Concept paper on an open European software-defined vehicle platform for the vehicle of the future

Prepared by Directorate-General for Communications Networks, Content and Technology, with support by McKinsey & Company

Disclaimer: this discussion paper is based on the discussions during the workshops organised by DG CONNECT, and on subsequent input from participants. The content of this document does not necessarily reflect the views of all workshop participants nor of the European Commission.

Executive summary

This concept paper reflects on the **critical challenge of software for the EU's automotive industry** and on the **value of open European collaboration**. It is based on workshops and discussions organised by DG CONNECT with a 'Sherpa Governance Group' of representatives of many major European automotive OEMs and suppliers. Largely endorsed by the group's participants, it shows the ongoing convergence of views and areas for further discussions.

The shift to software-defined vehicles: a key challenge for the EU automotive industry

As vehicles become autonomous, electric, connected and service-oriented, hardware (HW) and **software (SW) are playing an increasingly important role** in managing their operations and enabling new features. In future "software-defined vehicles" electronics and SW will be more valuable than mechanical parts. Vehicle electronic architectures are becoming more centralised, fuelling the demand for next generation system on chip designs and high-performance processors, and redefining how software is built, integrated, and maintained. Enabling new functions through over-the-air SW updates raises new challenges. The SW layers (e.g., operating system, middleware) between HW and applications, including interfacing with the cloud, play a key role in this paradigm shift.

Automotive players are transforming themselves into software-defined companies but are facing some **difficulties with software development**. Software complexity is rising sharply with lines of code in a vehicle expected to grow from 100 million today to a billion by the end of this decade. Increased complexity of functionalities and sharing of computing resources across electronic control units, vehicle domains and the mobility and cloud infrastructures reduces the **software development productivity**, with redundant and non-value adding efforts to adapt to different platforms. This leads to delays and cost overruns for software projects. Additionally, the industry is facing a major **software talent shortage**. All these call for focusing more on modular software with improved maintainability and portability. The European automotive industry is facing **increased global competition**. Some new non-EU manufacturers have an advantage on software productivity as they adopted a software-driven approach from the outset. Large tech companies are entering the market and already dominate certain domains. Large non-EU semiconductor companies are offering integrated HW-SW platforms and have announced numerous automotive partnerships leading to vendor lock-in and dependencies. Hyper-scalers are expanding their power on consumer platforms into the vehicle. These transformations are putting the sovereignty and competitiveness of the European automotive industry at risk.

So far, **EU car companies have focused on developing their own technology platforms**, impeding efficiencies when such investments replicate efforts on elements that are not differentiating and visible to the customer. A **rising number of partnerships and alliances** across varying types of actors of the automotive and digital ecosystems shows a growing openness to join forces. They however do not cover systematically all the non-differentiating elements of the software stack and lack sufficient implementation. They would benefit from stronger cross-initiative coordination and governance.

Value and initial focus of an open European collaboration on vehicle software

In the context of the Chips Act, the European Commission is considering complementary but distinct initiatives to reinforce EU sovereignty and leadership in the automotive value chain on the vehicle of the future, addressing, on the one hand, an **open automotive HW platform**, and on the other hand, an **open software-defined vehicle (SDV) ecosystem** driven by European actors. The SDV initiative focuses on an **open and pre-competitive collaboration across European OEMs and suppliers on non-differentiating elements of the vehicle software stack.** The concept paper is describing the initial agreement on its scope and characteristics.

The SDV joint effort should support the development of **standardised SW building blocks and interfaces** in the vehicle and at its edge. Complemented by SW development and validation toolsets, these shall be **used in evolving SDV architecture scenarios of OEMs and Tier1s**. They will facilitate the decoupling of SW-implemented functions from the underlying HW, helping to reduce dependencies and vendor lock-in. Becoming HW agnostic, however, does not mean becoming HW-ignorant: HW

requirements must be defined from the SDV application perspective, and emerging HW-features must be taken advantage of for purposes of performance optimisation, security, etc.

The initial focus of the SDV initiative should be on interfaces between the cloud and the vehicle and towards high-performance integration platforms (domain controllers, central controllers, zone controllers) as well as other non-differentiating layers of the technology stack. In the longer term, common interfaces and building blocks could lead to a convergence between different SDV architectures. The initiative should adopt “code first” principles to create tangible outcomes that can be used for continuous testing, integration, and delivery by industry. Together with demonstrators and ecosystem building, **open-source code development** will become the foundation and a crucial success factor of the European SDV ecosystem and drive industry standards and agile and widespread adoption, as well as reduce time-to-market.

Whereas the European SDV initiative should be independent from specific hardware, it must be well co-ordinated from the outset with **European efforts under the Chips Act on supplying an open automotive hardware platform for the vehicle of the future:** Though being addressed in separate strands of a European vehicle of the future Initiative, the next generation HW architecture including processors with AI computing capacity must be driven by specifications responding to the needs of the applications under the SDV platform, e.g. autonomous driving functionality. Vice versa, the integration of emerging European high-performance HW should be well facilitated by the European SDV ecosystem. Compliance with applicable regulation related to data sharing, cyber security, product liability, functional safety, competition law and state aid provisions must be ensured. Considering that automotive companies operate at the global level, the international landscape must be considered to avoid creating a regional silo.

The European SDV initiative will reinforce the co-ordination and integration of different initiatives and alliances such as ECLIPSE SDV, COVESA, AutoSAR, SOAFFE and digital.auto. This will be achieved by identifying missing elements and **orchestrating distributed developments** through a governance framework, while complementing them by future-looking research, innovation, and piloting actions.

This concept paper presents the potential **path towards a European SW ecosystem for the vehicle of the future**, its scope and guiding principles, its open and pre-competitive collaboration set-up, and its role in outreach and broader collaboration. So far, the SDV initiative has received strong interest by participants of the Sherpa Governance Group across major European OEMs and suppliers. As a starting point, the Key Digital Technologies Joint Undertaking (KDT JU, to become the Chips JU soon, following the recent adoption of the Chips Act) under the Horizon Europe research and innovation framework, has thus launched two workstreams in February 2023. First projects are envisaged to start in late summer 2023:

(1) **Governance, co-ordination, and ecosystem building:** A co-ordination and support action shall define the scope, collaboration model and roadmap, and help incubate a developer ecosystem. It shall further support alignment with other private, national, and European initiatives, like the open automotive HW platform under the Chips JU and the CCAM and 2ZERO partnerships. Starting from the Sherpa Governance Group, it is targeting future engagement of senior managers to guide the initiative.

(2) **Development of an open European SDV platform and ecosystem:** As part of a layer-based approach, a first R&I action will support the development of building blocks in the complete scope of the SDV ecosystem, with a focus on the HW abstraction layers. This will create a baseline for joint developments, while the governance workstream will help identify priority areas for future actions under this workstream.

As a next step, endorsement of the above approach at highest possible level by OEMs in close co-operation with suppliers from Tier1s to IDMs, and with the European Commission acting as a neutral convener for joint efforts, is targeted.

Introduction

This concept paper discusses the critical challenge of software for the EU's automotive industry and the value of an open European collaboration in this area. It is based on workshops and subsequent discussions organised by DG CONNECT with a 'Sherpa Governance Group'[1] on an open European software-defined vehicle platform, comprising representatives of major automotive OEMs and suppliers. The paper reflects the progress made towards a convergence of views among participants and highlights the areas where further discussions are required to strengthen and broaden the emerging consensus.

The vehicle of the future will be autonomous, electric, connected and servitised

The next few years are critical for the European automotive industry to close the gap to leading new OEMs and tech players with regards to software and user experience to defend the leading position in the automotive industry. While OEMs and suppliers are at different levels in terms of skills, capabilities and time-to-market, several players have already started to transform themselves into more software-driven companies. The focus, so far, has been on individual efforts towards own technology platforms, impeding efficiencies across the industry when such investments replicate efforts on elements that are not visible to the customer and sources of competitiveness.

In the context of the Chips Act, the European Commission is working with the industry to ensure the automotive sector, as an essential sector for the EU, profits from the initiative. On 15 September 2022, a workshop in Bologna on car operating systems and processors for the automotive industry, organised by CINECA, in collaboration with DG CNECT, allowed a first discussion with representatives of automotive OEMs, suppliers, semiconductor companies, computer engineering companies, academia and government.

Following the workshop, it was proposed to launch a European vehicle of the future initiative with two complementary and closely coordinated strands to reinforce EU sovereignty and leadership in the automotive value chain. Its should address on the one hand, an **open automotive hardware platform**, and on the other hand, an **open software-defined vehicle platform,** both driven by European actors. Considering the trend towards separation between hardware and software, and the differences in hardware and software development speeds, discussions showed that keeping the two initiatives as separate strands would allow to progress faster and ensure broader participation and adoption by the automotive industry. At the same time, close co-ordination between the two initiatives is essential to allow the two streams to leverage synergies. The next generation automotive hardware architectures must be driven by specifications responding to the needs of applications under the SDV platform. Vice versa, the integration of emerging European high-performance HW, for example based on open RISC-V[2], should be facilitated by the European SDV ecosystem.

Against this backdrop, a workshop on the software-defined vehicle platform took place on 29 November 2022, in Brussels, with representatives of major European automotive manufacturers and suppliers[3]. The objectives were aligning with the industry on key challenges related to software-

[1] The Sherpa Governance Group is a group of representatives of European-based automotive OEMs, Tier1s, and associations with the objective to act as an initial governance group for a European SDV initiative. Group members were requested to have the management support for representing their respective organisations in the group.

[2] For more information, consult the roadmap on open-source hardware and software. A specialised paper on a High Performance RISC-V automotive reference platform is under preparation.

[3] For a list of companies and associations involved in workshops so far, see Annex.

defined vehicles, discussing how the industry players can collaborate on non-differentiating, precompetitive SW development, and how such an initiative could be supported and driven at the European level. Members of the industry associations VDA, PFA, and ANFIA contributed to the organisation the workshop and were present. McKinsey & Company supported the preparation and moderation of the workshop.

Drawing from the conclusions of the 29 November workshop, a Focus Area on software-defined vehicle was proposed under the Key Digital Technologies Joint Undertaking[4] (KDT JU, to become the Chips JU soon, following the recent adoption of the Chips Act) to support first related actions. An open workshop on 20 December in Prague, gathering industry associations, public authorities (Member States, European Commission) and representatives of key companies (OEMs, suppliers, integrated device manufacturers (IDM) and system integrators), allowed a broader consultation on the proposed approach and Focus Area. In particular, a first alignment with the European CCAM and the 2ZERO partnerships was reached. These partnerships focus on R&I related to automated driving and electric vehicle innovations, respectively, whereas the Chips JU would focus on system-level integration of all digital components in the vehicle of the future through the "vehicle operating system" or the "software-defined vehicle platform". The Governing Board of the KDT JU approved the Focus Area on 24 January 2023. This led to launch of a first call for two projects open from 7 February until 3 May 2023[5].

On 7 March 2023, the Commission hosted another meeting of the Sherpa Governance Group for an open European software-defined vehicle platform in similar format but with slightly extended participation, following-up on the 29 November workshop. It focused on (i) the non-differentiating elements of the vehicle software stack calling for pre-competitive collaboration, (ii) the links with existing initiatives and, (iii) the governance and co-operation framework for the initiative.

This concept paper aims at summarising the findings of the workshops and of subsequent discussions regarding key challenges, the potential scope and form of a collaboration, and the role that the European Commission could play to support such an initiative.

Summary of status quo and key challenges

Why should the European automotive industry act now?

Customer preferences for vehicles and their features are changing – customers expect vehicles to behave like connected consumer devices. With software-capable players such as Tesla blazing a new trail in this regard and anchoring customer expectations, OEMs are forced to catch up and rapidly build sought-after features. Customers value new infotainment, connectivity, and ADAS/AD functionality and are willing to switch brands for better features.

On the **technology** side, vehicle electric/electronic (E/E) architectures are evolving, reframing how systems and software functions should be built and integrated. Traditional distributed E/E architectures, with a high number of electronic control units (ECUs) assigned to specific functions and a high software-hardware integration, are unable to deal with the increasingly complex functions of new vehicles due to drawbacks in scalability and performance, as well as increased integration across ECUs and vehicle domains. The industry is shifting towards centralised E/E

[4] The Key Digital Technologies Joint Undertaking (KDT JU) is a public-partnership for research, development and innovation focusing on electronic components and systems (https://www.kdt-ju.europa.eu/). It should become the Chips Joint Undertaking in 2023, benefiting from additional funding under the European Chips Act.

[5] HORIZON-KDT-JU-2023-2-RIA and HORIZON-KDT-JU-2023-3-CSA-Topic-3

architectures (see Figure 1). An initial step is the consolidation of functions at domain-level (e.g., powertrain, autonomous driving, cockpit, body) with dedicated domain controllers. E/E architectures are then expected to evolve toward zone- and vehicle-centralisation, with central control unit(s) running functions or services in different domains. This centralisation will require a separation of hardware and software, with vehicle systems built on a layered architecture with clear abstraction points. This evolution will fuel the demand in the automotive industry for a next generation of Systems on Chip (SoC) with specialised automotive processors providing mid-range to high-end performance.

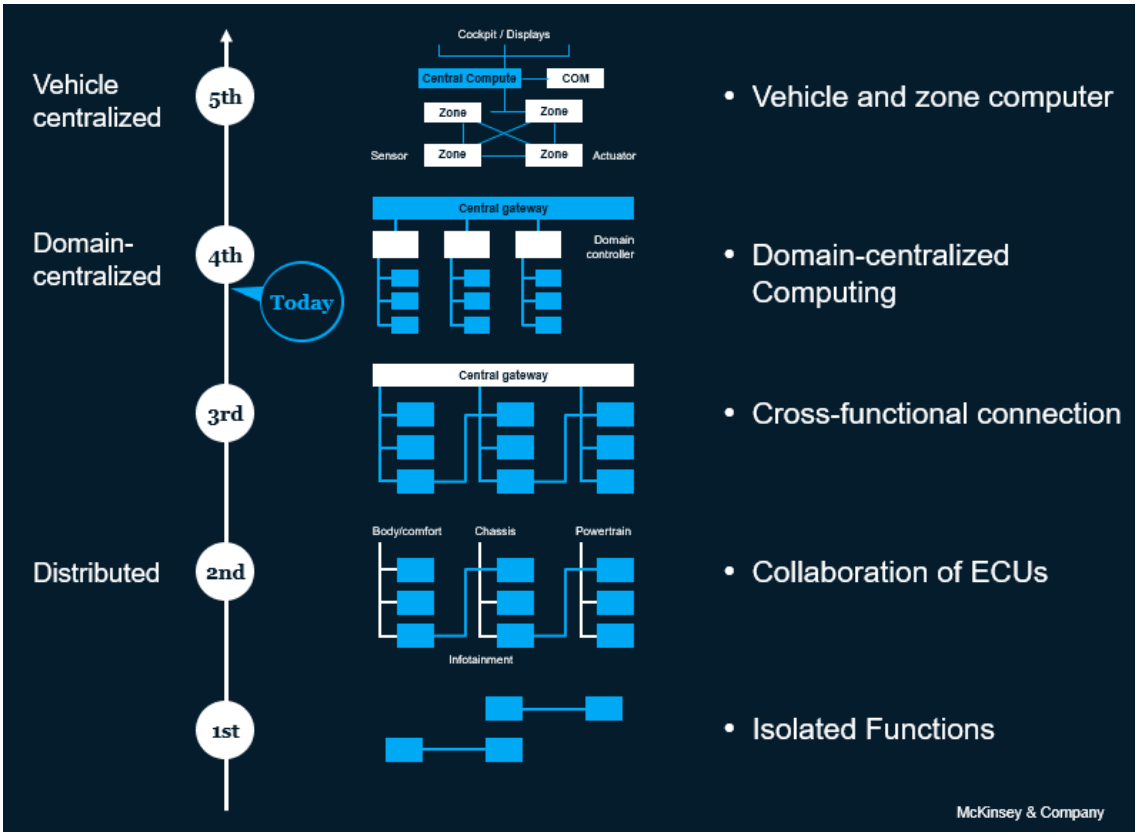

Figure 1: Evolution of the Automotive E/E Architecture (McKinsey & Company)

Regarding software, the enablement of over-the-air updates – both from a regulatory requirement standpoint and as a means of satisfying consumer expectations – presents specific challenges related to version management and safety. More generally, complexity is increasing exponentially due to the introduction of more complex and distributed functionality (for example, autonomous driving and infotainment) and the effort to integrate multiple functions within and across on-board and off-board domains.

While software complexity is increasing exponentially, the **productivity of software development cannot keep up** (See Figure 1). At the same time, the difference in performance between top- and bottom performers is significant especially in software. The complexity is further driven by lack of harmonised implementations across the industry, leading to high degree of redundant efforts to adjust towards different technologies and an overall loss of efficiency of the European Automotive Industry.

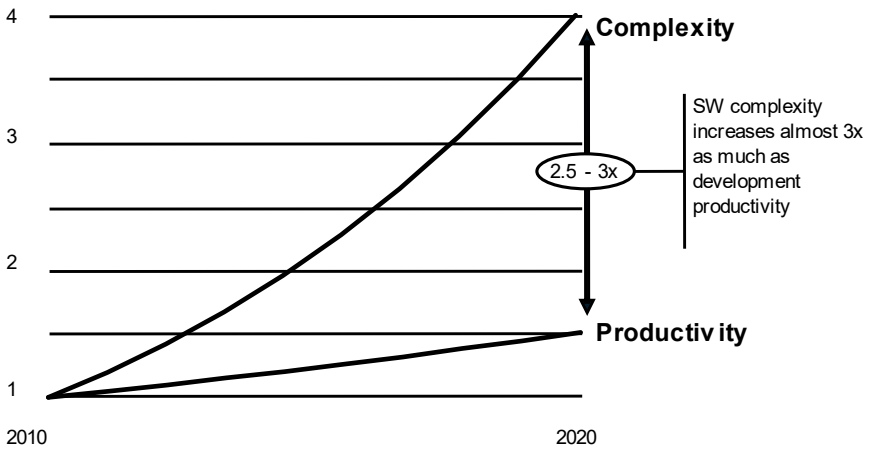

Figure 2: Relative growth of SW complexity and productivity over time (Source: McKinsey's Numetrics SW benchmarking)

New E/E architectures have an increased share of electronic hardware, notably higher-performance processors for domain or zonal controllers. The automotive industry has been strongly impacted by a severe chips shortage. OEMs have to secure the supply of chips in the future, in a context of geopolitical tensions, to avoid delays in the launch of new E/E architectures. The absence of a general concept for hardware abstraction prevents the reuse of tested and proven software and increases the cost of launching new E/E architectures.

New headwinds are arising from **new competitors,** for example, new OEMs from other global regions focusing on battery electric vehicles, and tech players. Incumbent OEMs and tier-one suppliers are already (significantly) behind new OEMs, which have started with greenfield architecture. The lead of new, often non-European OEMs, which are building up software capabilities, might even increase over the next years if incumbent OEMs and tier-one suppliers are not successful in managing the transition and acting immediately. New tech players, such as Google, have also entered the market with competitive offerings and the advantage for their customers to save on development costs. Large non-EU semiconductor companies are offering integrated hardware-software platform and have announced a large number of automotive partnerships. New OEMs, such as Tesla or Nio, benefit from new E/E architectures with a high degree of centralisation and no legacy. Tesla has also built state-of-the-art over-the-air software update capabilities, which are used to sell upgrades to customers and generate revenue with the existing fleet. Furthermore, in terms of software skills and capabilities, these new OEMs tend to outperform incumbent OEMs in, for example, number of software developers, software development toolchains and large-scale agile software development processes, leading with a software-first mindset, and access to a large amount of field data for development.

With fewer innovations in software and new business models, products of incumbent OEMs have lost competitiveness compared to new OEMs, which might ultimately lead to lower sales figures and lower margins. Some Chinese OEMs might also transform into software companies faster and use this advantage to compete with European OEMs in China and, potentially, even in the European market after adjusting for European data privacy regulation. In addition to new OEMs, tech players with extensive software experience are moving into the automotive software market, for example, Alphabet with Android Auto, Android Automotive, and Google Automotive Services, Waymo, and Amazon with Echo Auto. Today, the infotainment stack is already dominated by screen mirroring solutions from Apple and Google, and Google Automotive Services will likely be the most used embedded infotainment system in a few years. In addition, Android will likely become the dominating operating system in the infotainment domain, increasing OEM and tier-one supplier

dependence on Google. For autonomous driving, Waymo is consistently attracting more and more partners, while incumbent OEMs are reducing their development efforts associated with autonomous ridesharing vehicles. Increasing dependency on new tech players leads to the commoditisation of the infotainment stack, less revenue with high-margin features, and less differentiation. This ultimately makes it increasingly difficult to maintain and defend a "premium status" depiction vis-à-vis customers.

Regulation demands OEMs provide new features; for example, the upcoming EU General Safety Regulation requires OEMs to make certain safety features mandatory from 2022 on. New regulations also add additional requirements to components and systems, for example, new safety requirements from the UNECE cybersecurity regulation and the UNECE software update regulation. Cybersecurity and software update regulation will also likely require OEMs to build up cybersecurity and software update management systems. Finally, legislation on access to vehicle data, functions, and resources (Data Act, access to in-vehicle data, functions and resources) will have a significant impact on the industry. The integration efforts for secure data provision or access to on-board resources could be reduced through an increased use of virtualisation, software isolation and standardised interfaces.

With the first setbacks in software development and delayed timelines arising, the **openness to join forces is increasing.** Currently, a rising number of partnerships between OEMs and suppliers/tech players can be seen, as development costs are too high to be covered by a single player alone. There is a growing realisation that joining forces would also help to use existing development resources more effectively to increase speed and master the complexity trap. The changing attitude toward more cooperation on open-source software and open standards can be seen by the evolution and foundation of several initiatives to standardise automotive software, such as AUTOSAR, COVESA, Eclipse Software-Defined Vehicle Working Group, SOAFEE, and digital.auto.

In conclusion, the market is being reconfigured. New platforms are being developed with an approach borrowed from the tech sector that aims to disrupt the status quo in automotive, just as it did in other industries (e.g., smartphones). To remain leading players in the industry, OEMs need to transform and build up new capabilities. New digital and software productivity has become mission critical to create competitive products and increase shareholder value.

What are the key challenges for the automotive industry?

Across players the workshop participants mentioned several key challenges:

- **Delayed software projects** leading to the delay of new vehicle launches
- **Project are exceeding planned budget** leading to reduced profit
- **Difficulty finding the required software talent**
- **Effort to comply with regulations**, for example, antitrust laws, product liability laws, the Cyber Resilience Act, and uncertainties on the commercial use of solutions developed under research and innovation programmes, making collaborations slower and more complex
- **Tight R&D budgets due to required transformations**, for example, the transformation to electric vehicles or fulfilling the EU7 emissions standards
- Similar to Linux in the operating system worlds, initial **de facto standards have been set in specific domains by tech players, leading to an increased dependency on them**, while at the same time missing common architecture and tooling standards prevent suppliers from reusing their SW features across OEMs

For OEMs, several challenges were mentioned:

- **Losing competitiveness** in several disruptive features versus new and Chinese OEMs, for example, advanced driver assistance systems, over-the-air updatability, and connected services
- High degree of effort required to fix current software problems, leaving players without **enough capacity to start building next-generation software platforms**
- **High costs** of developing software, mainly driven by the need to redevelop existing functionalities for other hardware, often OEM proprietary platforms due to low compatibility
- **Unmet user demand of frequent software updates** (similar to smartphones) due to rigid SW frameworks, as well as high development and maintenance costs and complexity
- High efforts and costs related to managing **software complexity, backward compatibility**, and **software maintenance** after SOP, mainly driven by missing interfaces and standards, as well as poor portability
- **High switching costs** of each player from legacy systems to new (jointly developed) software platforms
- **Time-to-market as a critical success factor** limiting the magnitude of change between platforms

Similar automotive suppliers and software companies face several comparable challenges. In the workshop, participants mentioned the following:

- **Software development capabilities**, for example, state-of-the-art software development toolchains and number and quality of talent, are not usually sufficiently competitive compared to tech players entering the automotive software market, leading to long integration cycles and delays and budget overruns in software projects
- **High share of non-value-adding efforts** to integrate applications/functions in multiple OEM platforms cannibalise capacity to develop differentiating software features
- Need to **reduce dependency on supply of microelectronics chips**, especially for emerging zone-based and central E/E architectures.
- **Need to reduce development effort** aimed at software development for specific tailor-made projects to focus more on modular software with increased maintainability and portability
- **High share of legacy software** used by OEMs and tier-one suppliers, as well as poor portability and non-existing interface standards resulting in high maintenance efforts
- Challenges to increase the share of **virtual validation**, which would lower the overall validation costs
- **Too high variance** of **E/E** and **software architectures**, underlying **software technologies, vehicle APIs** and **naming schemes**, as well as **development tools** and **environments** across different OEMs, requiring high customisation efforts and resulting in low software productivity.

How to complement existing initiatives?

An open European SDV platform initiative should build on and collaborate with existing initiatives that aim to standardise components of the vehicle software stack. The participants recommended to cooperate in priority with the following initiatives:

- **Eclipse Foundation Software-Defined Vehicle Working Group**: Focusing on accelerating innovations in automotive-grade in-car software stacks using open-source software and open specifications, based on a code-first approach.
- **COVESA**: Focusing on the development of open standards and technologies that accelerate innovation for connected vehicle systems (e.g. with regards to standardised cross domain signal specification)
- **AUTOSAR**: Defining an automotive open system architecture standard to support the needs of future in-car applications
- **SOAFEE**: Focusing on bringing cloud-native development paradigms and cloud ecosystems to automotive software platforms, delivering open-source reference implementations
- **digital.auto**: relying on a use-case driven co-innovation approach and providing a playground of emerging software-defined vehicle components and tools.

Although participants of the workshops subscribe to many of the goals of these initiatives, most European automotive players do not see them as sufficient yet as:

- They do not cover all aspects of common software development and non-differentiating elements.
- Most of them primarily focus on setting standards but lack sufficient implementation, demonstration and validation. Usage of open-source implementations may be impeded e.g., due to lack of common interfaces or unclarity on questions of product liability for contributing entities.
- While participants agree on the benefits of bottom-up, code-first approaches, for some the speed of these initiatives is not fast enough and they often are not ambitious enough as they have the tendency to create the least common denominator.
- Current initiatives would benefit from a strong cross-initiative coordination and governance, notably addressing the lifecycle and maintenance of mature components and tools.

A majority of participants have raised the view that a European SDV initiative should reinforce the coordination and integration between these existing initiatives while complementing them through future-looking R&I actions.

Concretely, an open European Software-defined Vehicle initiative could aim at orchestrating distributed developments by:

- Defining **common goals**;
- I**dentifying gaps and missing** elements, **components**, and building blocks;
- **identifying the most suitable open-source initiative(s) to implement them** and take care of the required development and maintenance through the members of those initiatives;
- where needed proposing to support certain **future-looking research and innovation needs under EU funding instruments.**

Potential path towards a European software platform

After acknowledging the challenges facing the industry, there is a shared view that it needs to strengthen standards and reduce complexity and variance in non-differentiating components of the technology stack, increase cross-industry collaboration, and reduce redundant and unrequired efforts. Especially in Europe, activities such as these can help to increase the competitiveness of the industry and direct investments, financial and skills, into innovation instead of customisation and maintenance. In light of this, there was a strong support and willingness by all participants – OEMs and suppliers – to engage in an open European software-defined vehicle platform and to use the current momentum to make it happen.

Scope and guiding principles

Initial agreements have been reached on the common direction of a joint European effort towards an automotive software platform focusing only on non-differentiating software elements of the vehicle of the Future:

- The effort could support the development of **standardised software building blocks**. This would cover both in-vehicle and cloud-based solutions. The building blocks should have open interfaces with well-managed APIs to enable continuous evolution in a decoupled manner, and the development of an open ecosystem of third parties. Possible examples include a vehicle abstraction layer, or standardised data formats.

- The development of standardised non-differentiating software building blocks must be accompanied by the creation of corresponding **development and validation tools** matching state of the art CI/CD tool chains in order to achieve the required productivity gains in automotive ADAS, AD, infotainment, sensing and control software, etc. For example, synchronised release management across all contributions and migration strategies to later versions would be crucial for adoption across the industry.

- The open SDV platform should facilitate the **decoupling of software-implemented functions from the underlying hardware** and support the deployment of new functions. The approach of commonly developed SW building blocks should aim at reducing dependencies and vendor lock-in, especially regarding high-end processing functions in the vehicle platform. While the platform should largely be hardware agnostic, it should however not be hardware-ignorant, but should take into account the dynamic evolution of hardware computing capacities.

- The effort should embrace "**code first**" principles to create tangible outcomes that can be used by industry through pursuing a strategy of continuous integration, delivery, and test, where a working reference software is always available. As such, it should **be open to different architecture scenarios** by providing a framework with common building blocks which could be used in different architecture designs. At a later stage, this may lead to further convergence of current and emerging reference architectures.

- A joint effort should enable the **standardisation of interfaces**, and **touchpoints** – both within the vehicle (for example, interfaces between high-performance and Controller Area Network Bus based systems as well as standard interfaces in electronics hardware) and at the vehicle edge, i.e. the interfaces of the vehicle in the ecosystem (for example, access API). While there is no final agreement yet on all details related to the scope of the collaboration, there is a clear preference of participants to focus initially on interfaces between the cloud and the vehicle as well as on interfaces towards the high performance/integration platforms (domain controllers, central controllers, zone controllers) as well as non-differentiating layers of the technology stack. Replication of existing standards, e.g., AutoSAR in the I/O area, should be avoided.

- Further, there is no consensus yet on whether to focus as a first step on non-safety critical components only (favoured by a majority of OEMs) or on a broader approach applied from the outset taking into account both, safety and non-safety critical areas.

Open collaboration based on open-source developments

- **Open source**, in particular for reference implementations, will play a crucial role in facilitating open industry standards that go beyond specifications to standards in implementation and have proven to be an incubator of ecosystems in other industries as well. Hence, open source needs to be an integral part of a joint European effort.

- The targets of such an effort need to: a) drive **widespread adoption** to significantly reduce complexity across the industry (which only can be achieved by such widespread adoption) and b) support the industry to significantly increase speed and thereby **time-to-market** by building on mature software components created in an open-source ecosystem.

- The success of open-source contributions heavily depends on its **usage in real life applications**. Therefore, it is extremely important that an industry mindset and best practices around the production usage of open source is established, and improvements based on real applications are contributed. In this context availability of **demonstrator or blueprint applications** will be extremely helpful for productisations by different companies, though commercial productisation building on open sources is not considered as part of EC funding.

- Important aspects of open-source use, which need to be agreed further, are the question of **ownership, licensing, and IP creation**. Different initiatives are applying different models here and alignment may be needed to allow for optimal commercial exploitation.

Ecosystem building and broader co-operation

- The strong interest of the automotive industry to **leverage investments in the supply of chips** in Europe through the Chips Act requires tight alignment and integration of the SW architecture, middleware functionality, and HW interfaces with the emerging topologies of E/E architectures.

- Whereas the European SDV initiative should be independent from specific hardware, close **links must be ensured from the outset with European efforts on an open automotive electronic hardware platform** under the Chips Act. Though being addressed in separate strands of a European Vehicle of the Future Initiative, the next generation HW architecture including processors with AI computing capacity must be driven by specifications responding to the needs of the applications under the SDV platform, e.g. autonomous driving functionality. The development of an open SDV ecosystem should facilitate the integration of the emerging European automotive hardware platform (e.g. RISC-V automotive processor, IP, SoC, etc.).

- In addition to delivering technical standards, a joint effort needs to **incubate a developer ecosystem** (for example, through automotive software development conferences) to proliferate shared standards, invite open-source contributions, and thereby accelerate innovation – this should also include the involvement and effort of universities and other research institutes to enhance skills building in Europe.

- Considering that automotive companies operate at the global level, the initiative would need to **consider the international landscape** and initiatives in other regions and aim for a global reach to avoid creating a regional silo.

Collaboration model and regulatory aspects

- Most participants agreed that the form of collaboration in a European initiative should be "**orchestrated distributed development**". Participating companies would be responsible for

developing open-source software and maintaining modules based on joint standards. The creation or acquisition of a dedicated entity did not appear as necessary, at least in an initial stage.

- The EU can support the industry by acting as a **convener** of such efforts and supporting the build-up of the ecosystem with **dedicated funding and investments into specific research and demonstration projects**.

- A **strong governance framework** would help define goals, identify the most suitable participants and initiatives to implement them, and where needed propose to support certain goals under EU instruments.

- One challenge to address is **clarifying the regulatory framework**, for example, with regards to antitrust considerations, product liability, cyber security regulations, functional safety, compliance, or IP usage (co)created through public funding. Not only will all of this require a concentrated effort by the industry, but it may also require support from European regulators. The European Commission should help to clarify the regulatory environment, e.g., regarding the impact of the Cyber Resilience Act on open-source software development, or regarding compliance with competition rules[6].

Initial approach and next steps

In view of the broad alignment on the challenges and the acknowledgment that collaboration on non-differentiating features is needed, the first cornerstones a European collaboration on a software-defined vehicle should be implemented as soon as possible to build on the momentum. The unresolved issues, in particular determining with more precisions the concrete goals and scope of the joint development effort, should be addressed through follow-up discussions.

To keep the momentum and not to lose more time vis-à-vis strong competition, the following approach has been adopted based on the conclusions of the workshops and follow-up discussions, and in view of the support from stakeholders:

1. Launch a workstream on **governance, coordination and ecosystem building** of the SDV platform:

    - The workstream would define the roadmap, drive consensus on the scope of collaboration, define an open reference architecture, clarify the regulatory framework, and set up the cooperation framework, including the coordination with existing related initiatives

    - It could also help to incubate and grow a dynamic developer ecosystem to promote a wide adoption and use of the shared standards. Possible actions could include the organisation of a European conference on automotive software, targeting software engineers and developers, building on the open-source projects stemming from the European SDV platform and related initiatives, and involving universities and research institutions to support skill building.

[6] Based on the Guidelines on the applicability of Article 101 of the Treaty on the Functioning of the European Union to horizontal co-operation agreements (OJ C 11, 14.1.2011, p. 1) (“Horizontal Guidelines”), and on the Commission Regulations (EU) No 1217/2010 (Research & Development Block Exemption Regulation - 'R&D BER'). The Horizontal Guidelines and R&D BER are currently under review, with the aim to adopt new versions in the first half of 2023.

- This work stream has kicked-off immediately. A Sherpa Governance Group, based on participants of the 29 November workshop and few additional participants representing commercial and two-wheel vehicle manufacturers, met on 7 March 2023 to continue discussions to resolve open questions, broaden and strengthen the emerging consensus and commitment. A follow-up meeting is planned for Q2 2023. The Sherpa Governance Group should allow the participation of actors with different degrees of commitment, to give more hesitant participants an opportunity to stay involved and to actively participate at a later stage if they decide to. The work stream will target the engagement of senior managers from participating companies in the governance of the initiative.

- Starting from Q3/Q4 2023, the workstream is expected to be supported by a coordination and support action funded under the KDT JU, for which a call was opened on 7 February 2023. This will ensure it has sufficient resources and a clearly defined mandate.

2. Launch a workstream to **develop an open European SDV platform and ecosystem** under a **pre-competitive collaboration**:

   - The overall aim of the platform would be to define standards for non-differentiating elements of the software stack, to implement these standards in software published to a large extent under an open-source license, and to validate them through reference implementations. A common platform could include operating systems, middleware, hardware abstraction layers, open interfaces, both to lower-levels and to applications (in the vehicle and the cloud), data sharing mechanisms and automotive specific SW toolsets. A strong emphasis would be put on building a standard software development framework, addressing notably life cycle management and over-the-air updates, leveraging an agile DevOps approach. Supporting a dynamic ecosystem will be essential.

   - This workstream has already been started in February 2023 through a first call for an R&I action. As part of a layer-based approach, this first research and innovation action under the KDT JU will focus on a subset of the software-defined vehicle platform, while aligning with a broader SDV framework of architectures. It will be jointly developed by a critical mass of key industrial players. This will allow the creation of a baseline for a joint development, while in parallel the governance, co-ordination and support workstream will help identify priority areas for future actions based on a common roadmap.

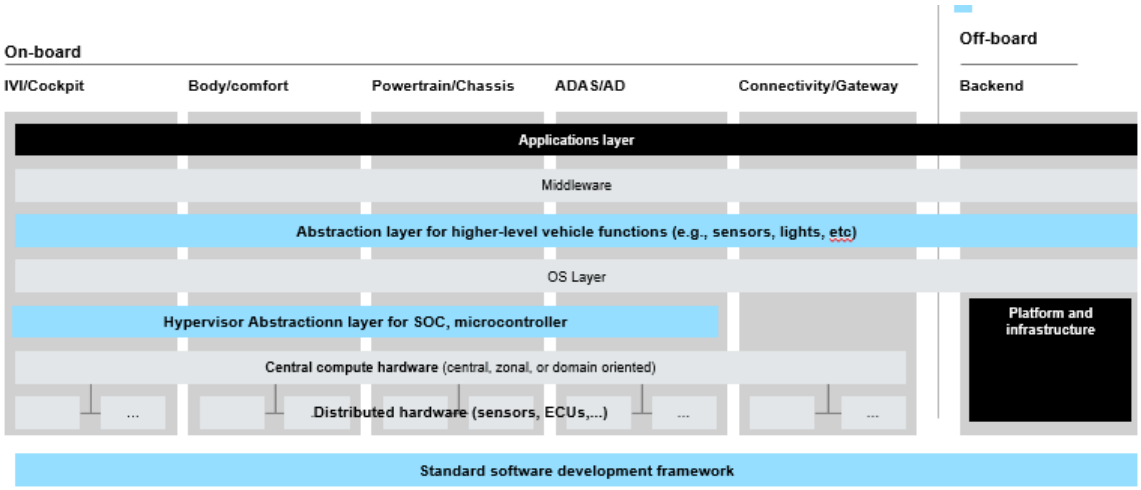

Figure 2: Indicative illustration of the software technology stack and initial focus

- The first area for joint development will focus on abstraction layers and the standard software development framework for safety-critical and non-safety critical applications (see

figure 2). The abstraction layers encapsulate underlying central or distributed processor topologies (e.g., microprocessor, SoC,) and include concepts like hypervisors, as well as provide common abstraction for higher level vehicle functionality, e.g., sensors, LED lights, wipers, etc. The action will define a concept, reference architecture and standardised open application programming interface for these abstraction layers.

- The action will support a standard software development & validation framework and tools to facilitate software development and reduce integration efforts. This approach and solutions will be demonstrated through proofs of concept for functionalities like safety-critical systems (chassis/powertrain), energy including battery management, ADAS & automated driving functions, and non-safety critical functions, (e.g., body and comfort). With a clear open-source strategy, the action should help develop a dynamic ecosystem, enabling contributions and innovations from the community.

- Follow-up actions could be launched in the coming years for areas where further work is required to build consensus, based on the roadmap defined with the governance and coordination workstream. This could include the middleware layer, the interfaces to applications and connectivity to the cloud as well as the necessary development and verification and validation tools. Later efforts could then focus on optimising the SDV platform for emerging HW and large-scale piloting, in connection with an initiative on automotive hardware platforms addressing, for example, an open-source automotive processor.

Key **success factors** for an open European software-defined vehicle initiative include:

- Buy-in on highest management level of a significant and representative number of OEMs and suppliers from across key European Member States
- Working closely with other relevant initiatives (e.g., Eclipse SDV WG, COVESA, AutoSAR, SOAFEE, digital.auto, etc.)
- Identifying a sustainable cooperation framework, which is expected to take the form of distributed opens-source development orchestrated by clear governance mechanisms.
- Developing own reference source code and not only specifications and standards.
- Early customer adoption and implementation on OEM vehicles projects.
- Global perspective, considering developments in other regions aiming at international impact.

These two workstreams are expected to benefit from funding under the KDT JU, under the approved Focus Area. First projects are expected to start in 2023.

This European initiative on the vehicle of the future, addressing both software and hardware, should leverage and build upon the broad range of efforts in the European Union. This includes private investments and initiatives, actions under the CCAM partnership[7] focusing on connected and automated driving functionalities, and under the 2ZERO partnership[8] focusing on electric vehicle

[7] The CCAM (Connected Cooperative Automated Mobility) Partnership is a co-programmed research & innovation partnership under the Horizon Europe programme aiming to ensure European leadership in safe and sustainable road transport through automation (https://www.ccam.eu/)

[8] The Towards zero emission road transport (2Zero) is a co-programmed Partnership funded under the Horizon Europe programme and aiming at accelerating the transition towards zero tailpipe emission road mobility across Europe (https://www.2zeroemission.eu/)

and charging functionalities, as well as projects supported by Member States. The Commission, in consultation with stakeholders, will identify the most suitable instruments to achieve sufficient scale, speed and coordination.

As a next step, endorsement of the above approach at highest possible level by OEMs in close co-operation with suppliers from Tier1s to IDMs, and with the European Commission acting as a neutral convener for joint efforts, is targeted.

Annex: Workshop Participants "Towards a European SW-defined vehicle platform" (Sherpa Governance Group)

- **Vehicle OEMs**: BMW, Mercedes, Renault, Stellantis, Volkswagen Group, (passenger cars), Volvo Group, Iveco (trucks), Piaggio (motor cycles),
- **Automotive suppliers**: AVL, Bosch/Etas, Continental, Forvia, Marelli, TTTech, Valeo, ZF
- **Associations and facilitators**: ANFIA, PFA, VDA, CINECA
- **Moderation support**: Mc Kinsey & Company
- **European Commission:** Directorate General CONNECT, responsible unit: E4 IOT

Note: not all organisations were present at both workshops (29 November 2022, 7 March 2023).