As OEMs integrate more software-defined solutions into their vehicles, there is the potential for future vehicle architecture to be defined by the software it uses, and the platforms adopted from its ecosystem. The end goal is a Software-Defined Vehicle—a car that leverages software to reduce the cost of development, boost performance, and enhance the in-vehicle user experience.

SBD Automotive’s Car IT Team has created The Software-Defined Vehicle report to support OEMs and suppliers. It identifies the Software-Defined Vehicle and outlines how OEMs can utilize platforms and services to build cars that can be continually updated, and progressively maintained, by cross-platform software.
Key features & benefits

> **Defines the SDV:** Understand the Software-Defined Vehicle, the KPIs, high-level architecture and patterns, and the key technology domains.

> **Core technologies:** Go in-depth on the hardware and software powering the Software-Defined Vehicle.

> **Global OEM activities & impacts:** How Software-Defined Vehicles are changing OEM businesses, as well as their partnerships, investments, platforms and organizations.

> **Supply chain activities and impacts:** How tier 1s, tier 2s and service providers support the Software-Defined Vehicle.

This research supports

- **PRODUCT PLANNERS**
- **MARKETING**
- **ENGINEERS**
- **C-SUITE**

Do I have access?

Request a quote for

The Software-Defined Vehicle

Request price
July 2021

THE SOFTWARE-DEFINED VEHICLE

Enabling the updatable Car - Business, technology, & supply chain
Introduction ≫

Executive Summary ≫

The Software-Defined Vehicle ≫

- Overview and KPIs
- High-level architecture & patterns
- Key technology domains

Core Technologies ≫

- Overview
- Hardware
- E/E & Networking
- Operating Systems
- Middleware & Communications
- ADAS
- Connectivity & IVI
- Cloud & Edge Computing
- DevOps and OTA Software Updates

OEM Impacts ≫

- Overview
- Business & KPI Impacts
- Organizational Impacts
- Technology Impacts
- Supply Chain Impacts
- Market Segmentation Impacts

Supply Chain Impacts & Activities ≫

- Supply Chain Overview
- Tier 1 Impacts

- Tier 2 Hardware Impacts
- Tier 2 Software & Cloud Suppliers
- Tier 1 Suppliers & Technologies:
  - AISIN
  - Aptiv
  - Bosch
  - Continental
  - DENSO
  - Faurecia
  - HARMAN
  - Hyundai Mobis
  - Lear Corporation
  - LG Electronics
  - Marelli
  - Mitsubishi Electric
  - Panasonic
  - Pioneer
  - Sumitomo Electric
  - Valeo
  - ZF

- Tier 2 Hardware & Cloud Suppliers:
  - Amazon (AWS, Zoox)
  - BlackBerry
  - ExcelTec
  - Google (Android, Waymo)
  - GuardKnox
  - Microsoft

Global OEM Activities ≫

- Overview and Timeline
- Software-Defined Vehicle Maturity Index
- OEM Groups:
  - BMW

- Overview and Timeline
- Software-Defined Vehicle Maturity Index
- OEM Groups:
  - BMW

Contact Us ≫
Introduction
## SDV Levels to Principles

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>E/E Patterns</th>
<th>User Experience</th>
<th>Updatability</th>
<th>Connectivity</th>
<th>S/W Architecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle 1.0</td>
<td>Zonal</td>
<td>Personalized</td>
<td>Vehicle Software Updates</td>
<td>5G with Edge</td>
<td>Edge Container Runtime</td>
</tr>
<tr>
<td>Functional</td>
<td>Functional Domains</td>
<td>Connected IVI</td>
<td>Firmware Updates</td>
<td>Multi-Channel</td>
<td>Service-Oriented Architecture</td>
</tr>
<tr>
<td></td>
<td>Functional Bandwidth</td>
<td>Connected IVI</td>
<td>Phone App Updates</td>
<td>4G</td>
<td>Cockpit S/W Apps</td>
</tr>
<tr>
<td></td>
<td>Multi-CAN</td>
<td>Static IVI</td>
<td>No Updates</td>
<td>None or eCall Only</td>
<td>Tightly Coupled</td>
</tr>
<tr>
<td>Vehicle 2.0</td>
<td>Zonal</td>
<td>Personalized</td>
<td>Vehicle Software Updates</td>
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<td>Personalized</td>
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<td>5G with Edge</td>
<td>Edge Container Runtime</td>
</tr>
<tr>
<td>Updateable</td>
<td>Functional Domains</td>
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<td>Firmware Updates</td>
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<td>Service-Oriented Architecture</td>
</tr>
<tr>
<td></td>
<td>Functional Bandwidth</td>
<td>Smartphone Projection</td>
<td>Phone App Updates</td>
<td>4G</td>
<td>Cockpit S/W Apps</td>
</tr>
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</tr>
<tr>
<td>Vehicle 4.0</td>
<td>Zonal</td>
<td>Personalized</td>
<td>Vehicle Software Updates</td>
<td>5G with Edge</td>
<td>Edge Container Runtime</td>
</tr>
<tr>
<td>Software-Defined</td>
<td>Functional Domains</td>
<td>Connected IVI</td>
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</tbody>
</table>
Example slides from the report

Please note: These slides are taken from the pre-release report and may be updated before the final release.
The Software-Defined Vehicle abstracts hardware from software

Automakers do not manufacture their own silicon. For any given computing module in a vehicle, a hardware platform is sourced from a vendor that specializes in system-on-chip components.

Many system-on-chip components have system services, platforms, or APIs which are unique to that component or manufacturer. When software is written on these services, that software becomes “tightly coupled” with the hardware – that is, the software will only run on that specific hardware platform.

As automotive computing platforms become more capable, the introduction of hardware abstraction layers provides, on one side, support for hardware-specific system services, while on the other side, these services are exposed as homogenous interfaces.

Software developers can then “loosely couple” their software as applications, leveraging the abstraction layer and other services to isolate functionality as services while being portable to any hardware which supports the same abstraction layer.

The transition from tight coupling to loose coupling is the ethos of the software-defined vehicle.

### Design Principle
- **Tight Coupling**
  - Software developed as monolith, unseparated from other functions or services provided by the component.
  - Hardware drivers & system services are unique to the system.

- **Loose Coupling**
  - Software developed as independent applications based on function or service.
  - APIs & middleware added which provide hardware-agnostic interfaces for interacting with hardware services or messaging with other applications.
  - An abstraction layer provides services which map hardware-specific services, functions and data to hardware-agnostic services, functions and data defined in the higher-level.

### Impact
- Updating is difficult due to dependencies between components.
- Higher costs from hardware complexity and fragmentation with unique software for each.
- Software can be updated or added more easily due to separation of functions by application.
- Software can be developed independently of the specific hardware while applications can apply service-oriented architecture.
- Reduction or elimination of hardware fragmentation due to software incompatibility.
High-performance computers are the key to abstraction

- **Applications & containers leverage services on the GPOS** to run portable software integrated with the hardware abstraction services offered by the GPOS or other middleware.

- **Multiple CPU clusters alongside sizable memory availability allows for simultaneous execution of real-time and general purpose operating systems.** The RTOS provides deterministic computing for safety-critical functions, while the GPOS allows deployment of more general services, features, and data processing applications.

- **Type 1 hypervisor provides hardware-optimized virtualization services,** ensuring safe operation of the RTOS alongside GPOS guest OS(es).

- **HPCs provide a variety of physical interfaces** to integrate both with CAN, LIN, and FlexRay sub-networks whilst allowing for high-bandwidth communication with other components via Ethernet, USB, and PCIe.

- **GPUs power the processing of camera & radar data** for ADAS/AV applications as well as power rendering for digital cockpit interfaces.

- **CPU clusters ensure redundant processing** for both RTOS and GPOS applications with separate contexts for deterministic and non-deterministic operations.

- **Multiple HPCs may be deployed to provide high availability, optimized, redundant AV services** and/or specialized digital cockpit applications.

*In zonally configured E/E architectures*
SDVs create long-term scalability for ADAS & AV functionality

- Higher levels of automation create significant new hardware and software requirements for vehicles, requiring cutting edge technologies to provide the relevant input, quickly and reliably process input data, and improve the performance of the system over time through integration with the cloud & other autonomous vehicles.
- The operational requirements of higher levels of autonomy mandates the need to move from a strict fail-safe to a more fail-operative strategy: fault detection and reaction needs to be controlled by independent hardware, resulting in unique AV software architecture requirements.
- The goal of the implemented redundancies is to allow the driver (for SAE L3) to take over the driving task when required but also be able to implement a minimum risk manoeuvre if absolutely necessary.
- Dedicated high-performance computer systems are required to deliver real-time sensor data processing, sensor fusion and trajectory planning with the broader numbers & types of sensors in highly autonomous vehicles, and this software requires significant integration with the cloud to be able to improve & update over time.

**ADAS Domain Requirements for Software-Defined Vehicles**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Design Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>AV/ADAS controllers must be able to support the highest levels of safety assurance at any level of autonomy</td>
<td>Hardware &amp; software redundancy, e.g. multiple sensing modalities, independent power supplies, lockstep mechanisms, consensus-driven AI, etc.</td>
</tr>
<tr>
<td>AV/ADAS controllers must provide the highest levels of cybersecurity protection in the vehicle to prevent threats to driver/passenger safety</td>
<td>Both the hardware &amp; software of the AV operational domain must be secured by design, leveraging best-in-class countermeasures to both defend and react to security and safety threats</td>
</tr>
<tr>
<td>AV/ADAS controllers must be able to support new and enhanced functionality over its lifetime through software &amp; configuration updates</td>
<td>The vehicle should integrate reliable access to high-speed, low-latency, low-cost data networks for OTA, and the domain hardware should be considered with a multi-year lifespan (or mid-cycle upgrade) strategy</td>
</tr>
<tr>
<td>AV/ADAS controllers must be able to support dynamic, localized applications to support data processing &amp; functional validation</td>
<td>ADAS/AV high-performance computers should allow for edge-oriented application runtimes which can be used to rapidly develop &amp; deploy data cost-efficient functions</td>
</tr>
<tr>
<td>AV/ADAS controllers must be capable of ingesting &amp; processing high-bandwidth camera inputs in real-time</td>
<td>High-performance computers used for AV/ADAS systems should be equipped with specialized graphics processing and artificial intelligence capabilities</td>
</tr>
</tbody>
</table>

**Trend**

- Volume brands
- Premium brands
- EV Startups
- Distributed basic ADAS ECUs
- Partial consolidation of ADAS domain
- Consolidated ADA/AV domain
- Redundant HPC ADA/AV controllers

**Relationship with other layers**

- OTA: AV S/W Updates, Configurations
- Cloud & Edge: Data Processing, V2X, Local/Maps
- Middleware: Application Runtime, Service Integration
- OS/Hardware: RTOS, GPOS (Apps), GPU Acceleration
- E/E: Gigabit Ethernet
- ADAS/AV Domain: Connectivity & Infotainment, Cloud & Edge Computing, DevOps & OTA
Ford has jumped from laggard to near-leader in software in 5 years

**Key Messages**

- Ford has completely overhauled its infotainment and E/E platforms as it shifts its portfolio to include a high EV mix.
- Ford is the first manufacturer to offer over-the-air software updates for almost all ECUs in its F-150 truck series.
- Ford’s cloud strategy, centered around Ford Smart Mobility, pairs with its new FNV E/E to create a strong volume OEM technology stack, which also includes co-investments with Volkswagen.

**Business Model/Supply Chain Insights**

- **EV shift underpins tech strategy**
  
  As Ford targets 40% of its sales by 2030 to be EVs, it has rapidly evolved its technology development strategy to offer significant in-house capability.

  Ford Smart Mobility manages cloud & MaaS development, while product engineering manages in-vehicle software development.

**Organization Insights**

- **Ford Motor Company**
  - Ford Smart Mobility acts as a subsidiary and manages its cloud portfolio.
  - Team Upshift is a co-staffed team from Ford & Google using Google’s cloud platform for data analytics & services.
  - Ford's in-vehicle software engineering is primarily managed in-house via product engineering.

- **Smart Mobility LLC**
  - Team Upshift (Google/Ford)

- **Autonomic LLC**

- **Team Ford Pass**

- **Product Eng.**

- **Team Upshift (Google/Ford)**

**Technology & Platform Insights**

- **Connectivity**
  - OTA Updates via Embedded 4G

- **Infotainment**
  - SYNC 4
  - OTA
  - Live Mapping
  - BlackBerry QNX

- **ADAS**
  - Driver Assist
  - Mobileye
  - AUTOSAR Classic

- **OS & Middleware**
  - No Middleware
  - Classic AUTOSAR
  - BlackBerry QNX

- **E/E**
  - Single Gateway
  - Multi-CAN, ADAS Flexray

- **Hardware**
  - SYNC 4 IVI Controller (2x power of SYNC 3)
  - Microcontroller ECUs

**SDV Maturity Index**

- **1.0**
  - Most ECUs updateable
  - In-house cloud s/w

- **2.0**
  - Google data partnership

- **3.0**
  - Some level of ECU consolidation

- **4.0**
  - Android Automotive
  - Adaptive AUTOSAR

**Roadmap**

- **In Market**
  - “Power Up” OTA Software Updates for Full Vehicle

- **Announced**
  - Android Automotive OS
  - Adaptive AUTOSAR

- **R&D**
  - Fully Networked Vehicle (FNV-2)
  - TBD

*Based on analysis of open job postings*
Suppliers are adopting the Tier 0.5 model

The Tier 1 Model

The traditional supplier model relies on Tier 1 suppliers to manage the entire lifecycle of the high-tech component which it is manufacturing for the OEM.

The Tier 0.5 Model

When designing and building highly differentiating components, OEMs will source partners — Tier 0.5s — rather than just “suppliers” to facilitate co-creation.

The Tier 0.5 model also gives rise to specialists along the supply chain, provided either by the supplier or selected by the OEM to work in cooperation.

While other, specialized companies have existed throughout the automotive hardware & software supply chain, Tier 1s have traditionally acted as the central hub for aggregating supplied products and technologies into a usable component. Some of the biggest Tier 1s are now evolving their business model to act more like a “partner” to OEMs — a Tier 0.5 — while other specialized suppliers and OEMs themselves replace or augment services traditionally provided by Tier 1s for highly differentiating components and associated software.

### Specialized Suppliers

<table>
<thead>
<tr>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>White-Label OEM</td>
<td>Complete vehicle design, development &amp; manufacturing</td>
</tr>
<tr>
<td>Engineering Management Services</td>
<td>Custom design &amp; manufacturing for specialized hardware</td>
</tr>
<tr>
<td>Low-Cost Supplier</td>
<td>Commodity hardware manufacturing</td>
</tr>
<tr>
<td>Vertically Integrated Supplier</td>
<td>Supplier builds both automotive components &amp; underlying silicon/SoC</td>
</tr>
<tr>
<td>Software Engineering Services</td>
<td>Contract development &amp; engineering resources</td>
</tr>
<tr>
<td>Software Products &amp; Platforms</td>
<td>Non-differentiating software that accelerates time to market</td>
</tr>
</tbody>
</table>
Supply Chain Tier 1s

Bosch is well-positioned as full-stack SDV technology supplier

Key Messages

Bosch is a titan in the race for the software-defined vehicle, offering both products and services in the vehicle and in the cloud to enable development & integration of new E/E and software.

While Bosch offers a wide variety of automotive solutions, its strategic direction is clearly aligned to CASE and SDV, as evidenced by the consolidation of its 17,000 in-vehicle software and platform experts into its Cross-Domain Computing Solutions organization.

News & Insights

Headline | Insight
--- | ---
Bosch/Microsoft SDV Platform | Bosch’s integration of its OTA & in-vehicle software solutions with Microsoft’s suite of Azure development, hosting, and deployment tools foreshadows the future of software deployment for SDVs.

Bosch wins orders worth billions for vehicle computers | Bosch is establishing itself as a leader in software-defined vehicle computing technology through multiple orders for billions of euros worth of vehicle computers which underscores Bosch’s vertically integrated SDV value proposition to OEMs.

Strategic Direction

<table>
<thead>
<tr>
<th>Products &amp; Services</th>
<th>Technology Domains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud SaaS</td>
<td>Infotainment &amp; Connectivity</td>
</tr>
<tr>
<td>IoT Cloud offers cross-vertical device management services; plus partnership with Microsoft</td>
<td>Bosch offers full-stack infotainment &amp; connectivity hardware &amp; software solutions</td>
</tr>
<tr>
<td>System Integration</td>
<td>Autonomous Driving</td>
</tr>
<tr>
<td>The foundation of Bosch’s overall automotive footprint &amp; offering</td>
<td>Extensive components, platforms, and investments for AV/ADAS</td>
</tr>
<tr>
<td>Development Tools</td>
<td>Shared Mobility</td>
</tr>
<tr>
<td>ETAS, Escrypt, and Bosch all offer a fragmented portfolio of tools, but not specifically SDV-oriented</td>
<td>Bosch Connected Mobility offers some Maas-centric solutions, but not core focus</td>
</tr>
<tr>
<td>In-Vehicle Software Products</td>
<td>Electrification</td>
</tr>
<tr>
<td>Bosch’s portfolio is less product-centric, but some AUTOSAR-related products</td>
<td>Bosch provides solutions in all powertrain sectors, as well as BEV drive systems</td>
</tr>
<tr>
<td>Component Manufacturing</td>
<td>Non-Software Domains</td>
</tr>
<tr>
<td>Offered for all major software-driven components, including digital cockpit, HPCs and E/E, zonal controllers, ADAS, etc.</td>
<td>Bosch offers a wide variety of vehicle components throughout almost every domain in the vehicle</td>
</tr>
</tbody>
</table>

SDV Strengths & Weaknesses

**Strengths**

- **Consolidated Organization** – Mirroring its customers, Bosch has consolidated its in-vehicle computing and software expertise into a single organization – Cross-Domain Computing Solutions – which gives Bosch a global, scalable organizational platform from which to build SDV-oriented products and services.

- **Embedded Security** – Bosch’s key software subsidiaries (ETAS and Escrypt) offer an embedded development and cybersecurity pedigree that enhances the Bosch’s credibility in providing “automotive-grade” SDV-oriented services.

**Weaknesses**

- **Automotive Insider** – Bosch is a stalwart of the automotive industry, but this can work against them in the SDV domain, where many OEMs are looking to the semiconductor and consumer electronics industries to help modernize and accelerate their processes and platforms.

- **Too Big?** – Bosch’s significant engineering footprint and experience define its SDV value proposition, but this can also lead to a more expensive portfolio of products and services which may not be as competitive as modular, “slimmer” solutions from specialists.

---

Bosch is a stalwart of the automotive industry, but this can work against them in the SDV domain, where many OEMs are looking to the semiconductor and consumer electronics industries to help modernize and accelerate their processes and platforms.

Too Big? – Bosch’s significant engineering footprint and experience define its SDV value proposition, but this can also lead to a more expensive portfolio of products and services which may not be as competitive as modular, “slimmer” solutions from specialists.

---
### Key Messages

- AUTOSAR is a long-standing industry alliance focused on the development of open standards for ECUs and in-vehicle software applications, from which suppliers can develop software which implements the standard, and OEMs (or suppliers) can develop application software which is guaranteed to run on AUTOSAR-compliant solutions.

- AUTOSAR Classic is a full RTOS specification for microcontroller ECUs, while AUTOSAR’s other main output – Adaptive Platform – is a novel application middleware standard intended for high-performance computers.

### News & Insights

**Headline**

AUTOSAR release R20-11 published

**Insight**

AUTOSAR continues to iterate on both Classic and Adaptive standards to ensure viability in modern vehicle software architectures. Adaptive is still relatively young but sufficiently mature for usage in production.

### Members/Contributors

**Core Partners**

- **BOSCH**
- **DAIMLER**
- **TOYOTA**
- **Porsche**
- **Continental**

**Strategic Partners**

- **FORD**
- **NISSAN**

**Premium Partners**

- **60 companies**, including Aptiv, BlackBerry, Baidu, Honda, Hyundai and others

**Development Partners**

- **59 companies**, including TTTech, OpenSynergy, Excelfore, Airbiquity and others

**Associate Partners**

- **147 companies**, including other OEMs, suppliers and service providers

### Organization Type

**Output(s)**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classic Platform</td>
<td>Standard</td>
<td>Standard for Classic, including basic software (BSW) and runtime environment (RTE)</td>
</tr>
<tr>
<td>Adaptive Platform</td>
<td>Standard</td>
<td>Standard for implementing the Adaptive Runtime for Applications (ARA), which contains a variety of components for managing embedded software applications</td>
</tr>
<tr>
<td>Foundation</td>
<td>Standard</td>
<td>Standard for shared components between Classic and Adaptive to ensure interoperability between the platforms</td>
</tr>
<tr>
<td>Acceptance Tests for</td>
<td>Specification</td>
<td>Specification of tests which verify compliance with AUTOSAR Classic standards</td>
</tr>
<tr>
<td>Classic Platform</td>
<td>Specification</td>
<td>Specification of domain-specific interfaces i.e. powertrain, body and comfort, chassis, etc.</td>
</tr>
</tbody>
</table>

### Maturity

- **Exploratory**
- **Incubation**
- **First Output**
- **Limited Adoption**
- **Widespread Adoption**

### Strengths

- **Uniqueness:** Adaptive platform is not only first-to-market for a much-needed capability, it is also the most mature solution, enjoying implementation by many suppliers & OEMs.

- **Heritage:** AUTOSAR Classic is nearly ubiquitous in traditional ECU development; this builds the support framework & credibility of Adaptive, with many of the OEMs who would need such a solution already supporting the Alliance.

### Weaknesses

- **Emerging Applications:** The industry is still working out the best way to implement hardware abstraction in HPCs, and Adaptive may not end up failing to meet many OEM requirements.

- **Cloud Integration:** Adaptive platform supports connectivity, but there is no specific standard or platform for holistic management of software and configuration – a key area of R&D for cloud vendors, OTA solution providers, and OEMs.
Request the price
Do you have any questions?

If you have any questions or feedback about this research report or SBD Automotive’s consulting services, you can email us at info@sbdautomotive.com or discuss with your local account manager below.

info@sbdautomotive.com