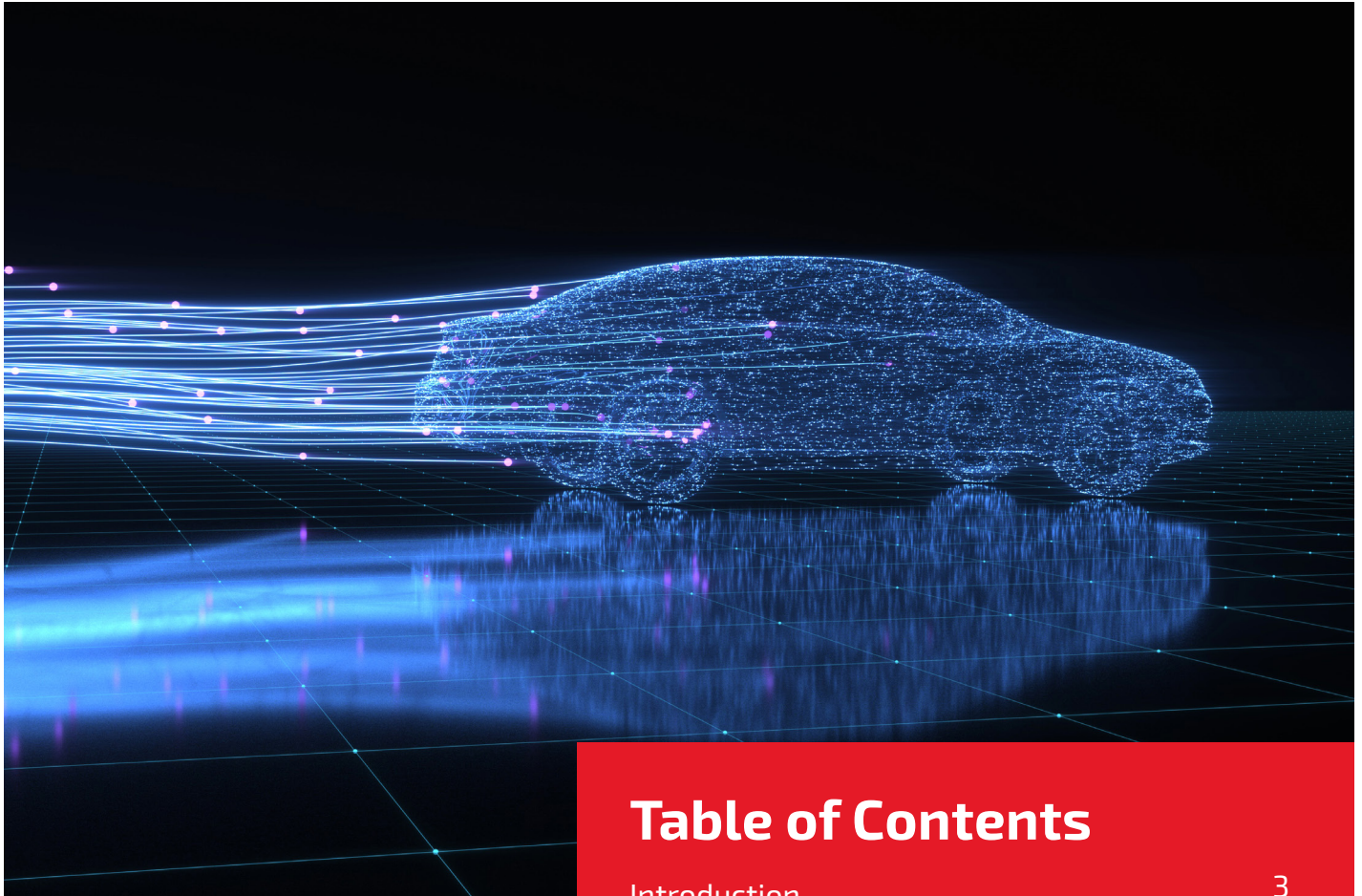WHITE PAPER

The Journey to Software-Defined Vehicles

How Evolving Vehicle Architectures Will Empower Future Mobility

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Introduction

During the past 10 years, the automotive industry has undergone disruption like never before – and this is likely to continue for the next decade, and beyond. Autonomy, connectivity, and electrification (ACE) technologies are combining to bring automotive into a new mobility era with a bright future. However, the incremental changes and additional features introduced in vehicles during this period have dramatically increased vehicle complexity and amplified time-to-market pressures, development challenges and maintenance costs to an almost unbearable level for many vehicle manufacturers.

These challenges, combined with new technologies and shifting market dynamics are now driving fundamental change in how the automotive industry approaches designing, manufacturing, and delivering new mobility solutions. The resulting high level of innovation offers new revenue streams and profit-pool opportunities to a larger and more complex automotive supply chain searching to find a new equilibrium.
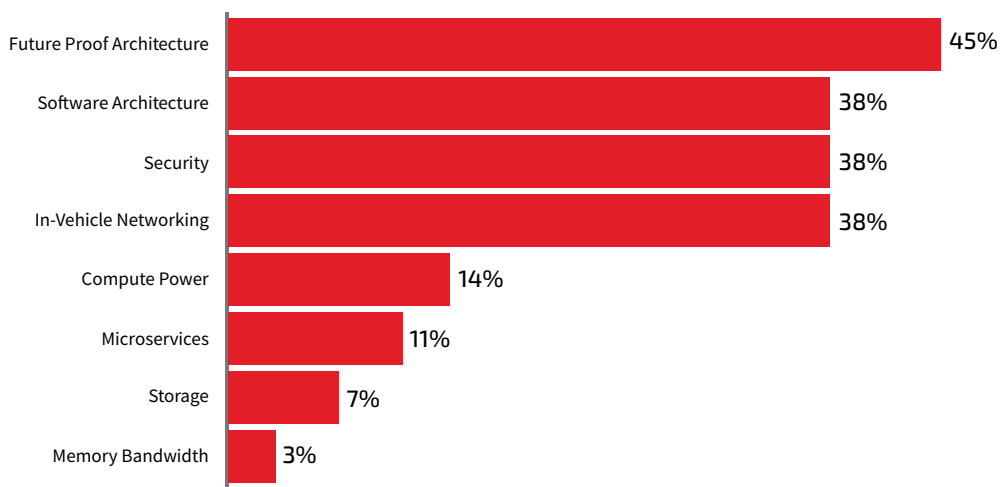
The Software Defined Vehicle

To accelerate innovation, OEMs are developing new electrical/electronic systems that can support today's advanced requirements as well as future unforeseen needs.

Based on a 2021 Wards survey - "Automotive Software and Hardware Architecture Revolution" – OEMs' identify their top system challenge as making their next-generation vehicles flexible and future proof (see Figure 1 below). Future-proof architectures would allow vehicle manufacturers to continuously update their vehicles throughout lifecycles and maintain a relevant user-experience that keeps pace with fast evolving markets such as IT and consumer electronics.

Closely following that, the respondents along the supply chain recognize the importance and role of a modern software architecture, improved security and in-vehicle networks that are up to the task. Hardware components and performance are considered less critical – likely because system integrators and OEMs are confident in the steady advancement and integration that is taking place in the semiconductor industry.

Biggest Systems Challenges That SDV Must Address (Figure 1)

Challenge	Percentage
Future Proof Architecture	45%
Software Architecture	38%
Security	38%
In-Vehicle Networking	38%
Compute Power	14%
Microservices	11%
Storage	7%
Memory Bandwidth	3%

Source: Wards Intelligence, 2021

Looking beyond the survey percentages, it is evident that to achieve such an aggressive innovation target requires all the elements of the equation to be well harmonized: new hardware, software, networking, and security technologies and designs, as well as a migration path from legacy to future architectures across OEMs' entire lineups.

On the hardware side, centralized and modular ECU hardware is already the state of the art, enabled by higher-performance and highly integrated semiconductor components. These high-powered computers, as well as data-rich sensors, require high-speed, low-latency network connectivity – a role increasingly fulfilled by automotive Ethernet, given its speed, security, flexibility and cost-effectiveness.

More significantly, the focus and center of gravity of in-vehicle electronics system is quickly moving from hardware-centric to software-centric designs. Software platforms and modules are becoming increasingly prominent as vehicle features are implemented primarily in hardware-agnostic software — leading many to describe these cars as "software-defined vehicles." In these future-proof architectures, functions and features will be upgraded via software updates applied to still essential, often "over provisioned," underlying hardware platforms.

In this software architectural revolution, technologies from the IT industry, such as microservices, SOA (Service-oriented Architecture) and virtualization will enable an efficient and cost-effective foundation to future-proof fleets and shorten time-to-market, as well as reduce development costs.

Software flexibility, especially over-the-air "updatability," will help maintain a vehicle's relevance during its entire lifecycle (still 7+ years), avoiding obsolescence and better aligning with consumers' digital and connected lives. And hardware-agnostic software will enable the separation of hardware- and software-development cycles – helping auto-companies accelerate software development and enhance in-vehicle features and functions independently of hardware cycles.

This massive transformation will profoundly impact operating processes along the entire supply chain – requiring vehicle manufacturers to transform their R&D and manufacturing organizations, as well as their business focuses. This is where new industry players, with expertise in software and data management, can engage in tight collaboration and partnerships with manufacturers and Tier 1s to close the technology gap for legacy players.

The SDV Journey

Wards Intelligence believes the industry is only in the initial stage of the SDV journey. Software-defined vehicles are expected to disrupt and significantly impact operations for OEMs, traditional suppliers and technology companies that are investing in automotive. Vehicles are the last link of the chain in a much wider eco-system that encompasses the OEM´s back-end operations and manufacturing facilities, as well as infrastructure that includes the "Cloud." In the past, these domains were largely separate; but they are becoming much more interdependent in the new world of mobility.

Connectivity is the underpinning technology enabling this revolution — bridging and synergizing previously disconnected worlds. Connectivity enables the creation, development and control of a new creature: the software-defined vehicle.

4G cellular networks enabled the Connected Car, with data-centric services such as General Motors' OnStar, content-services like Pandora and the beginning of OTA updates. 5G technology – which is expected to replace 4G over the next five years (see chart below) – will turbocharge connected services. Notably, 5G's greater bandwidth, higher speeds, and lower latency will support: a) extensive in-vehicle software updates, b) terabytes of data to be shared and monetized and c) real-time V2X services, mainly driven by safety functions.

Connected Car Transition to 5G (Figure 2)
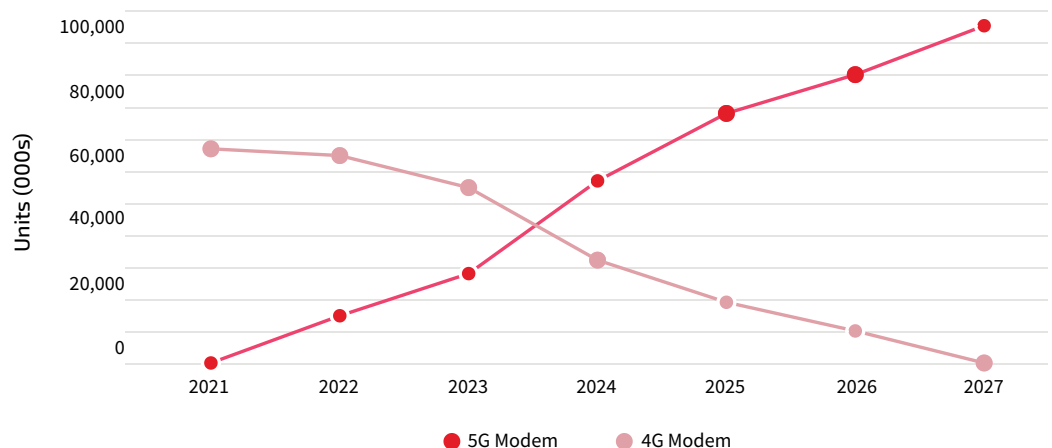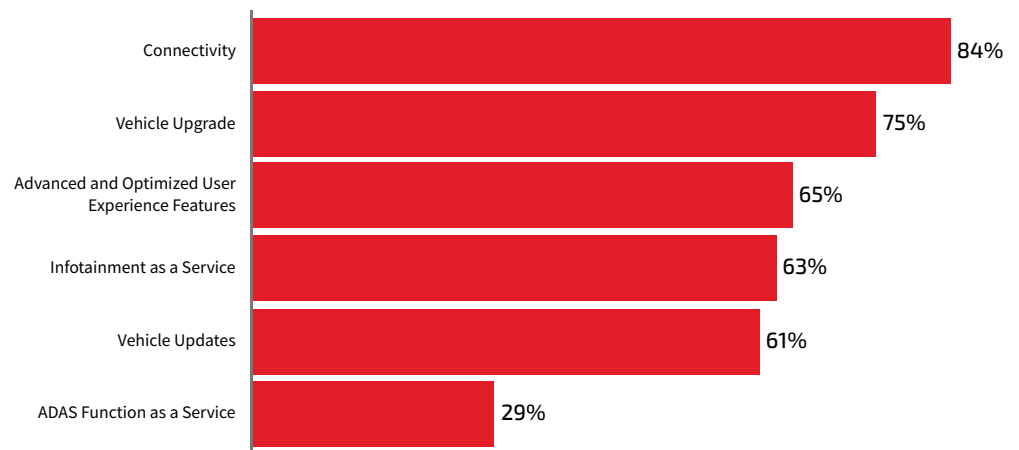

Source: Wards Intelligence, Omdia

The bidirectional flow of data to and from the car over these connections is the game changer that will open a vast range of market opportunities. Centralized data collection and management will be essential for the new mobility ecosystem, with the flexibility to decide exactly what data to collect and when – whether periodically, streamed in real-time, event-triggered or on-demand. Applications and services that leverage data created inside and outside the vehicle, combined with the ability to change or enhance vehicle capabilities dynamically, will enable use cases not previously possible, such as:
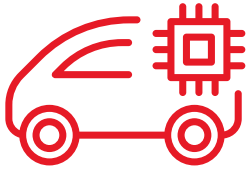
- Dynamically optimize a vehicle's performance throughout its lifetime
- Continuously analyze vehicle data for quality and cost improvement
- Capture diagnostic, validation, and testing data in near real-time to resolve issues quickly and reduce escalating support, warranty, and recall costs throughout the vehicle's life
- Align with consumers' digital life and subscription-based services
- Pave the way for the next generation of personalized in-vehicle features, enabling new use cases and profit pools. In-vehicle automation will be a powerful enabler for this.

These capabilities will foster new use cases and business models that add higher value to the market and slowly replace traditional sources of profit associated with vehicle sales. The figure below from a 2021 Wards survey on "Future Software Defined Vehicle" identifies the top services and monetization opportunities that OEMs and Tiers expect to generate significant revenue streams enabled by the new connected and software defined mobility approach. These and other new business models and revenue streams are expected to expand the profit pools, distributing it along the life of the vehicle, while, paradoxically, enabling vehicles to be sold at closer to cost.

What Type of Service Would Drive Revenue in a Subscription-Based Model? (Figure 3)

Service	Percentage
Connectivity	84%
Vehicle Upgrade	75%
Advanced and Optimized User Experience Features	65%
Infotainment as a Service	63%
Vehicle Updates	61%
ADAS Function as a Service	29%

Source: Wards Intelligence, 2021

Beyond OTA

Over-the-air updatability is a key capability of the SDV. The ability to remotely fix issues, enhance performance, and add new capabilities after production will significantly impact customer experiences and automakers' profits. For example, Tesla frequently deploys software updates — ranging from performance tweaks (e.g., braking, power management) to software fixes and the addition of major new functionality — to reduce costs and delight customers. Other OEMs are now delivering more OTA capabilities in their new vehicle platforms, such as Ford with the Mustang Mach-E and F-150.

However, continuously developing and deploying new software has significant implications, such as:

- Time to market
- Cost/ Total Cost of Ownership
- Deployment infrastructure and complexity (Cloud, Back-end, and Fleet)
- Potential Security risks
- Supplier/process quality management

As a result, innovative approaches are reaching the market that offer flexible dynamic configurability as well as automation capabilities that can reduce investment in software, infrastructure and in-vehicle electronics. Vehicle software that is dynamically configurable and controllable enables OEMs to enhance vehicle performance and add functionality without having to develop and deploy new software. It also provides a foundation for mass-personalization without burdening core software with unnecessary complexity.
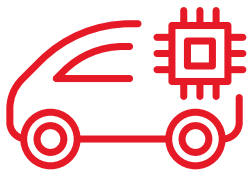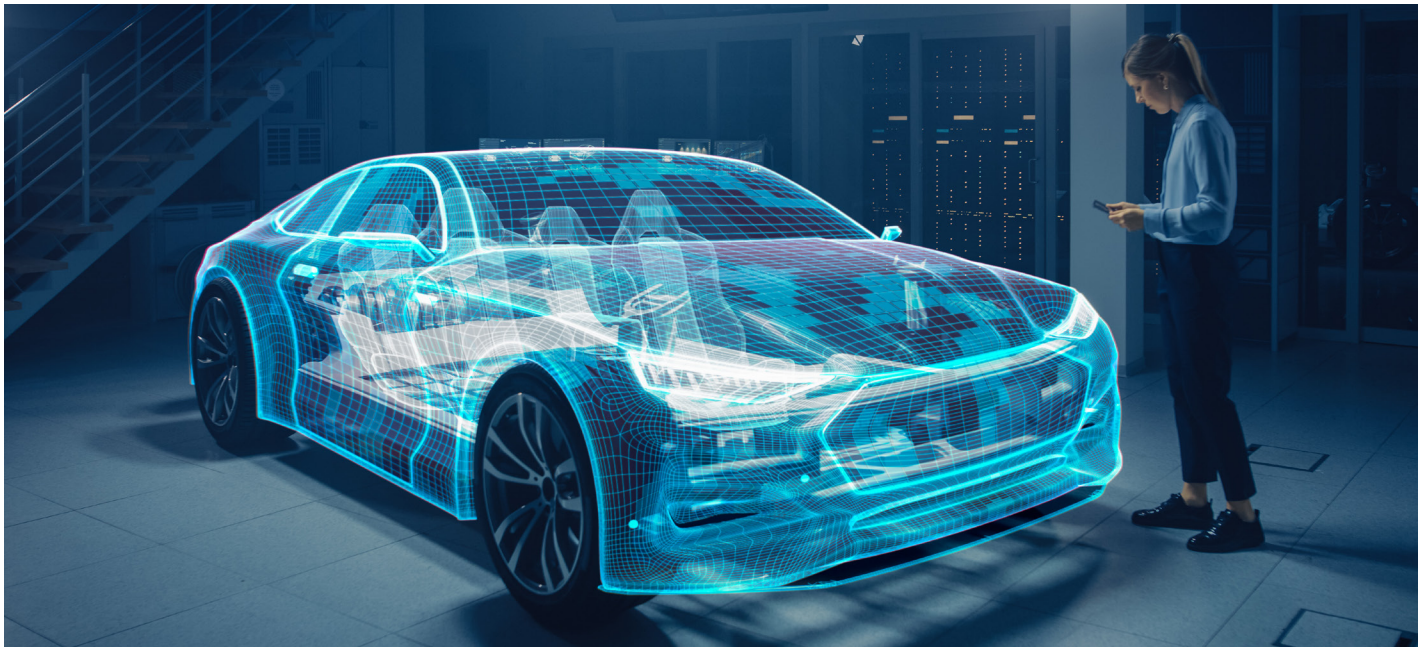
These new approaches can be integrated into existing hardware, thus enhancing vehicle relevance and the user experience without big changes in the vehicle architecture that would obsolete legacy fleets. For greater flexibility, automakers can build in additional capacity with their hardware and software components to provide room for future improvement. Doing this would minimize the need to update and requalify entire modules (SW and HW) to add features or functions.

For example, Sonatus, an automotive software platform supplier headquartered in Silicon Valley, provides a software-defined vehicle platform with dynamic configuration and automation. Its first-generation data collection and in-vehicle network (IVN) management solutions were developed and integrated into Hyundai vehicles in under 12 months without any hardware changes. Sonatus' second-generation Digital Dynamics™ platform – which recently shipped in the 2022 Genesis GV60 – introduced new vehicle and cloud software that dynamically orchestrates vehicle behaviour and enables automakers to harness vehicle data on the fly, control and secure vehicle connectivity, remedy problems, and add functionality — quickly without requiring software updates.

Making vehicles observable, dynamically configurable, and "automate-able" enables capabilities and use cases that software OTA doesn't support easily — such as flexible real-time vehicle diagnostics, proactive security and mass personalization of vehicle features. Therefore, this approach should be considered highly complementary to OTA updates, especially in the early stage when most vehicle software is not yet modular and portable and significant investments are needed to develop a scalable infrastructure for continuous development, integration and OTA deployment of this new software.
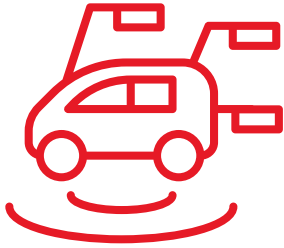
Build and Buy

Many OEMs (e.g., VW, Mercedes Benz, Toyota) have committed to developing their own vehicle software to differentiate their products and control their destinies. The key question is which software components should OEMs focus their efforts on and which should be left to external experts?

Vehicle manufacturers need to control and secure their entire value chain end-to-end — from design, testing, and validation to production, maintenance, certification, mobility services, and software updates — throughout the vehicle´s lifetime. As shown below, "software" covers a wide range of technologies and layers — OS, hypervisor, middleware, framework, applications, and services — both in-vehicle and on premises. Trying to develop and maintain this broad software spectrum risks defocusing OEMs from their core competencies and business differentiators, and significantly impacting investment costs and relative ROIs.

Layer	Description
Back-end Operation / CRM / R&D / Partner Eco-system	**Public and Private Cloud Infrastructure** — Data and Software Storage and Management, Data Analytics, R&D, CRM, Vehicle Simulation and Validation software, Digital Twin
User Application / User Application / Legacy Service	**Final Applications: Developed by OEMs or Tier"n"** — Brake assistance, ACC, Parking Assistance….
Runtime Framework / Runtime Framework / Runtime Framework — Middleware: APIs, Functions and Basic Services	**Runtime-Framework: Basic SW and Functional Module** — Developed by OEMs, Tier1 or SW Suppliers: Mapping, Perception, Planning…. **Middle Ware:** Developed by Suppliers and branded by OEMs: Diagnostic, Security, Logging
OS/Hypervisor	**Real time OS and Hypervisor**
Hardware / Virtual Machine	**SoCs, Accelerators**

Source: Wards Intelligence 2021

Wards Intelligence believes that manufacturers should identify and focus on their essential areas of differentiation, and partner with highly competent software and application providers that can offer innovative complementary solutions. The automotive industry has deep knowledge and competence in the domain of embedded software and vehicle features, but limited experience with advanced software technologies and architectures prevalent in other industries and domains. Now, experts from IT and Cloud domains are using their expertise in software and services, connectivity, cloud, and OEM premises architecture and infrastructure, to develop innovative solutions tailored for automotive. An increasing number of "software" suppliers and disruptors are investing in the mobility market and helping the industry leapfrog into the future of SDV.

Conclusion

The software-defined vehicle journey has just begun. In SDVs, software will not only define vehicle functions, features and mobility applications but also forge platforms and core components upon which added value will continuously be implemented. Software and data will enable the expansion of the automotive ecosystem across adjacent industry domains, beyond the vehicle itself, unfolding new business models and profit-pools.

OEMs are currently developing portable, updatable vehicle software to enable hardware flexibility, ECU consolidation, and remote updates to fix defects and add features after SoP (start of production). A new set of complementary technologies and solutions is emerging that leverages dynamic configurability and controllability to optimize vehicle performance, add new functionality and personalize the user experience without requiring new software. These new capabilities complement software OTA to enable new use cases and cost-effectively keep vehicles healthy, current and secure.

As OEMs continue down the SDV path, they should focus their internal software development on areas of differentiation and select expert partners to provide complementary innovative software to help them build world class mobility solutions.