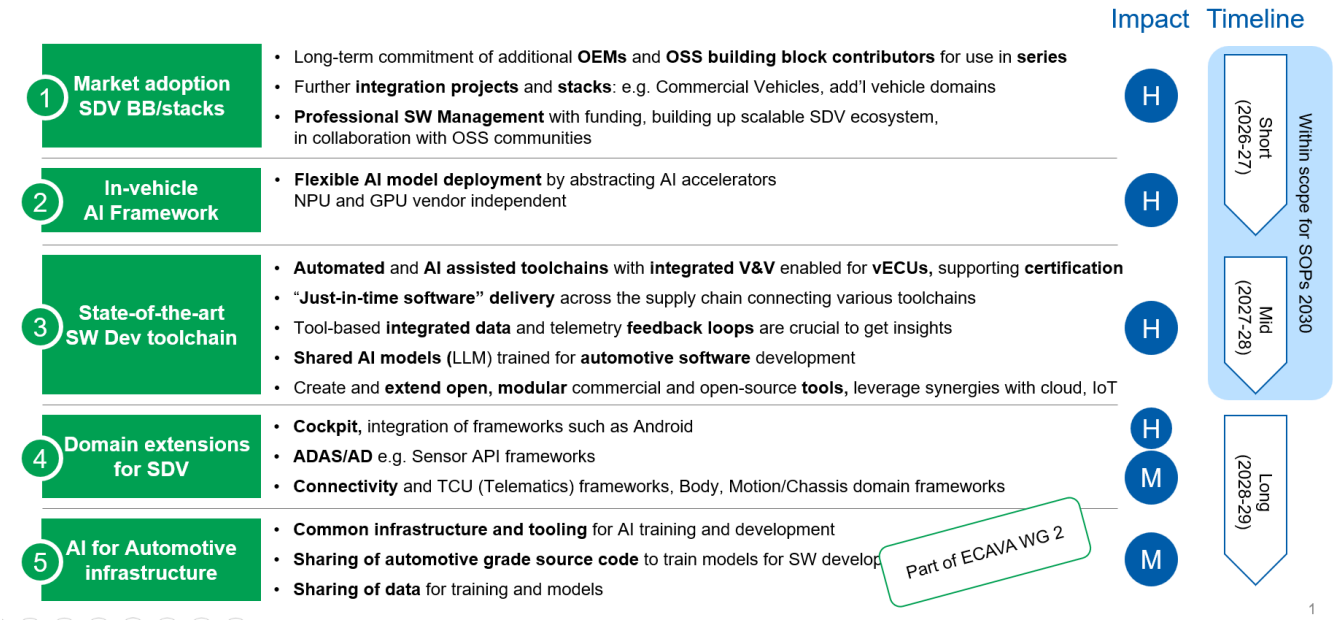

Figure 4: Roadmap and key priorities

1. **Market adoption** of SDV SW Stacks using SW Building Blocks developed collaboratively in the non-competitive areas of the stack, European OEMs and SDV consortia must be empowered to adopt standardized software stacks for series production. This includes expanding integration efforts across commercial vehicles and other domains, supported by professional software management and strategic funding. Collaboration with open-source communities will be vital to foster a vibrant and scalable SDV ecosystem.
2. **In-vehicle AI frameworks** to harness the full potential of artificial intelligence in vehicles, Europe must invest in frameworks that abstract hardware dependencies—particularly across AI accelerators like NPUs and GPUs. Seamless integration and independence of vendor technologies will enable more agile and efficient AI model development and deployment.
3. **State-of-the-Art SDV Development Toolchains**: A modern, automated, and AI-assisted SDV development environment (tool chain and process) is foundational for SDV innovation. These tool chains must support integrated verification and validation (V&V) for SDV electronic control units, while supporting certification requirements. Open-source-based tools, continuous integration/continuous deployment (CI/CD) platforms,

and telemetry-driven feedback loops will be essential to build trust and accelerate development. A shared toolset with agreed interfaces between tools across OEMs, Tier 1 suppliers, and module developers - leveraging existing expertise - will further streamline the process.

4. **SDV ecosystem extension with domain-specific frameworks**. In addition to common Operating System/Middleware building blocks, there are significant domain-specific non-differentiating software components that enable abstraction and reuse of application functions. This includes cockpit systems, advanced driver assistance systems (ADAS) and autonomous driving (AD), body and chassis automation as well as AD sensor APIs, and connectivity modules such as telematics control units (TCUs) for communication to the cloud.

5. **AI infrastructure for the European automotive sector** must establish a common infrastructure for automotive-grade AI development. This includes shared tooling, source code, and datasets to train models for robust verification and validation (V&V) scenarios. A culture of collaboration around data and model sharing will be critical to ensure safety, scalability, and innovation. The European Automotive industry has a big advantage based on its experience of bringing vehicles to the market successfully. Using data and source-code out of this expertise to train AI systems helps capitalize and transform this expertise into an AI-driven future. This requires new collaboration and IP models leading to partially collaboratively trained AI models using shared source code and other development work products. Additionally OEMs and tiers may specialize AI models with protected company specific data on company level too.

   OEMs are designing AI accelerators into their next-generation vehicle architectures and want to avoid silicon vendor specific AI frameworks. It is important to extend existing vendor agnostic AI frameworks to support the new AI accelerators.

These priorities represent high-impact areas where **public-private collaboration** can catalyze progress. By investing in these foundational technologies, Europe can secure its leadership in next-generation mobility and digital automotive innovation.

Collaboration in the European SDV ecosystem

Status of the SDV ecosystem

Europe's Software-Defined Vehicle (SDV) community stands at the forefront of the global shift toward software-driven mobility, underpinned by a robust and evolving ecosystem that fuses industrial expertise, academic excellence, and open-source collaboration. Coordinated R&D initiatives—strategically aligned with open-source frameworks—have laid the groundwork for scalable innovation and cross-sector synergy. To fully capitalize on this momentum, stakeholders must now focus on deepening collaboration, validating the modular architecture(s), and securing long-term contributor engagement. Crucially, sustained OEM buy-in is essential to ensure that open-source outputs are not only adopted but embedded into series production (SOP). Achieving these goals demands substantial additional investment, both public and private, to reinforce Europe's leadership and unlock the full potential of SDV technologies.

Key Strategic Approach

- **Open-Source Foundation**: Legal and contractual barriers for automotive OEMs and tiers in a collaboration in the non-differentiating layers of SDV SW stacks have been overcome by embracing **open-source software**. This shared technical base **reduces development costs** and **accelerates commercialization**—like how chassis designs were once shared across brands. Open-source initiatives (foremost **ECLIPSE SDV**, but also COVESA, AUTOSAR, AAOS and SOAFEE) bring in their open-source process knowhow and their SDV projects, which extends the development community significantly.
- **Pan-European Collaboration**: OEMs, suppliers, and universities across Europe have a long history of working together. This trusted network now forms the backbone of SDV innovation. Open-source initiatives and funded collaborative project consortia at Member-State and European level are working towards a common vision for a modular SDV SW platform building blocks with automotive grade quality, underpinned by this technology roadmap. On a Member-state level, a strong alignment with Member State-funded initiatives, such as **SofDCar, Autotech.Agil, and Ökosystem Mobilität 4.0,** amongst others, should be re-inforced. On the European level, The **Chips Joint Undertaking** and EU automotive R&I partnerships (**CCAM, 2ZERO**) support scaling and alignment of national SDV projects across Europe. Coordination efforts from DG-CNECT, FEDERATE and automotive industry associations help to align funded with open-source projects for example in ECLIPSE-SDV, COVESA, AAOS.

- **Unified Automotive Focus**: Unlike other EU-funded projects that span multiple industries, SDV efforts are rooted in a single domain: automotive. Open-source results and results from **multiple EU projects** are combined towards the common goal. This creates a common language and accelerates progress.
- **Scalable Project Structure:** To advance this effort, the European Commission announced applications to open in August 2025 for the European Connected and Autonomous Vehicle Alliance ECAVA to guide technological development and foster collaboration among automotive stakeholders. ECAVA focuses on EU-led initiatives in SDVs, computing hardware, automotive electronics, AI models, and autonomous driving, accelerating existing industry partnerships at the European level.
- **Efficient Contribution Model**: Results from EU-funded projects are fed into **open-source repositories**. Orchestration and proven OSS-processes avoid duplication and maximizing reuse in future production programs.
- **Governance and Ecosystem Building**: The close cooperation of the industry supported by their associations VDA, PFA and ANFIA, the open sources initiatives as ECLIPSE-SDV and COVESA and a coordination and support action FEDERATE which helps to coordinate and support strategic alignment created an ecosystem combining industry focus, agility, speed and provides a legal framework for efficient cross-partner collaboration in smaller and larger projects.

Accelerating Europe's Leadership in Software-Defined Vehicles

Europe has reached a promising starting point in the evolution of mobility. The **European driven SDV SW platform initiative** as part of the **European Digital vehicle initiative** - launched and strongly supported by the European Commission (under the lead of DG CNECT) - has laid the foundation for a new era of automotive innovation. It follows a **vision and roadmap document**[3] agreed by the industry in a **manifesto**[4] indicating the collaboration and signed by the relevant industry associations and companies.

[3] https://federate-sdv.eu/wp-content/uploads/2024/04/2024-04-12-SDVoF-Vision-document-ver017-final.pdf

[4] https://federate-sdv.eu/declaration-of-european-automotive-manufacturers-and-suppliers-manifesto/

A **Memorandum of understanding** (MoU)[5] signed by key European manufacturers and suppliers announcing to actively participate in development work to create the European driven open SDV SW platform mark a next step in the ecosystem building. Several more companies are in the process to sign the MoU too.

This combined approach is not merely a technical achievement; it represents a strategic blueprint for how Europe can lead in the global race toward intelligent, connected, and sustainable mobility.

Yet the pace of technological change in the SDV market is accelerating rapidly. To maintain momentum, we **welcome the next critical step**: The European Commission launched the **European Connected and Autonomous Vehicle Alliance (ECAVA)** to take the next step in providing strategic guidance and advice for technological developments and cooperation between automotive stakeholders in both European and global markets. ECAVA's activities will be focusing initially on near-term EU-driven collaborations in software defined vehicles (SDV), hardware computing architectures and automotive electronics, AI models, and the development, piloting and testing of autonomous driving. ECAVA will thus shape EU cooperations in all these areas, building on and accelerating any existing industry collaborations on Software-Defined Vehicles, Autonomous Hardware and Autonomous Driving at the EU-level. In addition, in the long term ECAVA will offer strategic guidance for the Strategic Research and Innovation Agenda (SRIA) for the next MFF (2028-2034) which will be developed under the MoU in preparation by Commissioner Zaharieva and the Horizon Europe automotive partnerships

Driving Efficiency and Collaboration in Europe's SDV Software Ecosystem

Thanks to this leadership this initiative enabled diverse industry stakeholders to work together in open-source communities and collaborative funded EU-projects, co-developing non-differentiating software building blocks at unprecedented speed. The EU projects follow the roadmap depicted in Figure 5.

Without this coordinated push, such rapid and cross-sector collaboration would not have been feasible. EU-funded projects - including **HAL4SDV** and **SHIFT2SDV**—have aligned with the Eclipse **S-CORE** project, which serves as first reference integration project for SDV software stacks. Other integration projects are following, where building blocks of the SW platform will be integrated.

As one of the pains in SDV development are the high integration efforts, the Eclipse S-CORE project introduces a streamlined, structured process that simplifies the integration of modular software building blocks. By adopting the widely recognized open-source principle of "**Documentation as Code**," the initiative ensures that all work

[5] https://www.vda.de/dam/jcr:50e82fa0-dd27-4db5-834f-80032c57b1b3/MoU%20Automotive%20Grade%20Open-Source%20Software%20Ecosystem%20signed.pdf

products are machine-readable, transparent, and easily reusable—boosting development speed and cross-project compatibility. Other OSS initiatives are also working on this issue.

Industry stakeholders have shaped a **Technology Roadmap**, outlining the development of modular software building blocks in different collaborating projects in open-source initiatives and public funded EU-projects and their integration into reference SDV stacks. A modular approach is essential to meet diverse market needs across SDV domains—from automated driving to infotainment and beyond.

To maintain speed and focus, the first integration project is being built around the **S-CORE** project within **ECLIPSE-SDV** program, targeting applications in automated driving. Key contributors include the active **EU-funded** collaborative projects, which are accelerating early implementation and integration going on in S-CORE as the first SDV integration project.

This **SDV technology roadmap** is not static - it will be **continuously updated and expanded** with new building blocks and reference integration projects. It reflects a dynamic, coordinated effort to ensure Europe remains at the forefront of automotive software innovation.

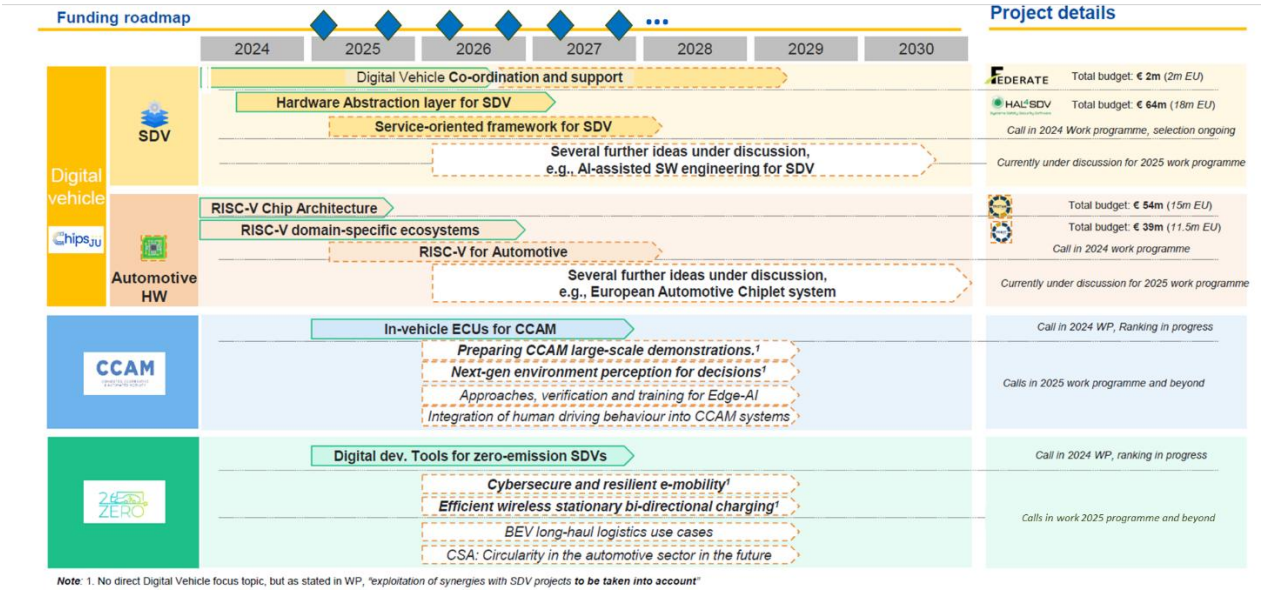

Figure 5: Roadmap of EU driven Digital Vehicle ecosystem

As indicated in the Digital Vehicle Ecosystem, a strong link to ongoing Hardware initiatives is sought-after. The development of more powerful centralised processors exploiting key trends in the semiconductor industry such as chiplets, advanced packaging and cutting-edge chip nodes are key elements for realising automotive AI chips. This will enable modularity and customisation while maintaining high performance and safety. Developments on SDV stack are targeted to be hardware-agnostic, hardware agnostic – maintaining flexibility for the exchange of

components due to the risk of trade restrictions - while allowing for the integration of emerging European processors.

Further, the development of a European testing infrastructure is essential for supporting the development of the above architectural elements. The SDV ecosystem envisages a collaborative environment for **SDV and AI engineering** and as a **testbed for innovation in application layers,** including autonomous driving. It should be based on a agile and modular approach to accelerate standardization and their deployment in vehicles.

Collaboration models

The Technology Roadmap outlines **five modes of collaboration** between open-source projects and public funded partner projects:

- Requirement Alignment: EU projects gather and align feature requirements with OSS-project leadership.
- Joint Development: Project partners actively participate in feature development and management.
- Feature Creation: New building blocks are developed within an OSS integration project using its standardized process.
- External Contribution: Building blocks created in other open-source environments (e.g. Eclipse SDV, COVESA) are integrated and tested for compatibility with the OSS integration project.
- Integration Protocols: A formal procedure ensures that all contributions meet quality and architectural standards.

Biannual "SDV Convergence Conferences" with participation from all key stakeholders from industry, OSS projects and EU-projects work on the alignment of the different activities towards a common modular SDV SW platform. In October 2025 the 2nd SDV Convergence Conference will take place in Brussels. Guidelines for a modular architecture were created, which will be aligned in the upcoming SDV Convergence Conference (see appendix b at the end of the document).

As Europe's first **SDV integration project**, S-CORE fulfils three strategic roles:

- **SDV Development Process Innovation**: It extends open-source development models to support rapid and **certifiable safety compliance**.
- **Core Components Development**: It builds foundational software components for ADAS and automated driving, leveraging also proven code from existing OEM deployments donated to open-source initiatives.
- **SW Stack Integration**: It assembles and validates a complete reference software stack, ensuring functional integrity and architectural alignment. The roadmap is using this S-CORE timeline as base.

This collaborative framework marks a new level of efficiency in European automotive R&D. It enables faster innovation, reduces duplication, and strengthens Europe's position in the global race for software-defined mobility.

European driven SDV platform initiative: Strategic Contributions to Open-Source Ecosystems

As part of Europe's commitment to accelerating innovation in Software-Defined Vehicles (SDVs), the **HAL4SDV** and **Shift2SDV** projects are spearheading coordinated contributions to key open-source platforms. These efforts reflect a broader strategy to strengthen Europe's digital sovereignty and industrial competitiveness through collaborative software development.

An additional EU-project (as envisioned in the SDV vision and roadmap document) is in the proposal state to add the creation of an AI assisted SW development ecosystem with interfaces between tools. It will focus on two innovations: (1) Automate integration of building blocks from different development centres using different tools, (2) Extend AI assisted development automation to the complete DevOps lifecycle.

Strategic Alignment with Open-Source Communities

This technology roadmap aligns the **EU-projects** with the development projects in the Eclipse-SDV ecosystem, particularly the **S-CORE** project, as well as with **COVESA, digital.auto,** and other leading platforms as AAOS in future. This alignment is enabled by a strong collaboration between the projects, as many EU project partners are active contributors in the open-source communities too. Developers are **co-creating components** in both EU-funded and Open-source unfunded initiatives, ensuring no duplication of funding while maximizing impact. Many resulting innovations are donated to **open-source foundations**, reinforcing transparency and accessibility. It is also possible that open-source building blocks from collaborative or open-source projects can have a functional basic open-source version and a more advanced non-OSS version to allow business for contributing companies.

S-CORE release overview

The ECLIPSE-SDV project **S-CORE** concentrates on the completion of a reference SW core stack for the use in Automated driving applications. The project started in late 2024 and will reach the first milestone end of 2025. The details of the roadmap and architecture of S-CORE SDV SW reference stack are shown in Figure 6. It contains two major release milestones relevant for the alignment with the EU-project activities. In future this milestone list will be expanded.

End of 2025: **v0.5 certifiable MVP** of a reference core-stack for automated driving applications:

- all selected components (C++) are currently being used in series projects and are being modified to match the S-CORE architecture, processes and tools
- V0.5 shall be integrable into a HPC platform

End of 2026: **v1.0 complete SW stack**:

- Many components (C++) are currently being used in series projects and are being modified to match the S-CORE architecture, processes and tools
- development start of AD platform

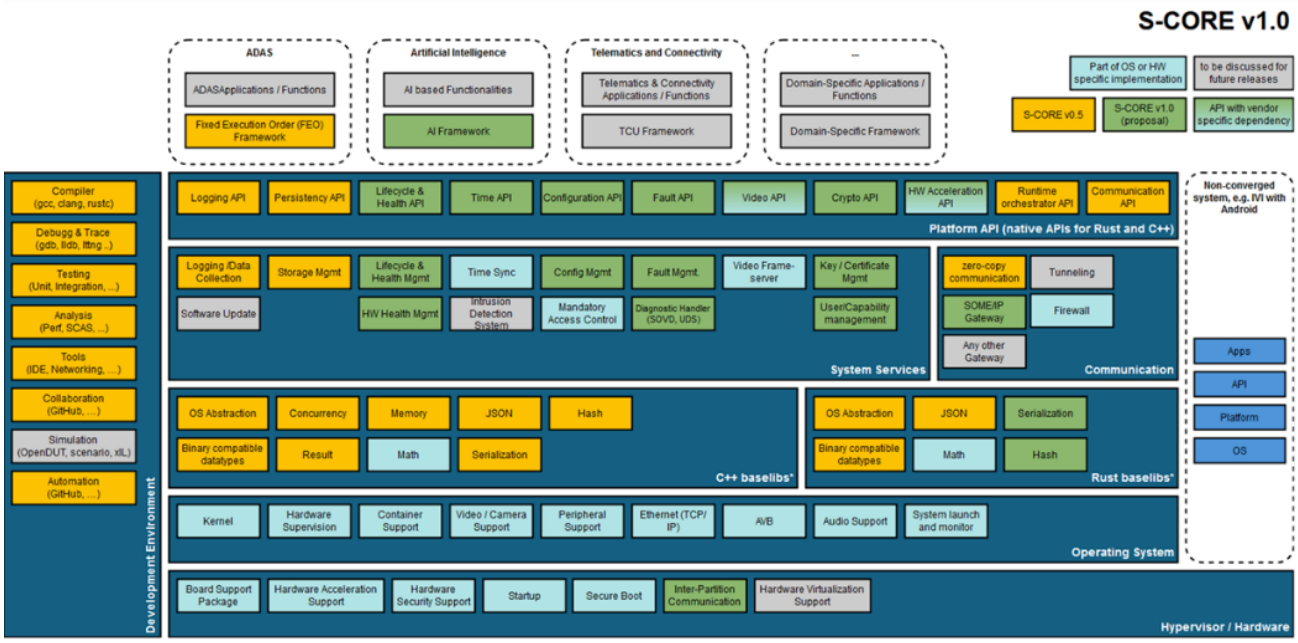

Figure 6: S-CORE 1.0 overview

Technology Roadmap for integration of building blocks (BB) from EU projects

The roadmap outlines a structured integration strategy built on the modular building blocks and diverse collaboration models described on page 17 and as detailed in the accompanying table.

These integration steps align with the S-CORE roadmap, which guides the evolution of an unified software architecture. In version 0.5, most of the C++ components are based on software already deployed in series

production and are adapted to conform with S-CORE's architecture, processes, and tooling. The transition to version 1.0 is currently underway, with a strong emphasis on leveraging a proven code base to ensure reliability and scalability. Strategic discussions with HAL4SDV and Shift2SDV are ongoing to shape contributions to S-CORE v1.0 and future iterations, reinforcing a shared commitment to open collaboration and industry-wide alignment.

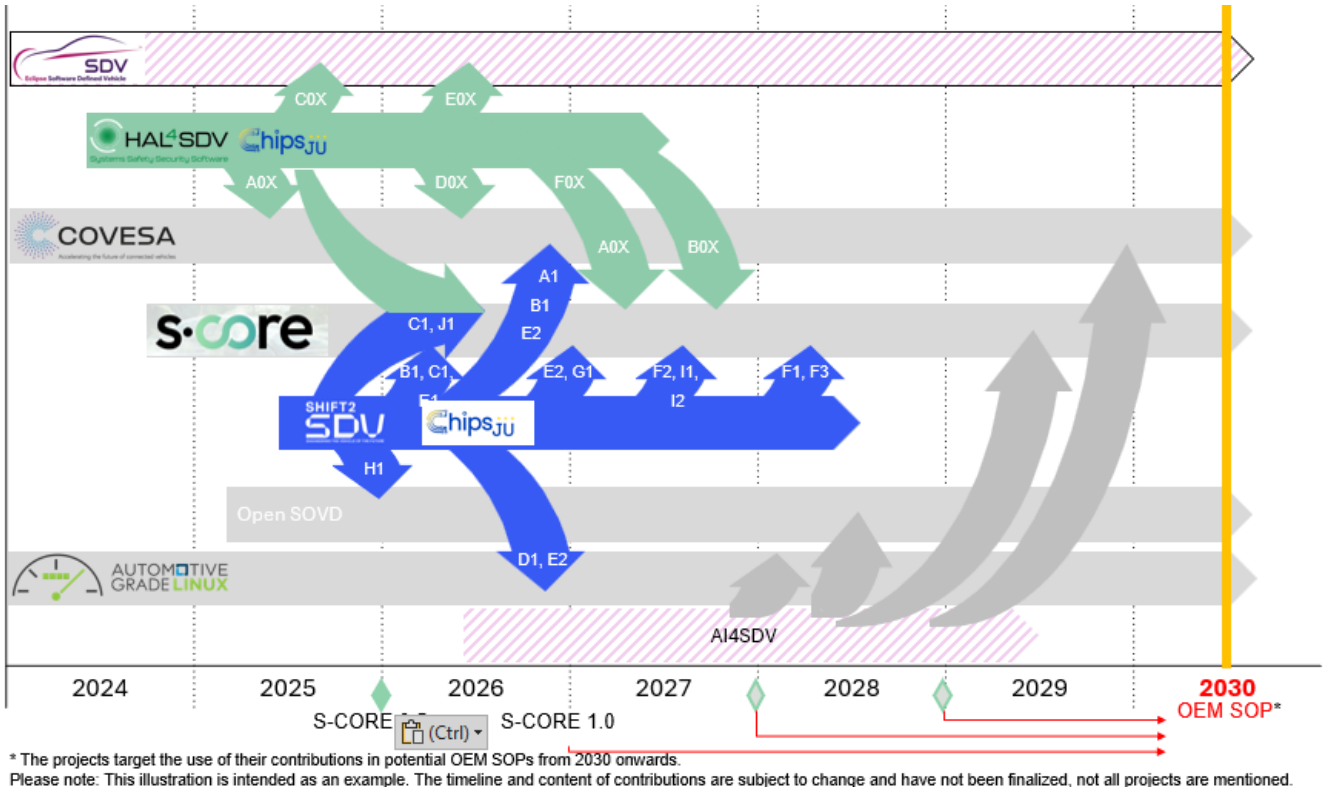

Figure 7: SW Technology integration roadmap of the European driven SDV SW platform initiative

The alignment with other OSS projects is underway and will be added in future releases of this document. The integration of building blocks from the EU projects follows the process defined in the OSS integration projects (as S-CORE) to ensure fast integration while achieving high SW quality. Therefor the roadmap in Figure 7 remains indicative - subject to the rigorous quality gates of the OSS process. But it outlines a clear trajectory for integrating EU project outcomes into the broader SDV software landscape.

Eclipse-SDV plans to take over results on a common architecture of the SDV SW platform from the EU-project HAL4SDV and create a new Eclipse-SDV specification project. This architecture is already well aligned with the Eclipse S-CORE architecture. The new workgroup will continue to abstract the current architecture and enable an interoperable set up.

Key Building Blocks & Planned Contributions from EU-projects to OSS initiatives

The following table describes the building blocks from the EU-projects, which are planned for integration into the first SDV SW integration project S-CORE as well as other open-source integration projects. The table contains information about the scope (feature) of the building blocks, the collaboration type and the milestone for the integration.

Table 1: Building blocks from EU-Projects planned for integration in Eclipse S-CORE

Building Block from EU-project	Target focus Area in OSS initiative	Intended contribution	(OSS) Project	Status (idea, in alignment, aligned, confirmed)	intentions for first contributions	Type of collaboration
A1 Sensor API		VSS sensor specifications	COVESA	in alignment	2026	Joint dev.
B1 Motion APIs		Additional actuator signals	COVESA	in alignment	Q4 2025	Req.alignment
	Chassis function standardization	Tool to the Eclipse Automotive API framework repository, integrating it into the Eclipse S-CORE ecosystem	Eclipse S-CORE	in alignment	Q4 2025 first MVP	New feature
C1 Plug & Charge	Platform API	Enhanced standards for Secure charging communication	Eclipse S-CORE	in alignment	Q4 2026	Joint dev. & potentialy New feature
		Discussion about collaboration towards OSS projects	HAL4SDV	in alignment		
D1 Multimedia API		Integration of driver monitoring and communication stacks	Automotive Grade Linux	idea	Q2 2026	New feature
E1 In-Vehicle Communication Middleware	GenAI test environments	GenAI-empowered integration of simulated and testbench environments for evaluating open SDV stacks	Eclipse S-CORE	in alignment	Q1 2026	New feature
		Runtime configuration mechanisms for TSN-based vehicle networks	TSNConf	idea		
E2 V2X Communication Middleware		define a common data model for vehicle signals	COVESA	idea		New feature
	Communication	requirements for a generic V2X interface	Eclipse S-CORE	in alignment	Q4 2026	

F1 Intrusion Detection, F2 Anomaly Detection, F3 Security and Safety API	System Services	Feature proposals for Eclipse S-CORE	Eclipse S-CORE	in alignment		New feature
G1 Digital Twin		Extend communication middleware with a simulation binding for Digital Twin use cases	Eclipse S-CORE	in alignment	2026	Joint dev.
		extending configuration module to import parameters and variant sets	Eclipse S-CORE	in alignment	2026	Joint dev.
		integration of the formal modeling toolchain Dezyne into S-CORE's Bazel-based build and test workflow	Eclipse S-CORE	in alignment	2026	New feature
H1 SOVD	Remote diagnostics & OTA	focusing on implementations around the SOVD Gateway, Server, Client, Classic UDS adapter, and OTA updates	Eclipse Open SOVD	aligned	Q4 2025	Joint Dev.
I1 Microservice Management		extension of the embedded workload container orchestrator to support a new runtime and event handling	Eclipse Ankaios	idea	Q4 2025	Joint Dev.
I2 SDK: Library & Variant Management		tooling to provide developers with effective access to vehicle APIs and manage API libraries	Eclipse S-CORE	idea	2027	New tool
		tooling to check application code for correct API usage and vehicle compatibility	Eclipse S-CORE	idea	2027	New tool
J1 SDK: Data-Centric Access		VSS support for SystemState and VSS extensions for Fleet Management System (FMS)	HAL4SDV		Q4 2026	Joint Dev.
Managed DDS from UNIcar.Agil project	Communication	additional gateway in communication			tbd	New feature

Contributions to other projects such as Everest, KUKSA.val, Eclipse Hono, Eclipse Mosquitto, Eclipse Zenoh, and Eclipse Ankaios are currently under evaluation.

Annexes

a. Consulted Organisations

Between July-September 2025, participants from the following organisations / Projets were consulted and actively contributed to the development of this document:

Table 2: Consulted organisations

OEMs	Suppliers	Technology & Tool Providers	RTOs	Projects	Associations /Foundations	Public Sector
AB Volvo	Bosch / ETAS	Accenture	UniDAS	COVESA	Android Automotive Open Source	European Commission – DG CNECT
BMW Group	Brembo	AVL List	RWTH-Aachen	Eclipse S-CORE	Eclipse Foundation	
Cariad	Continental	OPMobility	TU-Darmstadt	Eclipse SOVD	INSIDE	
CORETURA	FORVIA	Rimac	UniBw München	FEDERATE	PFA – Plateforme Automobile	
Daimler Truck AG	ZF	TTTech Auto		HAL4SDV	VDA – Verband Der Automobilindustrie	
Mercedes-Benz Group		Vector		Shift2SDV		
Renault/Ampere						
TRATON						

b. Guidelines for Modular Software Architecture

To ensure Europe's leadership in Software-Defined Vehicles (SDVs), the automotive industry must adopt a modular software architecture that fosters scalability, interoperability, and sustainable innovation. This architecture should be built on a foundation of open-source collaboration and robust engineering principles, enabling faster development cycles and cross-industry alignment. The SW platform architecture shall follow the principles depicted in Figure 8 and described below.

Technical Objectives	Flexible micro-services-based architecture, brand-specific application development, practical viability through use cases
Modularity Principles	Single Responsibility, Encapsulation, Loose Coupling, Reusability, Replaceability
Standardized Interfaces	Interface Definition Languages (IDLs), versioning, changelogs, backward compatibility, semantic versioning, language-agnostic design, open standards (e.g. MQTT), data formats (e.g. JSON)
Compatibility Strategies	Abstraction Layers, Configurable Build Systems (CMake, Bazel, Meson), Containerization (Dockerfiles, OCI), Continuous Integration, Continuous Deployment (CI/CD) Documentation and Examples
Open Source Best Practices	Permissive Licensing (Apache 2.0, MIT), Community Governance, Transparent Roadmaps, Upstream/Downstream Collaboration, Early source code publishing, Educate non-engineers
Extensibility	Plugin Architectures, Configuration Over Code, Event-Driven Patterns, Feature Flags
Testing and Validation	Unit Testing, Integration Testing, Conformance Testing, Performance and Scalability, Security Testing
Documentation	API References (Doxygen, Sphinx, Javadoc, GenAI), Semantic APIs, User Guides, Architecture Overviews, Troubleshooting, Changelog and Migration Guides
Security and Safety	Secure-by-Design, Data Integrity and Privacy (TLS, GDPR), Fail-Safe Mechanisms, Certification Readiness
Continuous Improvement	Issue Tracking, Metrics and Telemetry, Community Forums, Release Cadence

Figure 8: Guidelines for modular SW architecture

At the core of this approach is a flexible, microservices-based architecture that supports brand-specific applications while allowing for continuous technological evolution. Modularity must be driven by principles such as single responsibility, encapsulation, loose coupling, and reusability—ensuring that software components can be easily replaced or upgraded without disrupting the system.

Standardized interfaces, including RESTful APIs and semantic versioning, are essential to maintain backward compatibility and enable seamless integration across platforms. Interoperability must be prioritized through language- and protocol-agnostic interfaces, supported by semantic interoperability frameworks.

Configurability is another key pillar, with parameterized layers and modern build systems like CMake, Bazel, and Meson enabling tailored deployments. Scalability should be achieved through containerization technologies (e.g., Docker, OCI) and continuous integration/deployment (CI/CD) pipelines that support agile development.

Effective data management requires decentralized storage, clear data ownership, and robust access controls. Communication layers such as DDS, MQTT, and Kafka must facilitate upstream and downstream collaboration across stakeholders.

Rigorous testing and validation—spanning unit, component, integration, and system levels—are non-negotiable for safety and reliability. Quality assurance must be guided by transparent roadmaps, external patterns, and feature flag mechanisms to ensure accountability and traceability.

Security and safety must be embedded from the ground up, with role-based access controls, API restrictions, and dedicated architecture for both domains. Comprehensive documentation—including API references, design documents, tutorials, and sample code—will support developer adoption and reduce onboarding time.

Community engagement and support structures are vital to sustaining momentum. This includes user and architecture guides, service-level agreements (SLAs), and responsive support channels. Compliance with data privacy regulations such as GDPR, and the use of secure protocols like TLS, must be rigorously upheld.

Finally, fostering an active open-source community through issue tracking, telemetry, forums, and predictable release cadences will be key to driving innovation and maintaining trust.

By aligning on these guidelines, Europe can build a resilient and future-proof SDV software foundation—one that empowers OEMs, suppliers, and developers to collaborate at scale and compete globally.

c. Manifesto on Collaboration in a European Software-defined Vehicle of the Future Ecosystem

November 2024

Declaration of European Automotive Manufacturers and Suppliers "Collaboration on a European Software-defined Vehicle of the Future Ecosystem"

We, the European automotive industry (OEM and Tier-n suppliers), are facing very significant common challenges for our companies. One of the biggest challenges is the increase of software complexity within vehicles in combination with cloud-based services. We believe that Europe can only fulfil the potential of our automotive industry with a collective approach, supported by a political will to lead this battle. Compared to other software-driven industries, we need to ensure safe and secure solutions over the entire product lifecycles, which are much longer than most other industries. Consequently, the number of software variants will rapidly increase, but need to be maintained over the entire product lifecycle.

These challenges can no longer be managed by any company on its own. Software stacks consist of huge number of components coming from different sources, especially from non-automotive industries and from open-source ecosystems. Non-differentiating software building blocks need to scale across the industry. With this approach, software complexity can be managed in an efficient way over a long period of time. This can only be achieved with new collaboration models in the automotive industries.

A transversal framework is needed for these Software-Defined Vehicles. Most OEMs have already launched in-house developments on what some call "vehicle OS" which risks creating silos preventing cross-industry synergies. The initiative detailed in this manifesto intends to break down these silos and facilitate a significant re-use of assets.

In the context of pre-competitive, non-differentiating software building blocks, we as the European automotive industry plan to establish a corresponding open software ecosystem with the support of EU and national funding programs. With this approach, we will enable the European automotive industry to stay competitive in the domain of software defined vehicles.

We have decided to join forces in software development for the European automotive industry, OEMs, Tier system and component-suppliers, and development specialists.

Our collective mission is to create an open software-defined vehicle (SDV) ecosystem driven by the European industry through pre-competitive collaboration on software development across European OEMs and suppliers focusing on enabling elements based on an open-source approach. The ecosystem will enable the automotive sector to fully profit from the European Chips Act and new industrial strategy.

The scope of our collaboration includes the development of:

- joint contributions to future proof foundational technology,
- standardized building blocks based on open source,
- open interfaces with well-managed APIs,
- contributions to hardware and software abstraction layers,
- in-vehicle solutions and cloud-based solutions,
- safety-critical and non-safety-critical functions,

- common processes and tools for simulation, integration and testing,
- an ecosystem using modular toolchains with open interfaces and exchange formats,
- specific demonstrators to prove the potential of the initiative.

In summary, the collaboration will take the form of a working group across our companies for pre-competitive building blocks and common standards, demonstrating efficient collaboration along the automotive value chain from technology companies, SW suppliers, and System suppliers to car manufacturers.

The scope of our collaborative work on SDV does not include hardware development but will benefit from potential synergies with any European automotive hardware activities.

Our collaborative activity is driven by strong common goals:

1. fast and efficient development to achieve shorter time-to-market,
2. reduction of development cost without sacrificing quality,
3. strengthen the collaboration within the automotive industry,
4. avoid strong dependencies and lock-in to specific hardware or software solutions,
5. orchestrate distributed developments through a clear governance framework,
6. support and leverage open-source communities for automotive,
7. attract talent to work on modern automotive software development.

The partners of this collaborative venture will follow and promote a software-driven mindset which embraces change, agility, pragmatism, and openness to new ideas from outside the automotive industry. Employing open-source practices for an increasing scope of the workload will offer the opportunity to achieve more at higher speed.

We will set up a clear set of governance rules and a transparent decision-making process which will be adapted to the needs of the initiative – flexible, fast and thorough. We will build upon the rules of existing open-source software ecosystems and keep new governance processes as lean as possible.

We welcome the Commission and the Member States' support and commitment to this collaboration through their funding programs.

We share the intent to develop the software-defined-vehicles ecosystem by contributing to pre-competitive research and innovation. By jointly providing steering and guidance to this initiative we ensure the alignment of our common SDV roadmap with the strategic direction of our companies.

We will promote for wider usage the software building blocks developed in this collaboration. We call for other companies sharing similar objectives and values to join the open collaboration.

Declaration of European Automotive Manufacturers and Suppliers:
"Collaboration on a European Software-defined Vehicle of the Future Ecosystem"

Ecosystem of Partners

Automotive OEMs
- BMW
- DAIMLERTRUCK
- FORD OTOSAN
- MERCEDES-BENZ
- RENAULT - AMPERE
- STELLANTIS
- VOLVO TRUCK
- VW - CARIAD

SW dev.tool providers
- AVL
- DASSAULT
- ECLIPSE EUROPE
- FEV
- METIS BALTIC
- TERAGLOBUS
- TRUSTINSOFT
- VECTOR
- VERUM

Semiconductor companies
- ARM
- CAE List
- INFINEON
- NXP
- ST MICROELECTRONICS

Automotive Tiers
- ACCENTURE
- BOSCH - ETAS
- CONTINENTAL - ELEKTROBIT
- CRITICAL SOFTWARE
- DIMECC
- FORVIA
- MICHELIN
- OP'nSOFT (OPMobility)
- RESILTECH
- ROVIMATICA
- SYSGO GMBH
- TENSOR EMBEDDED GMBH
- TTTECH
- VALEO
- VITESCO
- ZF

Industry associations
- ANFIA
- AUTOSAR
- COVESA
- EUCAR
- PFA
- VDA
- VDI/VDE-IT

Academia & RTOs
- AGEN.EST.CON.SUP.INV.CIENT.
- ASTAZERO
- BARCELONA SUPERCOMP.CENTER
- COMMIS.ENERGY
- DLR
- FRAUNHOFER-IKS
- FZI
- INRIA
- INSTITUTO SUPERIOR PORTO
- KIT
- POLITECNICO DI MILANO
- POLITECNICO DI TORINO
- RWTH AACHEN
- TU Berlin
- TU EINDHOVEN
- TU LULEA
- TU MUNICH
- UNI OSTRAVA
- UNIV BOLOGNA
- UNIV.COTE AZURE
- UNIV.STUTTGART
- UNIV.UOLU
- UNIVERSITA MODENA E REG.EMILIA
- VIF

Figure 1: Partners and associated members of approved SDVoF projects as of April 10th, 2024

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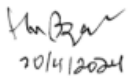
Declaration of European Automotive Manufacturers and Suppliers:
"Collaboration on a European Software-defined Vehicle of the Future Ecosystem"

Signature:	
Title, Name:	Henry Bzeih
Company/Organization:	Ampere (Renault Group)
Position:	Vice President SW&SYS

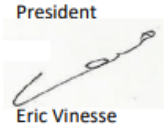
Signature:	
Title, Name:	Prof.Dr. Helmut List
Company/Organization:	AVL List GmbH
Position:	CEO

Signature:	
Title, Name:	Dr. Christoph Grote
Company/Organization:	BMW AG
Position:	Senior Vice President Electronics and Software BMW Group

Signature:	
Title, Name:	Gilles Mabire
Company/Organization:	Continental
Position:	CTO Automotive

Signature:	
Title, Name:	Dr. Thomas Irawan
Company/Organization:	ETAS GmbH, ETAS/P
Position:	(Bosch Group) President

Signature:	
Title, Name:	Christophe Aufrere
Company/Organization:	Forvia
Position:	Senior Vice President, CTO

Signature:	
Title, Name:	Eric Vinesse
Company/Organization:	MFP Michelin
Position:	Executive Vice President Research & Development

Signature:	
Title, Name:	Alexandre Corjon
Company/Organization:	Op'nSoft (OPMobility)
Position:	Executive Vice President Innovation & SW

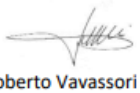
Signature:	
Title, Name:	Luc Chatel
Company/Organization:	PFA
Position:	President

Signature:	
Title, Name:	Dr.Stefan Poledna
Company/Organization:	TTTech Auto AG
Position:	CTO & Co-Founder

Signature:	
Title, Name:	Christophe Le Ligné
Company/Organization:	Valeo
Position:	CTO

Signature:	
Title, Name:	Hildegard Müller
Company/Organization:	VDA e.V.
Position:	President

Signature:	
Title, Name:	Dr. Dirk Walliser
Company/Organization:	ZF Friedrichshafen AG
Position	Senior Vice President Corporate R&D

Signature:	
Title, Name:	Roberto Vavassori
Company/Organization:	ANFIA
Position Signature:	President

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d. Memorandum of Understanding on Automotive Grade Open-Source Software Ecosystem

VDA | Verband der Automobilindustrie

Memorandum of Understanding

Automotive Grade Open-Source Software Ecosystem

May 2025

VDA Verband der Automobilindustrie

1 Background & Approach

The automotive industry is currently facing significant common challenges. One of the challenges is the increase in software complexity within vehicles in combination with cloud-based services. At the same time there is a need to reduce time-to-market and costs while continuously delivering innovation through software. Further, the automotive industry must ensure safe and secure solutions over the entire product lifecycle.

Much of the vehicle software is non-differentiating, i.e. without impact to customer experience, such as middleware that handles communication, authentication, and interfaces between the vehicle's operating system and the applications that run on it.

To address these challenges efficiently, we propose to join forces within the framework of applicable competition laws, for the creation of a shared, open-source software ecosystem that builds upon a common, secure core stack. With this approach, we will be able to gain more speed and efficiency in software development in order to stay competitive in the global markets. This approach focuses on the non-differentiating part of the vehicle software. At the same time, all parties remain free to continue developing, distributing and using other software solutions. This MoU is not exhaustive and is not intended to be legally binding between the parties.

2 Target-Picture & Roles

Our collaborative European initiative is driven by strong common goals:

- Contribute to an open-source software ecosystem with a code-first approach and thereby build the state-of-the-art automotive software platform.
- Create a first-in-industry development process for reaching an ISO26262 qualification utilizing open source.
- Open collaboration across OEMs, Tiers and Tech Players within the Eclipse SDV framework.
- Incentivize open-source contributions through recognition programs, like certifications.
- Build an ecosystem with a certifiable stack containing standardized software building blocks and toolchains.
- Enable the ecosystem to ensure ongoing maintenance and software evolution over entire vehicles' product lifecycles.
- Shorten time-to-market, reduce application development effort and costs by leveraging multi-use and drive innovation.
- Engage globally with automotive stakeholders and regulators to align standards and prevent regional fragmentation.

We (OEMs, Suppliers, Software Vendors, Public Private Partnerships) intend to contribute to an open-source stack, we (Suppliers, Software Vendors) intend to offer commercial products in a distributing role based on this stack, and we (OEMs, Suppliers) intend to use corresponding products and services.

VDA Verband der Automobilindustrie

3 Scope of collaboration

For engineering and development, we support the SDV working group within the Eclipse Foundation. Within this working group the project S-CORE creates the basis for a future open-source core stack. Main tasks include process and architecture definition, software coding, integration and technical support.

To support functional safety certification and cyber security regulations, S-CORE defines a certain infrastructure with a dedicated working model and corresponding open-source tooling.

We are aiming to establish a global open-source ecosystem and network that is open for new players and innovation. We welcome potential new partners to actively participate with contributions or enhancements at any point of time, independent of their size or origin.

We seek collaboration and intend to leverage relevant industry standards like AUTOSAR and COVESA in the ecosystem.

4 Roadmap & Milestones

Our activities follow the timeline and important milestones below:

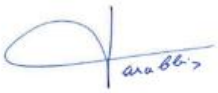
- End 2024: Project set-up S-CORE in Eclipse SDV with initial toolchain, infrastructure and definition of a minimum viable software stack. Achieved.
- Beginning 2025: process for safe software development in open source defined and externally audited for ISO26262 suitability. Achieved.
- Mid 2025: Definition of a reference architecture and feature requirements.
- End 2025: First public implementation of key modules of software stack.
- 2026: First complete software release, ready for series projects.
- At the latest 2030: First SOP with open-source software stack. Software stack integrated into series project.

5 Public Funding

This initiative is open and welcomes dedicated, sustainable European and national funding.

VDA | Verband der Automobilindustrie

6 Signing Parties

BMW GROUP BMW Group	Frank Weber Member of the Board of Management	
BOSCH Robert Bosch GmbH	Dr. Mathias Pillin CTO Mobility	
Continental Continental Automotive Technologies GmbH	Jean-François Tarabbia Head of Architecture and Network Solutions Business Area	
ETAS ETAS GmbH	Dr. Thomas Irawan CEO	
FORVIA HELLA GmbH & Co. KGaA	Guido Schütte EVP, Member of the Executive Board Electronics	
Mercedes-Benz Group Mercedes-Benz Group AG	Markus Schäfer RD Chief Technology Officer, Development & Procurement	
QORIX QORIX GmbH	Markus Schupfner CEO / Managing Director Dr. Nico Hartmann CTO / Managing Director	
Valeo Valeo BRAIN Division	Joachim Mathes CTO Valeo Brain Division	
VECTOR Vector Informatik GmbH	Dr. Matthias Traub Managing Director	
VOLKSWAGEN GROUP Volkswagen Aktiengesellschaft	Dr. Michael Steiner Member of the Extended Executive Committee Volkswagen AG, Group R&D Axel Andorff Group Chief Technology Engineer	
ZF GROUP ZF Friedrichshafen AG	Torsten Gollewski Executive Vice President Corporate R&D Innovation & Technology	

e. Glossary of Terms

Acronym	Description
2Zero	EU-Partnership - Towards Zero-Emission Mobility
AAOS	Android Automotive Open Source
AD	Autonomous Driving
ADAS	Advanced Driver Assistance Systems
APIs	Application Programming Interface
Autosar	Automtive Open System Architecture
BBs	Software Building Blocks
CCAM	EU Partnership – Connected Cooperative and Automated Mobility
Chips JU	Chips Joint Undertaking
CI/CD	Continuous integration/continuous deployment
COVESA	Connected Vehicle Systems Alliance
CRA	Cyber Resilience Act
DG CNECT	European Commission, Directorate-General for Communications Networks, Content and Technology
ECU	Electronic Control Unit
FEDERATE	Software defined vehicle support and coordination project
GDPR	General Data Protection Regulation
GPU	Graphics Processing Unit
HAL4SDV	EU co-funded project on a Hardware Abstraction Layer for a European SDV
MVP	Minimum Viable Product
MW	Middleware

NIS 2.0	European Union Directive on Cybersecurity
NPU	Neural Processing Unit
OEM	Original Equipment Manufacturer
OS	Operating System
SDV	Software-Defined Vehicle
SLA	Service-Level Agreements
S-CORE	Safe Open Vehicle Core
Shift2SDV	EU-co funded project on common software development framework
SOAFEE	Safe Open Architecture for Embedded Edge
SOP	Start of Production
SOVD	Service-Oriented Vehicle Diagnostics
SW	Software
TCUs	Telematics Control Units
UNR 155	UN Regulation on Cybersecurity
V&V	verification and validation