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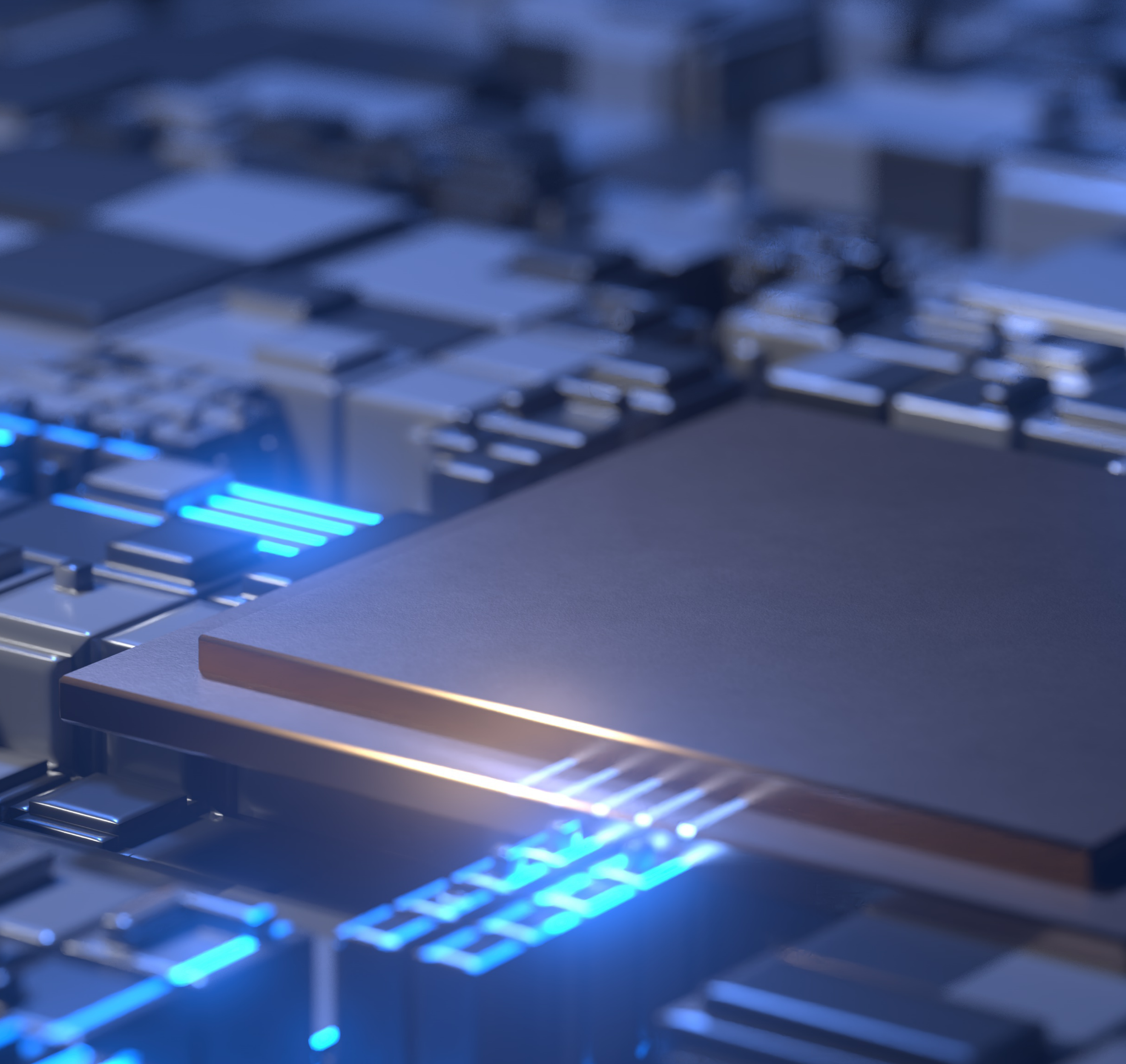
WORLD ECONOMIC FORUM

Centre for the Fourth Industrial Revolution

Unlocking Safety and Innovation in Vehicle Software

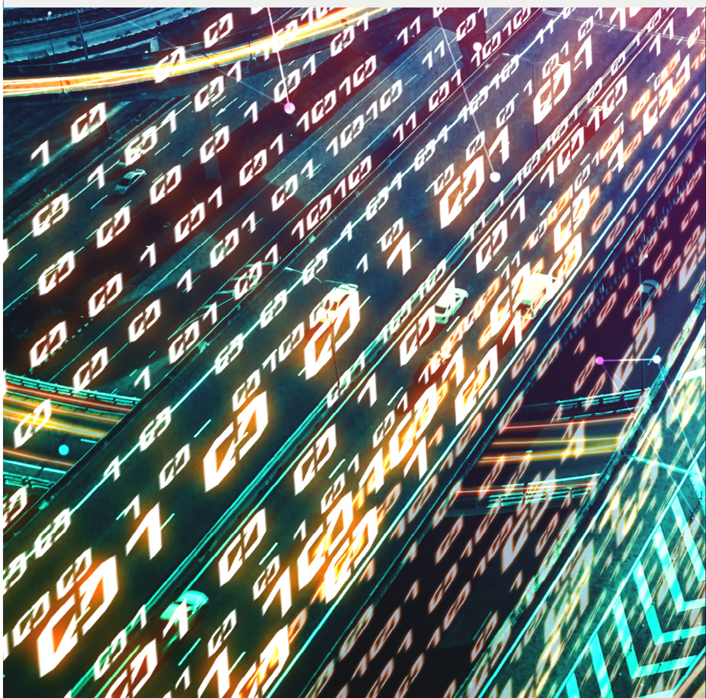
BRIEFING PAPER

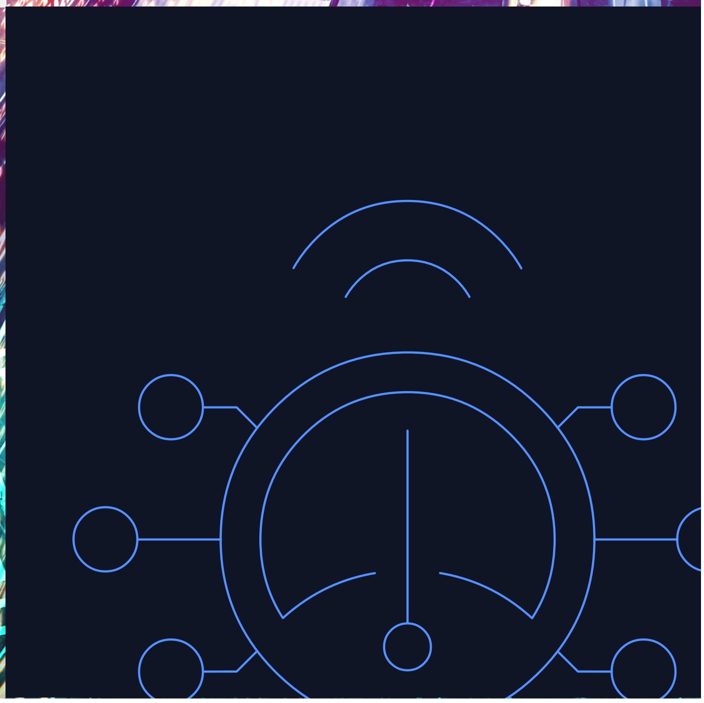
JUNE 2023



Images: Getty Images

> The industry is evolving rapidly and we need a common 'lingua franca' to provide clarity. The World Economic Forum's Automotive in the Software-Driven Era initiative helps to fill this need.
>
> Georg Kopetz, Chief Executive Officer, TTTech





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Automotive in the Software-Driven Era initiative

The automotive industry is undergoing its most challenging transformation in over a century. This is marked by a shift from internal combustion engines towards electric ones, and a shift from vehicles that are almost exclusively mechanical machines to ones with increasingly complex software-defined systems.

The software-defined vehicle is just emerging, and it will continue to evolve over the next decade. To prepare for the changes ahead, the World Economic Forum launched the Automotive in the Software-Driven Era initiative. This initiative aims to unlock the potential of cross-industry and public-private collaboration to help improve safety, inclusivity, sustainability and overall system resilience in the automotive sector.

To date, the initiative has engaged over 30 leading companies from the automotive, new mobility and tech industries to join the effort.

The challenge: A more unified, industry-wide, scalable vehicle software approach

One of the key components of the software-defined vehicle is the software platform, which orchestrates all signals, data, activities and processes in the vehicle (see Box 1 for a full picture of the software-defined vehicle layers). As the "brain" of the car, the vehicle software platform is essential to ensure safety, while also enabling more efficient use of resources and computing capabilities and supporting faster update cycles for user-centric innovation.

Every major OEM and many of the larger automotive and technology suppliers are developing their own full-fledged software platforms. Additionally, several specialist players and tech companies are making partial-tailored components for these platforms. A more unified, industry-wide, scalable vehicle software approach would:

- **Increase safety.** Clearer, more standardized interfaces and aligned platform architecture designs help increase stability and reduce error rates in software integration. Safety is crucial for devices as highly safety-critical as software-defined-vehicles, especially with increasing levels of autonomy.

- **Improve maintainability.** The life cycle of a vehicle, unlike for smartphones and other smart devices, spans several decades. Safety also needs to be ensured for the full life cycle. A more unified, industry-wide solution can ease the ability to manage, update and maintain the software for 20+ years.

- **Speed up innovation.** A more unified approach simplifies the development and distribution of safety-critical updates and additional value-adding functions. For example, software innovation contributes to energy efficient driving and battery management, with a positive sustainability impact.

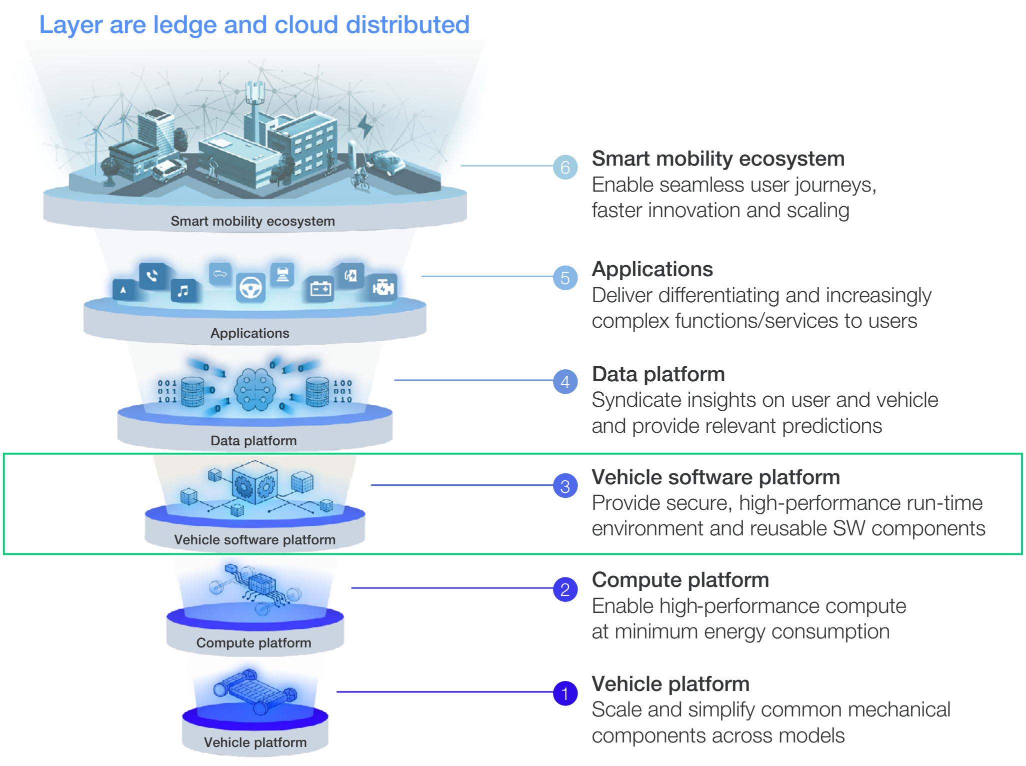
- **Reduce costs.** A more unified industry solution reduces unnecessary duplicities, freeing budget and talent resources to focus on enhanced safety, maintenance efforts and differentiating value-added innovation.

This briefing paper explores a target picture for the vehicle software platform. It also provides a timeline for how its different characteristics could evolve, and an overview of current related initiatives. The aim is to help the industry align on a more unified, sector-wide, scalable vehicle software solution that will drive safety during the life cycle of the software-defined vehicle.

BOX 1 | The vehicle software platform and its role in the software-defined vehicle

The vehicle software platform is one of the six key layers of the software-defined vehicle (see Figure 1). The platform includes four components: the hardware abstraction layer (HAL), which simplifies interaction between operating systems and different hardware; the base operating system, which controls all hardware resources such as I/O and security; base services (often referred to as middleware), which cover basic functions across all services and applications, including networking, communications, diagnostics and API management; and extended services, which provide key functions, such as perception and driver monitoring, across applications.

FIGURE 1 | Six layers of the software-defined vehicle



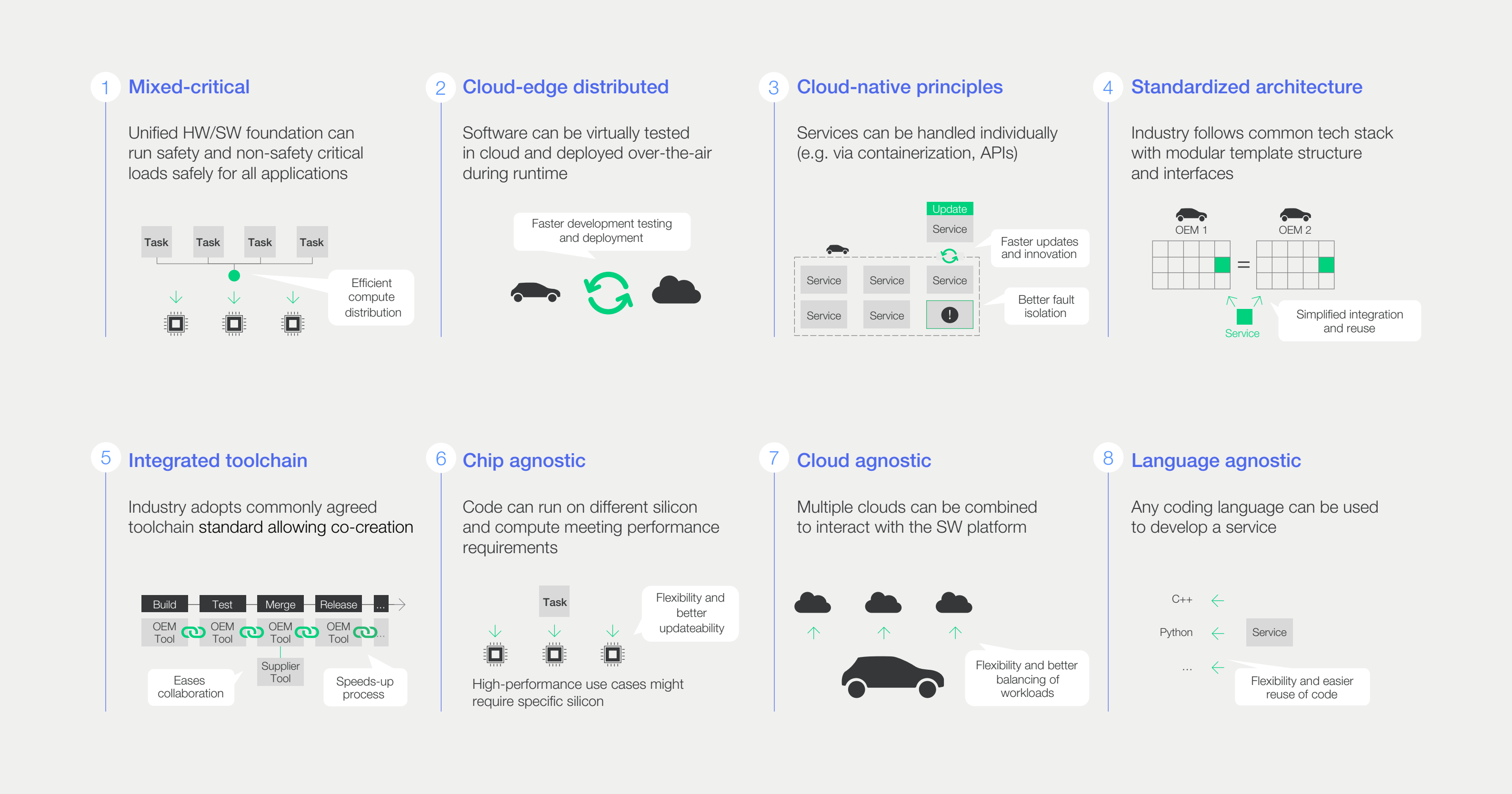
The need for an industry north star:
The vehicle software platform target picture

Many siloed vehicle software solutions with proprietary interfaces drive complexity and slow down feature development and integration. A more simplified and scalable structure is needed. Figure 2 outlines eight key elements of a target picture of the vehicle software platform, which would help streamline current development efforts and enhance software maintainability and safety benefits.

In the past, safety-critical and non-safety-critical workloads were separated. For the majority of use cases, however, **mixed-critical** solutions allow for more efficient use of vehicle compute, helping minimize execution time, and reduce power consumption through optimized hardware and software allocation. Ultimately, more efficient computing allows more high-performance operations, necessary for ADAS (Advanced Driver Assistance Systems) applications, and helps drive better next-generation digital cabin user experiences.

[1] https://www.informatik.rwth-aachen.de/cms/informatik/Forschung/Publikationen/Bibliographie-komplett-/~lolj/Details/?file=856836&lidx=1

FIGURE 2 | **Vehicle software platform target picture characteristics and their end-goal ambitions**



Safety-critical functions with hard real-time constraints (e.g. electronic stability programmes or ESP) require isolated handling in the foreseeable future.

Managing the increasing amount of software requires a seamless interplay between the vehicle as an edge device and the cloud, or **cloud-edged distributed**. This includes, developing, validating and testing a new service in the cloud, deploying it over-the-air while the vehicle is operating, getting real-time traffic information from the cloud, or shifting high intensity compute to a cloud environment.

To effectively orchestrate the development of services, they should be developed and updated individually. To this end, the platform should follow **cloud-native principles**, in which software consists of micro-services with clear APIs to ease interplay between the microservices, instead of a monolithic stack. This not only enables individual and faster updates and innovation, but also better fault isolation, driving overall software safety.

To leverage the cloud-native benefits at scale not only within a company but across the auto industry, companies should agree on a **standardized architecture** template – a modular tech stack with clear interfaces. This would help leverage cloud benefits across the industry, simplifying integration and reducing redundancy. Moreover, an **integrated toolchain**, where the industry adopts a common toolchain standard, would support simplification and acceleration of software development, validation and integration processes.

Interoperability is crucial to create flexibility not only for the services within the vehicle software platform, but also for the interaction with other vehicle layers (see Box 1 with vehicle layers). This also drives long-term maintainability as different software pieces can be updated individually.

Interoperability of the vehicle software platform should extend to the chip (**chip agnostic**), cloud (**cloud agnostic**) and coding language (**language agnostic**). All three are essential for improving updateability, better balancing of workloads and easier reuse of code.

Finally, in the journey towards the vehicle software platform target picture from Figure 2, cybersecurity should be guaranteed. Ensuring that cyber safety is built for vehicle software at the design level – software "secure-by-design and -default" – is paramount to unlock safety and innovation in the long run. This is especially so with views to the high connectivity and open-source dependency of advanced software-defined vehicles. New principles for software cyber safety are being published, among others, by different US cybersecurity agencies and the European Commission.

Catalysing the journey towards the target picture

Current vehicle software capabilities diverge significantly from the eight-part target picture described above. Not all these characteristics are equally easy to achieve (see Figure 3). For example, hardware and software are still closely interlinked in many vehicles. While hardware and software will certainly be routinely decoupled in the long term, selected high-performance or high-safety use cases might always require dedicated silicon/compute to meet performance requirements.

An industry-wide architecture template and toolchain designed for safety, flexibility and efficiency can serve as catalysts. While some of the elements in the target picture are already emerging today, others might never be fully achieved (e.g. chip agnostic). The industry discourse around some of the mentioned characteristics, especially chip agnostic and cloud-edge distributed, is subject to diverging technological and commercial interests, even if the target picture direction is shared across actors.

Three elements stimulate the progress of the remaining five (as shown in Figure 3), namely having an architecture that follows cloud-native principles, is standardized across the industry and paired with an industry-wide integrated toolchain. Efforts to accelerate them are thus necessary to advance the path towards the overall target picture.

Box 2 provides a starting point for future discussions towards the joint standardized architecture with cloud-native principles.

FIGURE 3 **Trajectories for the vehicle software platform characteristics**

BOX 2 | Towards an architecture template for the vehicle software platform

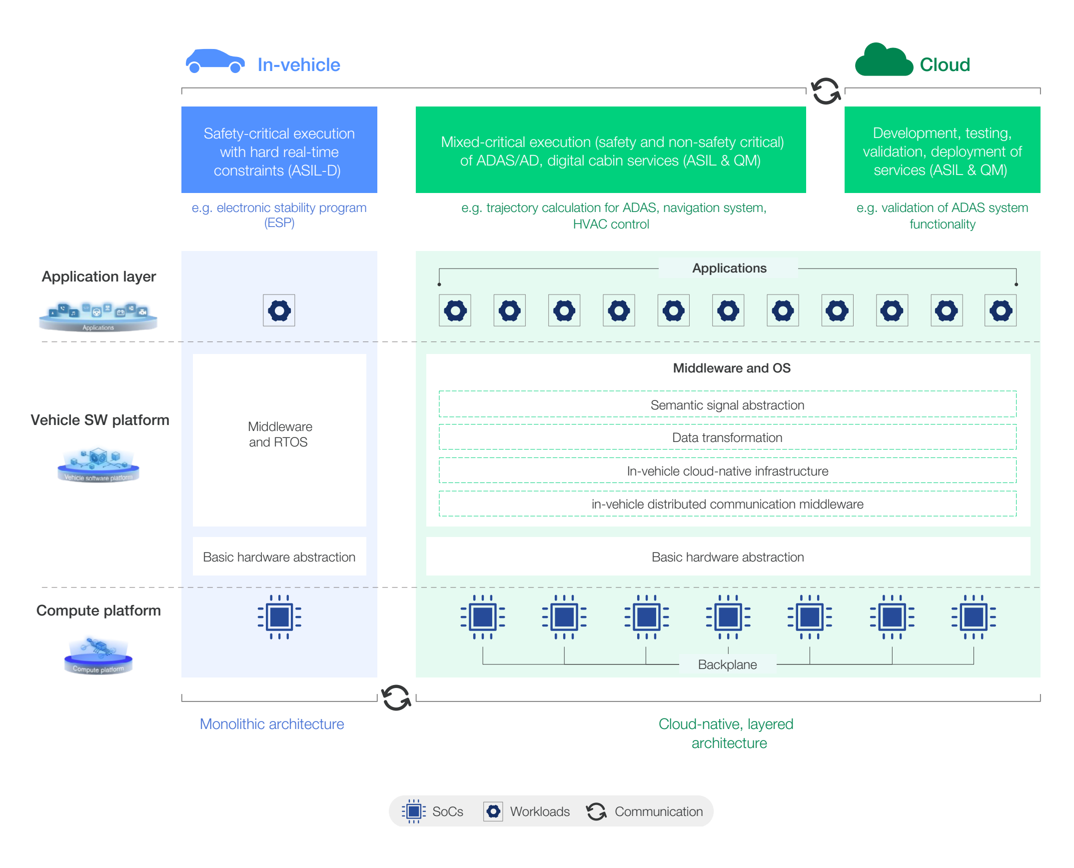
The standardized architecture template with cloud-native principles should provide safety, efficiency and flexibility by design (see Figure 4).

Three types of stacks with dedicated functionality and purpose can enable this. First, most functions will be led by a mixed-critical stack with layered architecture (ASIL & QM), where workloads are dynamically distributed. This enables an efficient use of computing and scaling up of software. Noting that different approaches will be necessary to build the safety critical and non-safety critical parts of this **mixed-critical stack** – for example, while non-safety critical applications can follow standard quality management (QM) methods for development and validation – the safety critical ones (ASIL-Automotive Safety and Integrity level) require special and longer validation methods.

Second, a **monolithic, vertically integrated stack** will be necessary, at least for the time being, for isolated handling of safety-critical cases with hard real-time constraints (ASIL-D), to minimize latency. And third, a **cloud stack**, which will enable a seamless interaction between the vehicle and the cloud, including development, testing, validation and deployment of software. To enable realistic virtual testing and validation of software in the cloud, the cloud stack should mirror the vehicle architecture for highest safety.

Communication happens on several ends. First, between the cloud and the in-vehicle stacks for agile, pervasive over-the-air updates during runtime. Second, within the vehicle, between safety-critical ASIL-D stack and mixed critical stack. And third, communication efforts are in place to communicate with the infrastructure and the broader mobility ecosystem.

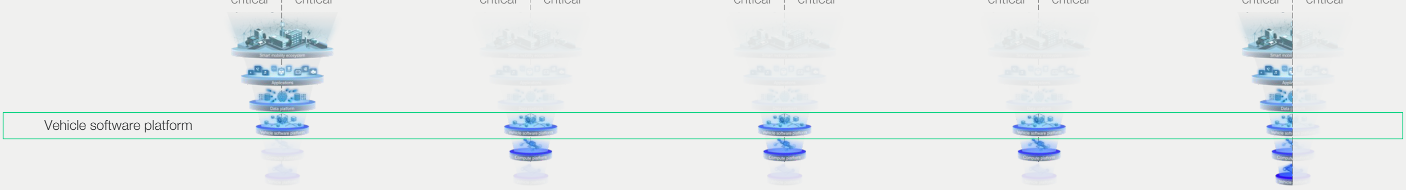
FIGURE 4 | Architecture template for the vehicle software platform. Adapted from Eclipse and SOAFEE



One way to accelerate the path towards the ideal target picture is via coordinated, global cross-industry initiatives that promote collaboration. Open-source efforts can especially be relevant for safety-related topics, and they play an important role helping complement competitive industry dynamics. Several initiatives have already been formed to this end. Figure 5 shows some major initiatives and their unique benefits that help accelerate the path towards a scalable vehicle platform. Current efforts are necessary in coordinating among the initiatives to maximize the synergies of the different initiatives and their impact in the roadmap towards the target picture.

FIGURE 5 **Overview of selected vehicle-software platform initiatives**[2]

	COVESA	SOAFEE	ECLIPSE FOUNDATION SDV working group	AUTOSAR	THE AUTONOMOUS
Ambition	Open standards for connected vehicles	Uniform SW architecture + tooling	Open-source SW collaboration	Uniform software architecture	AD collaboration ecosystem
Focus	Safety-critical / Non safety-critical	Safety-critical / Non safety-critical	Safety-critical / Non safety-critical	Safety-critical / Non safety-critical	Safety-critical / Non safety-critical
Members	>30	>50	>30	>300	>30
Reach	Global	Global	Global	Global	Global
Unique selling point	Drive semantic standardization	Architecture framework	Company independent	Established framework	Autonomous mobility focus



> **There are big challenges around the software-defined vehicle. Strong, long-term industry collaboration is key to overcome them in an efficient, timely and safe way.**
>
> Markus Heyn, Chairman, Robert Bosch Mobility Solutions

Further collaboration and strategic alignment

Leaving rigid legacy systems behind and moving towards an industry-wide scalable vehicle software approach will be a challenging, but crucial journey to untap the safety and economic opportunities of the software-defined vehicle over its entire life cycle. This paper, co-designed through a cross-industry endeavour, puts together a target picture and outlines the timeline to achieve it.

The paper also highlights that in order to unlock the societal and economic benefits of today's automotive transformation, a collaborative effort is necessary at both the technical and strategic levels.

Strategic guidance can help ensure alignment on the roles and responsibilities for the different initiatives, adding clarity to the technical efforts being currently undertaken. Technical efforts can, with that, also better align in their efforts towards a common join architecture and toolchain solution.

Such collaborative efforts contribute towards a more unified, industry-wide, scalable vehicle software approach that is maintainable during the entire vehicle life span – fostering safety, sustainability and long-term user value.

[2] SOAFEE, https://www.soafee.io/blog/2022/soafee_sig_journey_to_date_and_whats_next; Eclipse https://sdv.eclipse.org; Covesa https://www.covesa.global; The Autonomous: https://www.the-autonomous.com; AUTOSAR: https://www.autosar.org/.

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Acknowledgements

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