WE DEFINE
FUTURE IMPACT

P3: SW Defined Vehicles

Edition #1/2025

We analyze the global Software-defined Vehicle supply chain across three major market segments.

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What you can expect:

1	P3 & P3 SDV
2	Our Understanding of SDV
3	SDV Value Chain
4	Key Takeaways

P3 & P3 SDV.

Short Introduction

Portfolio as unusual.

SOFTWARE

- Android Automotive
- Business Intelligence
- Cloud Migration
- Cyber Security
- Data Analytics
- Enterprise Solutions
- Financial Systems
- IT-Architecture
- Certifications

TECHNOLOGY

- **Autonomous Driving & SDV**
- Battery Technology
- Electric Powertrain
- Energy Solutions
- Industrialization
- Charging Infrastructure
- Operations Excellence
- Task Force Management
- Testing & Engineering

CONSULTING

- Agile Transformation
- Artificial Intelligence
- M&A Strategy
- Marketing & Design
- Sustainability
- Project Management
- "Organizational Strategy"
- Quality & Compliance
- Systems Engineering
- UX/UI Design
- Transformation

Answers First: P3 insights on how to become a SDV organization

A SW-defined **STRATEGY**

INDUSTRY CHALLENGES

- OEMs need to have **architectural lead & control of the SDV stack**, but **not full inhouse** coverage
- Core competencies to be bound to **crucial control points in architecture/system design** & **quality control**

STEPS TO TAKE

- Analyze **market and tech trends** to create future positioning strategy (core / non-core)
- Define target picture and user-centric development strategy. **Start with PoC (dedicated team)** and finalize tech strategy dependent on results

B SW-defined **TECH CONSULTING**

INDUSTRY CHALLENGES

- Platform and architecture setup needs to **enable partnerships / switch of suppliers** (agnosticity)
- **Globally unified stack not possible** due to regulatory requirements (e.g., CN & US). Adapt with **local partners**
- **Modularity of SW components** is key to achieve higher efficiency

STEPS TO TAKE

- Establish SW-centric approach by making **functions the key driver** for HW decisions.
- Define **procurement strategy** (incl. make or buy) for SW departments to leverage tech player speed / open-source community and focus on core competences
- Analyze and aggregate technical **interfaces** to build-up SW supplier portfolio

C **SOFTWARE DEVELOPMENT**

INDUSTRY CHALLENGES

- **SW architecture** needs to be **modularized/containerized** using interface orientation (APIs)
- SW quality assurance cycle take too long today

STEPS TO TAKE

- **Implement more KPI driven SW dev.** to increase quality and speed incl. whole supply chain
- Establish **SW-centric release processes** independent to model releases
- Create **re-usable SW**, leveraging own contributions as well as open-source community

EXTRACT

Overview | P3's SDV portfolio

A SW defined **Strategy**

SDV due diligence
P3 conducts technical due diligence for international investors, Tier 1 supplier and OEMs

Market insights
P3 has deep **market understanding** and **insights generated through benchmarking** experience

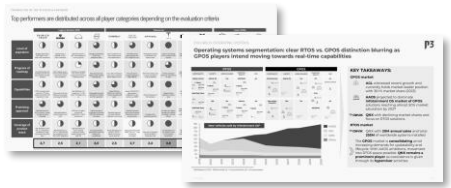
Supplier / JV / partnership selection
P3 provides specific solutions for partnering based on strong experience of all SDV layers

B SW defined **Tech Consulting**

SDV Architecture
P3 contributes its own development, research & consulting experience to design E2E SDV Architectures

SW-defined Org and process development
P3 development and organizational review and set-up according to SDV processes

Tech Roadmaps
P3 analyzes all relevant tech trends and roadmaps across the relevant SDV layers (e.g., OS, SoC, etc.)



C **Software Development**

Android Automotive
P3 has developed its own SPARQ OS IVI platform that builds on Android automotive OS

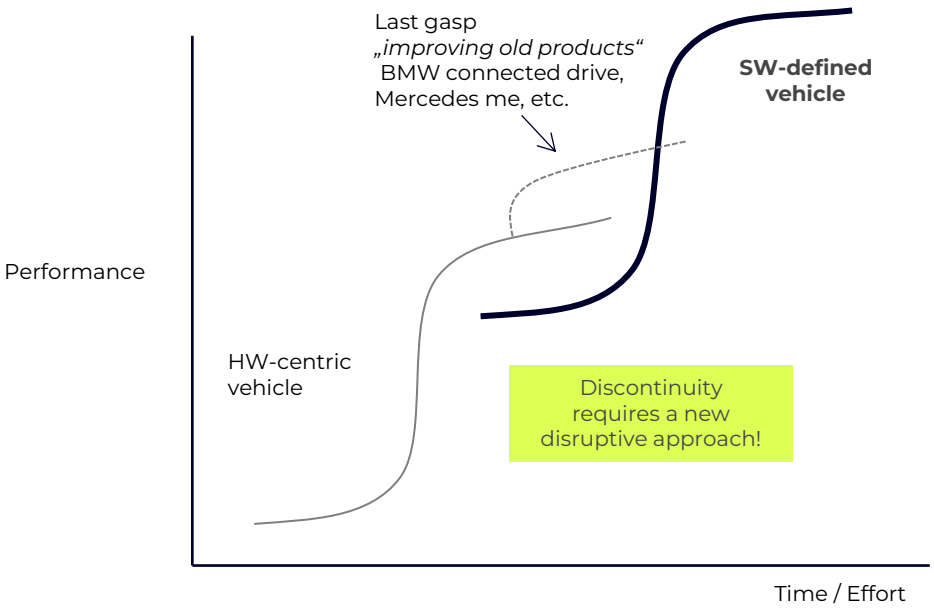
Google cTS certification & SW compliance
P3 is selected by Google as one of few accredited Android Automotive certification partners

Technical project management
P3 supports Technical PM, Interim mgmt, Task force mgmt to FuSa/CS

P3 Understanding of SDV.

Further increase in performance requires disruptive switch to next S-curve of a SW-defined vehicle

SW-defined vehicles as disruptive new S-curve



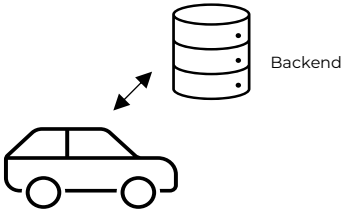
1. The transformation is disruptive because **new SW-driven platforms provide**:
   - **New user experience game** - new services and features
   - **New level of scalability** – same HW platforms with variances in SW
   - **Simplified organization** based on common SW stack (faster development cycles)

2. Performance of existing **HW-centric approaches is exhausted**:
   - **Digital experience does not keep up** with smartphone or is trailing
   - **Further optimization is not feasible**, complexity and cost not manageable

Achieving the vision of a SW-defined vehicle requires different technical enablers to be covered

Today

Connected vehicle



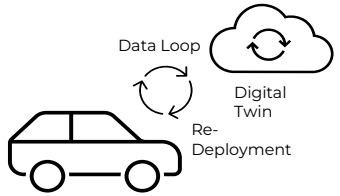
Updates
- Quarterly
- OTA/OBD

Functions (examples)
- Send destination to vehicle
- Lock-Unlock doors
- Spotify integration

Cloud enabled services	Onboard oriented services w/ some connected features via telematics devices	Fully cloud enabled features and on-edge processing
Middle-ware	Static definitions between apps and HW interfaces via CAN/LIN/FLEXRAY	Standardized Ethernet (Dynamic service abstraction)
Operating System	Specialized and toolchain-driven OS software	Hypervisor oriented architecture with universal OS
EE Arch.	Distributed gateway-oriented architecture	Full Abstraction of HW and centralized layout

Future

SW-defined vehicle



Updates
- Daily
- OTA

Functions (examples)
- Distributed computing
- Shadow mode
- Learning HMI

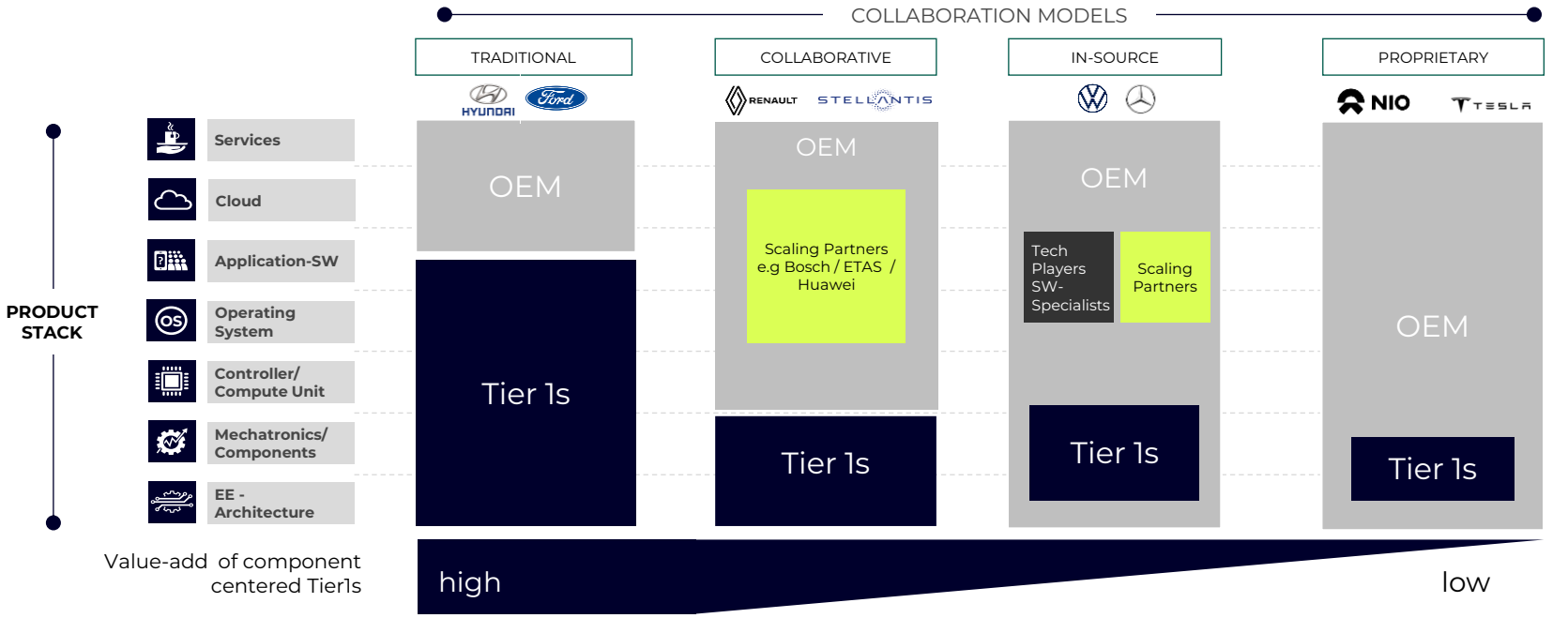
technical & organizational complexity
#competitive pressure from new entrants into the truck market
#customer expectations regarding updates, functionalities and open interfaces

Major players are already established for different layers of the Software-defined vehicle stack and drive their respective progress

EXTRACT

PRODUCT STACK			DRIVERS	MAJOR PLAYER
Cloud-enabled services	Services	Features and services delivered to the customers	Integration of 3rd party Services, but also OEM defined App Stores or based on GAS or Apptoid appstores	Google, amazon, CARIAD, MBITION, ASAPHUS VISION
Cloud-enabled services	Cloud	Extension of physical vehicle to enable further functionalities	Cloud becomes integral part of future Car SW-platform, most future services enabled by off board processing	Azure, aws, Google Cloud
SW-driven layer	Application-SW	SW modules for specific functionalities	SW modules from best-in class players with high compatibility to dominate OS	Google, MBITION, CARIAD, amazon
SW-driven layer	Operating System	Operating systems incl. middleware	Few dominant operating systems with strong abstraction of HW and open-source approaches	Linux, android, RTOS, QNX
Component layer	Controller/ Compute Unit	ECUs and other integrated compute units incl. firmware	Concentration of ECUs to fewer and powerful domain / zonal controllers with strong abstraction between HW/ SW	Qualcomm, Continental, HARMAN, LG, NVIDIA
Component layer	Mechatronics & Components	Components with mechanical and electronic functions	Components will be unbundled of their SW content and are becoming degraded to simpler mechatronic I/O devices	Valeo, SMP, LEONI, Continental, Yanfeng
Design Layer	EE - Architecture	Logical layout and architecture	Further unification of EE-Architectures, e.g., move to domain-based designs and zonalization expected	BOSCH, APTIV, Continental

Fast movers trend to become less dependent on traditional Tier1 cooperation to gain control of SW stack



- Focusing strongly on Tier1 for SW Stack
- OEM focus on cloud and service solutions
- Highly dependent on Tier1s

- Using Scaling partners like Bosch / ETAS / Huawei to cover Cloud / SW layers
- Less depend on Tier1 but on scaling partners

- Trying holistic approach to the stack: no proof of concept yet
- Focus on complete integration from service to HW (plan for own ECU designs etc.)

- Tesla with highest level of vertical integration (strong control of SW and product stack)
- Using replaceable HW suppliers for defined components with low embedded SW content

SDV.Value Chain Analysis.

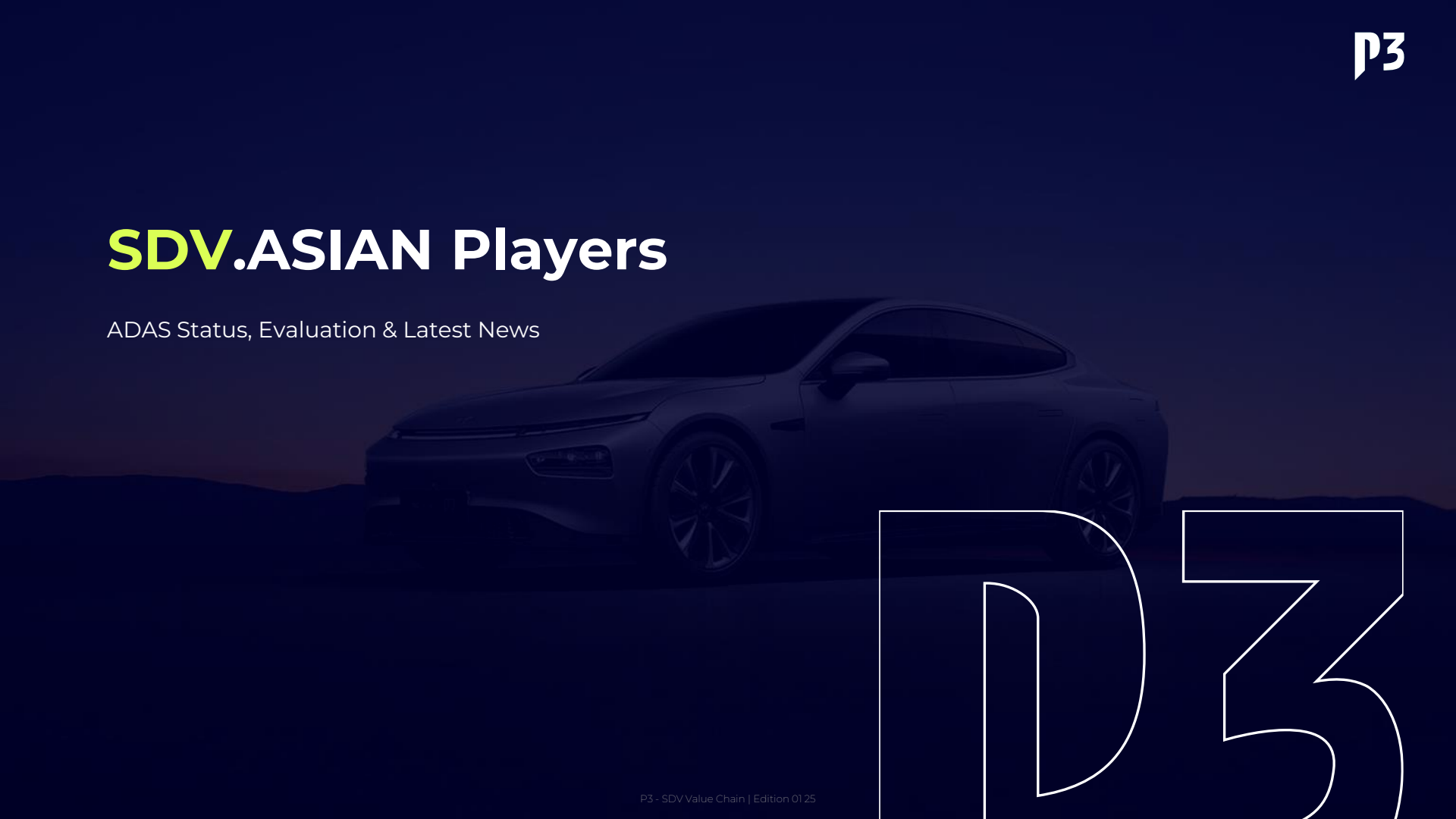
The P3 Software defined vehicle stack approach for each analyzed SDV player consists of Cloud-enabled services, a SW-driven layer and a Component layer

PRODUCT STACK	LAYER MODEL		PRODUCT / SOLUTION / FUNCTION
Cloud-enabled services		**Services**	Value added (paid) services delivered on the platform individually to the user (e.g., fleet mgmt. system). All services regarding the eco-system around the vehicle and related (e.g., parking, charging, toll services, health).	**Car-related (OEM)**: Remote charging, Remote door opening, Remote conditioning, Seat heating (FoD), Rear-axle steering (FoD) **IVI-related (3rd party)**: Intelligent Charging, Spotify / Youtube/ etc. …
		**Cloud**	Cloud systems as enabler for service layer and all functionalities executed in the cloud. Not safety or real-time critical.	**IVI** (e.g., routing), OTA-Updates, Fleet monitoring, Predictive maintenance
SW-driven layer		**Application-SW**	Implementation of vehicle functionalities running on top of an OS / platform (e.g., ADAS, motion, energy and charging and passenger experience).	e.g., **ADAS-related SW like ACC, ALKS** / planning functionalities, trajectory planning, safety functions, drivetrain control
		**Middleware**	"Middleware" as an abstraction layer of the OS with communication protocol mechanism running on controllers or on main computing devices (e.g., infotainment system) and allow communication between application SW and different OS'.	**Protocols**: e.g., MQTT, DDS (publish-subscribe), SOME/IP **Platforms**: e.g., Autosar, ROS/ ROS2
		**Operating system**	Connecting application data with the underlying more hardware-related interfaces and providing a unified platform to develop hardware-independent applications.	**OS & Hypervisors like** : RTOS (QNX, ROS, ROS2), GPOS (Linux and its derivates), QNX Hypervisor, Wind River Helix, Green Hills INTEGRITY Multivisor
Component layer		**Controller/ Compute Unit**	The computing part of a mechatronics component incl. the main controller, SoC, peripherals and respective firmware which provides the processing power for the software or any decision logic.	**System on chip** (e.g. Nvidia Orin/Thor, Qualcomm 8155/8295) that are the core of **high-performance computes** executing SW functions.

On the following slides for each analyzed market, the focus will be on **layers for cloud-enabled services, SW-driven components and hardware components like SoC and ECUs**. The layers for **mechatronics, further hardware components as well as for E/E-architecture** are neglected due to major hardware-related focus.

SDV.ASIAN Players

ADAS Status, Evaluation & Latest News



SDV Value Chain | ASIA

	Component	Software-driven Layer					Cloud-enabled Services	
	Compute incl. SOC	Operating System	Middleware	Application SW: ADAS	Application SW: Energy	Application SW: IVI	Cloud	Services
Li Auto	Horizon Robotics ● NVIDIA ● Li Auto	Li Auto	创景科技 ● Li Auto	Li Auto QCRAFT ●			Baidu 百度 ● amazon ● ByteDance 字节跳动 ●	honor ●
	tenstorrent ● Opsys ● NVIDIA ● bos ●	HYUNDAI MOBIS ●	HYUNDAI MOBIS ● 42dot ● SONATUS ●	here ● HYUNDAI MOBIS ● 42dot ●		tomtom ●	aws ● VMware Tanzu ● WNDRVR Studio ●	amazon ● SAMSUNG ●
TOYOTA	DENSO ● Panasonic ● NVIDIA ●	Renovo SYSTEMS ●	xevo ● woven by TOYOTA ●	woven by TOYOTA ●	prime planet energy & solutions ● woven by TOYOTA ●	Google Cloud ●	Google Cloud ●	aws ●

OEM ● Partnership or supplier deal ● Investment ● Acquisition ● Parent / Subsidiary ◆ Update ( ) Application of GenAI, ML/DL

SDV Value Chain | ASIA

	Component	Software-driven Layer					Cloud-enabled Services	
	Compute incl. SOC	Operating System	Middleware	Application SW			Cloud	Services
				ADAS	Energy	IVI		
NIO	NVIDIA ● QUALCOMM ● BLACK SESAME TECHNOLOGIES HUIXI ● NIO In-house SOC in development	NIO BlackBerry QNX ●		NVIDIA ● NIO	CATL ●	HARMAN ●	Tencent Cloud ●	Microsoft ● Baidu 百度 ●
Xiaomi	辉羲智能 RHINO ● NVIDIA ● BLACK SESAME TECHNOLOGIES ● QUALCOMM ●			NVIDIA ● Xiaomi	CATL ● FinDreams Battery ●		金山云 ●	INOVANCE Automotive ●
XPENG	NVIDIA ● QUALCOMM ● BLACK SESAME TECHNOLOGIES ● XPENG In-house SOC in development	XPENG		XPENG		Alibaba ● XPENG ●	Alibaba ●	

OEM ● Partnership or supplier deal ● Investment ● Acquisition ● Parent / Subsidiary ◆ Update [ ] Application of GenAI, ML/DL

SDV ASIA

P3 Evaluation

Li Auto has been progressively **investing towards SDV centralized E/E architecture and advancing autonomous driving capabilities**, positioning itself to **compete with both domestic and international EV companies by relying on in-house development**. In addition, Li Auto's software development strategy includes a focus on continuous over-the-air (OTA) updates, making it more adaptable to SDV standards. Li Auto announced that it **started in-house design** and **development** of SoC.

Hyundai Motor Group invested significantly in 42dot in 2023, aiming to make it the centerpiece of its SDV development. Additionally, Hyundai formed a **partnership with Samsung** to introduce **high-performance computing chips** for vehicles starting in 2025. Altogether, these steps reflect Hyundai Group's efforts to accelerate its competitive edge in the market.

Toyota is advancing its SDV capabilities with the **Arene platform, developed by Woven Planet**, to support **over-the-air updates, connectivity, and autonomous driving features**. Additionally, Toyota's Mobility Services Platform integrates vehicle connectivity with external services, positioning it for future applications in autonomous shuttles and robotaxis.

Latest **news**

Li Auto brings **HD map-free NOA feature** in latest software update.

(15.07.2024)

Hyundai and GM signed **Memorandum of Understanding** to explore collaboration on vehicles, supply Chain and Clean-Energy Technologies

(12.09.2024)

Toyota announced at CES 2025 that its **next-generation vehicles** will incorporate chips from **NVIDIA (Drive AGX Orin) with respective operating system DriveOS** to enhance automated driving capabilities.

(06.01.2025)

SDV ASIA

P3 Evaluation

Nio is working on a **centralized E/E architecture**, with a **clear focus on in-house development** for most of its vehicle systems. Where capabilities are missing, in-house development is complemented by partnerships with best-in-class suppliers, e.g., SoC strategy: Qualcomm for IVI, Nvidia for ADAS. In addition, NIO announced to start its **in-house design and development** of SoC.

Through Xiaomi's smartphone heritage, **consumer centric and in-house focused development is at the core of their business and software/hardware development strategy**. Xiaomi works towards a **centralized E/E architecture** as other Chinese OEMs. Whilst currently relying on Nvidia and Qualcomm for the ADAS and IVI chipset, investments in Rhino and Black Sesame show willingness to create Chinese focused product alternatives.

Alongside other CN OEMs, Xpeng's value chain is heavily vertically integrated, with even an **in-house designed SoC being currently under development**. Strong focus on implementation of AI-related features within the IVI stack.

Latest news

NIO announced **OTA software update for Smart System Banyan** to enhance user experience regarding charging performance, ADAS functions and infotainment features.

(16.09.2024)

Xiaomi announced to **fix safety hazards for ADAS functions** from its current software version in the SU7 for over 30,000 vehicles via **OTA software update** in China.

(24.01.2025)

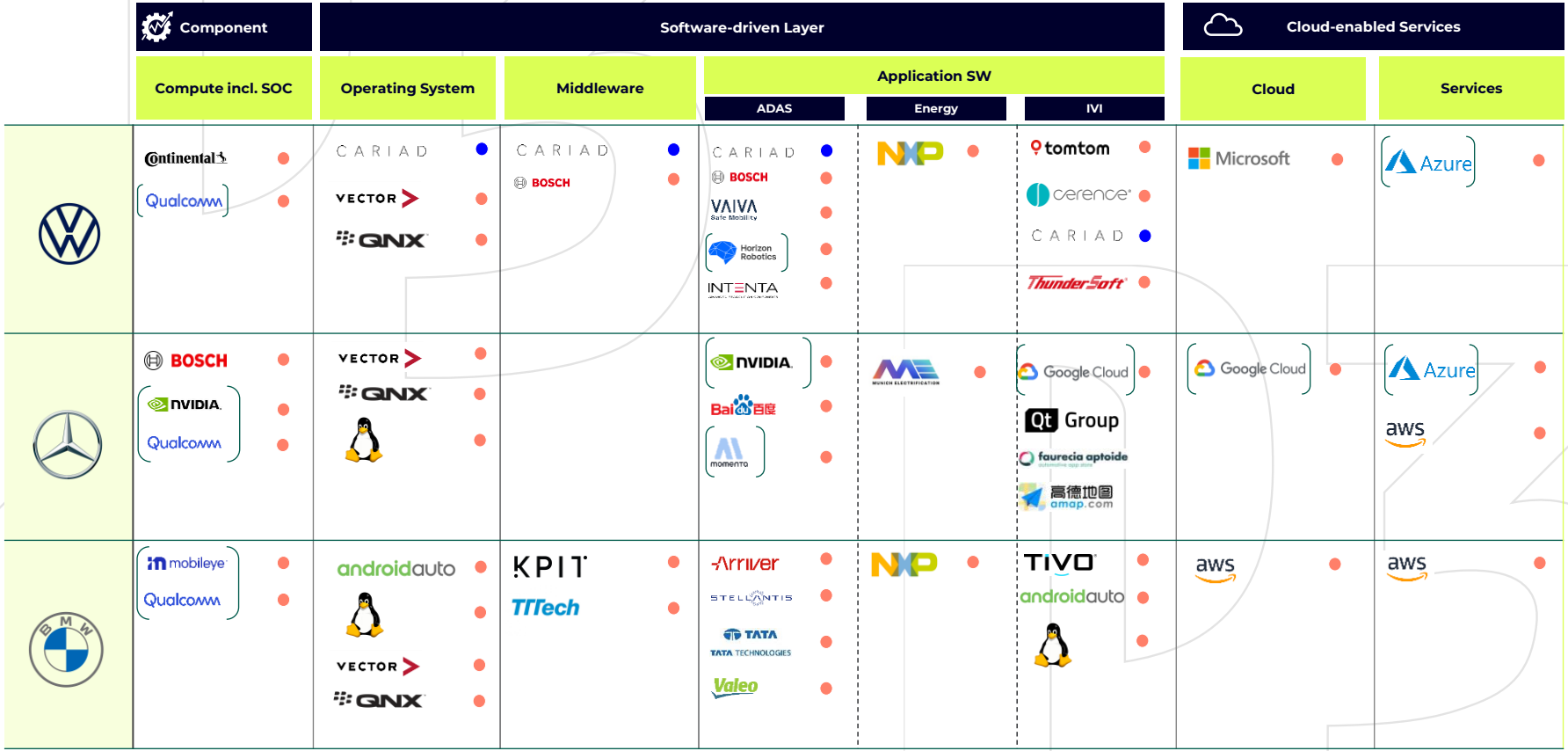
XPENG launched its new AI-defined electric sedan P7+ which is to learn from **individual users' behaviors and preferences**.

(18.10.2024)

SDV.EU Players

ADAS Status, Evaluation & Latest News

SDV Value Chain | EU Players



SDV EU

P3 Evaluation

VW is pursuing a SDV strategy to transform from a traditional HW-centric automaker to a SW-driven mobility provider. However, VW and its designated SW house Cariad is struggling with the transition from conventional vehicles to advanced SW-oriented designs. This is largely due to the OEM's **heritage, culture, and processes** being carried over into Cariad, leaving little room for an **independent setup.**

Mercedes-Benz is positioning itself as an **SDV leader**, **insourcing over 60%** of software and controlling architecture and integration. With the introduction of **self-developed operating system MB.OS in 2025** that enables integration of software and hardware components, **OTA software updates**, enhance **autonomous driving** and further **cloud-based services**. Mercedes-Benz extends the ecosystem around their vehicles with MB.OS.

BMW's two-pronged Software Defined Vehicle (SDV) strategy enhances current models with content services and ADAS features, while the **upcoming 2025 NCAR architecture will provide a flexible, scalable foundation** for future SDVs. This approach balances immediate enhancements with long-term innovation.

Latest **news**

Volkswagen and Rivian launch a **$5.8B joint venture** to develop advanced SW and electronic architectures for next-gen EVs. JV will be Co-led by Wassym Bensaid (Rivian) and Carsten Helbing (VW).

(12.11.2024)

In 2025, Mercedes-Benz will extend its **current infotainment solution MBUX to MB.OS** which represents the next step for digital vehicle architecture.

(27.01.2025)

BMW presented at CES 2025 the new **iDrive head-up display that displays** individually chosen information from the infotainment or ADAS system **across the whole windshield**.

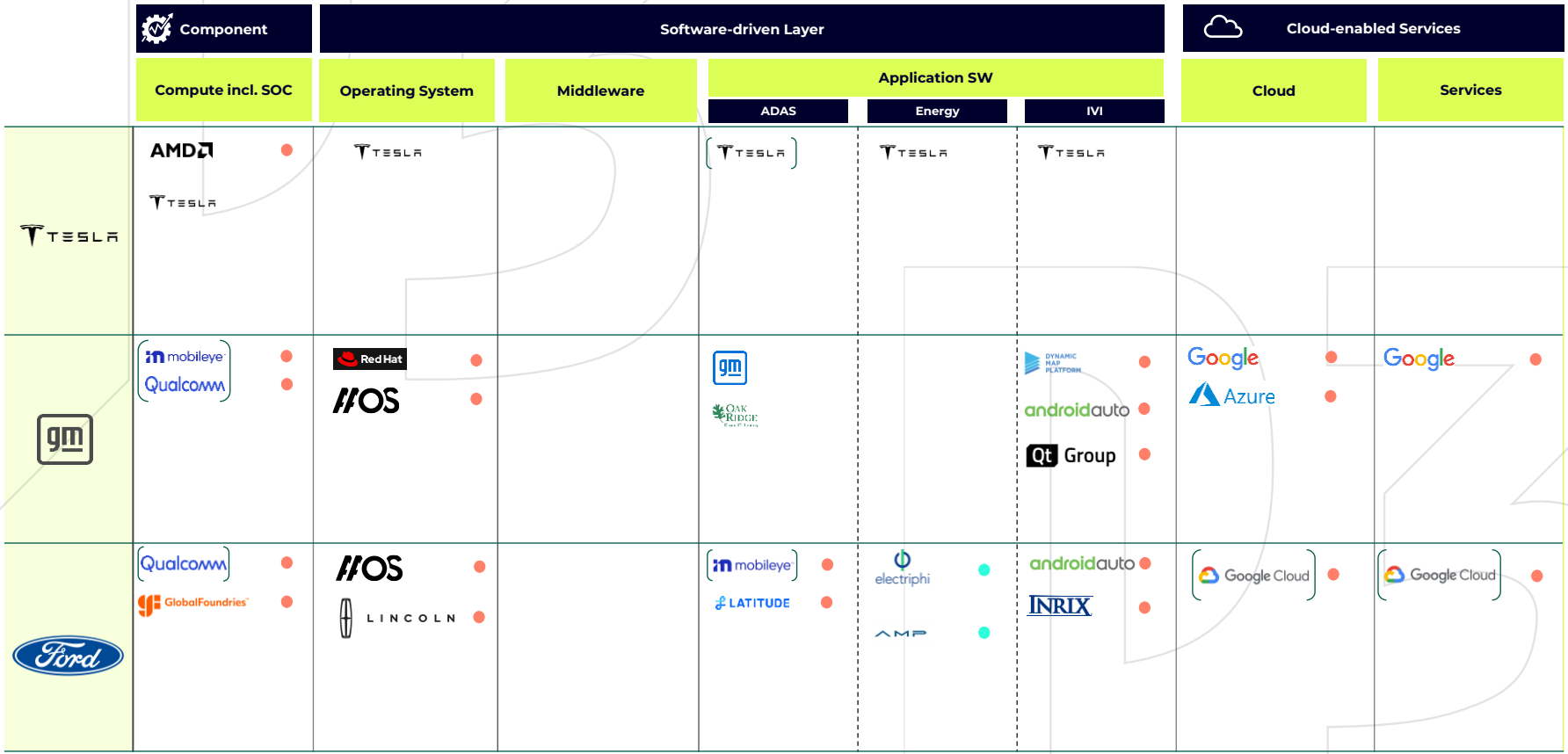
(07.01.2025)

SDV.NAR Players

ADAS Status, Evaluation & Latest News

Source: Tesla

SDV Value Chain | NAR Players



SDV NAR

P3 Evaluation

Tesla employs a vertically integrated strategy, with **extensive in-house value creation** centered on software. It **leads the industry not only in the U.S. but also on a global scale, setting standards across markets**. Notably, Tesla's organizational structure and streamlined processes enable the efficient release of new software updates on existing HW in their vehicle fleet.

GM is building its SDV infrastructure within their **Ultifi** software organization. Its **new E/E vehicle software platform enables frequent OTA updates**, **cloud connectivity**, and **V2X communication**. Ultifi presents a shift from **screen mirroring technologies like CarPlay or Android Auto towards a GM-personalized embedded infotainment system**, that builds upon open-source Android Automotive. Despite a temporary sales halt due to software issues in December 2023, GM is making progress in its efforts towards SDV.

Ford is transitioning to a SDV company by **integrating Android Automotive OS** into its infotainment systems, offering built-in Google services and **OTA updates**. Additionally, its cloud-first approach enables continuous software enhancements, including the rollout of BlueCruise hands-free driving updates and a fully software-updatable vehicle architecture.

Latest news

Tesla launched **new FSD version 13.2.5 for vehicles with HW 4** which enhance the neural network architecture

(05.01.2025)

GM **scales back in-house development** by cutting over 1,000 employees in its Software and Service organization. However, also announced. Simultaneously, GM signed and MoU with Hyundai. (see Hyundai)

(20.08.2024)

In January 2024, Ford unveiled its "Ford and Lincoln Digital Experience," an infotainment platform based on **Android Automotive OS.** This system offers built-in Google services, incl. Google Assistant, Maps, and access to the Play Store.

(22.01.2024)

Key Takeaways.

Summary and assessment

Source: Tesla

For the three observed archetypes, each faces unique challenges as they transition into software-defined organizations delivering software-defined products.

Exemplary models

	1 CURRENT LEGACY GENERATION	2 SDV WITH LEGACY (Transform)	3 FULL SDV (Target picture)
			
EXPERIENCE	• **Fragmented user experience** over different domains (e.g., IVI & ADAS) with **predefined feature set due to limited OTA capabilities**	• Improved customers experience with smoother integration of digital services. Some **feature expansion possible via OTA**	• **Full SDV experience with continuous feature updates,** dynamic **adaptions of vehicle** and **personalization** through AI and cloud-based services
ORGANIZATION	• **OEMs manage medium complexity** as development works on the **existing structures** • **Domain thinking and sequential processes** engrained in HW driven development with long release cycles	• OEMs face **significant complexity** in developing a fully SW-defined vehicle while **simultaneously maintaining and updating legacy systems** • **Ownership not embedded within org. & processes**. E.g., release processes and funding	• **OEM manages medium complexity** as due to **greenfield approach**, e.g., Huawei incorporated IBM–originated IPD approach • Chinese OEMs base **SW development expertise on consumer electronics**
DEVELOPMENT	• **SW follows HW**, embedded also in capability and tooling • Embedded SW with **minimal reusability and abstraction**: function-specific ECUs (1 function - 1 ECU)	• **Function-first approach** adopted; challenges due to unclear responsibilities when functions are **distributed across ECUs** • **Abstraction is introduced** via more standardized, service-oriented Middleware	• **HW follows SW** with cloud-native, microservice-based architecture that enables **updatability and exchangeability** • **HW-agnostic** SW stack with **full virtualization**

Between innovation and crisis: German automakers struggle to maintain leadership in global transformation.

P3 KEY FINDINGS

SDV Market observation

The Chinese market is driving the rapid SDV transformation, setting trends for the rest of the world. “China speed” is fueled by greenfield approaches from new players, but compromises on quality requirements; **varying regulatory regimes hinder global scaling.**

SW houses as the strategy of developing a SDV platform **has not led to success** for many traditional OEMs (see Cariad). **Independency** of SW houses is insufficient, as processes & **financing** are still tightly coupled to new model releases.

Legacy OEMs already reconsider their strategies and forge new alliances, such as **VW's joint venture with Rivian**. **As insourcing SW is not a goal in itself,** developing core **competencies in platform and architecture design** becomes essential to maximize **partnerships potential**.

Nvidia and Qualcomm dominate the ADAS/AD SoC market, **driving and controlling HPC costs.** Meanwhile, (Chinese) Technology OEMs are **developing in-house solutions to reduce reliance on these market leaders**.

Development Approach

Stack approach is **endorsed at management** level but fails to diffuse the organization, as **domain-driven thinking continues to dominate release** processes, keeping the driving experience tightly coupled to hardware.

The centralization of compute infrastructure will **reduce the number of ECUs in vehicles** and **consolidate fragmented OS field**. However, multiple OS (real-time vs non-real-time) will **still co-exist due to differing safety** and **domain requirements**.