SBD Automotive

The Software Defined Vehicle and OSS

OSS as an emerging key enabler to build SDV

AGL members F2F meeting

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About the presenter

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SBD Automotive Mission

Delivering **confidence** through **clarity, insight** and **vision**

Our Areas of Expertise

Connected

Autonomous

Shared

Electric

Secure

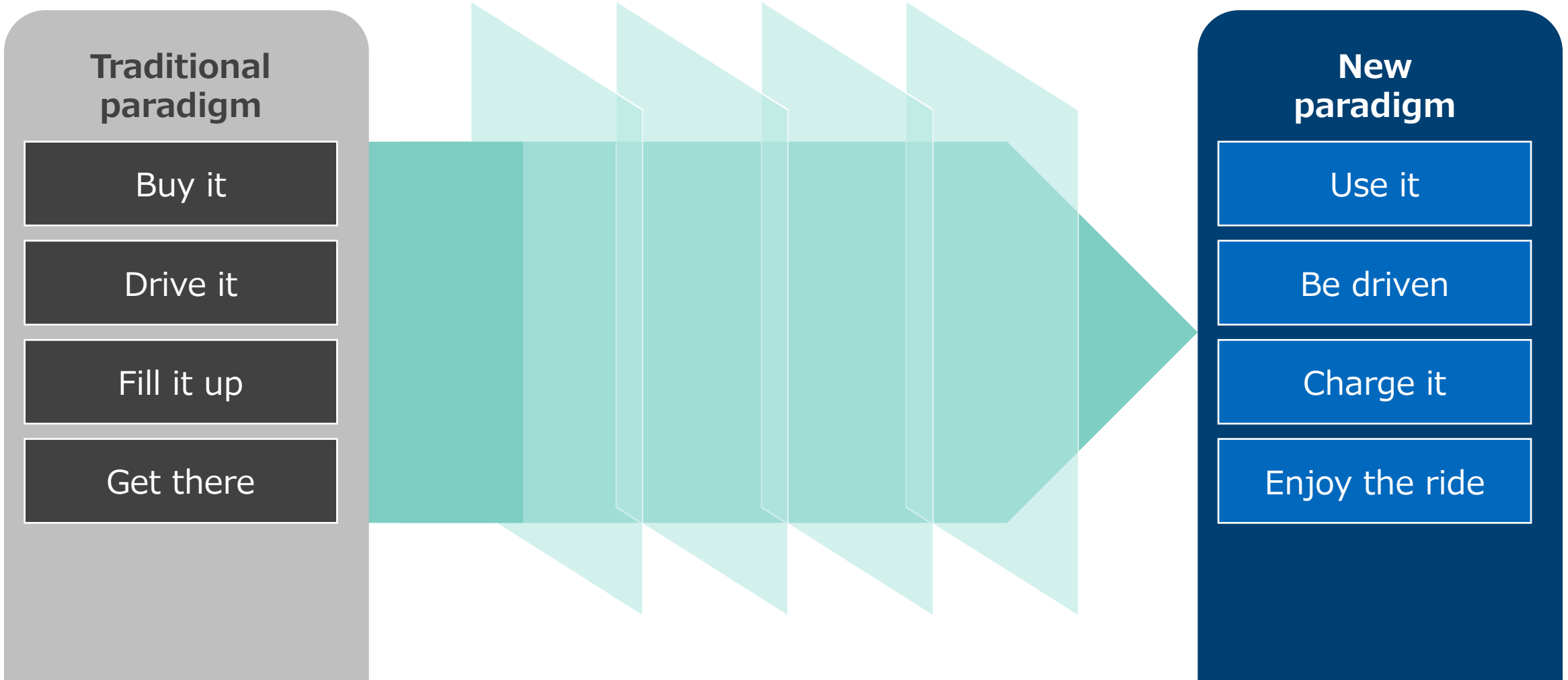
We are experiencing a life-changing mobility paradigm shift

Technology trends
- Sensors
- Connectivity
- Computing

Consumer habits
- Urbanization
- Digitization
- Mobility

New regulations
- Privacy
- Security
- Environmental

Evolving eco-system
- Tech giants
- Start-ups
- Suppliers



With heavy investment in connectivity, autonomy, and EVs

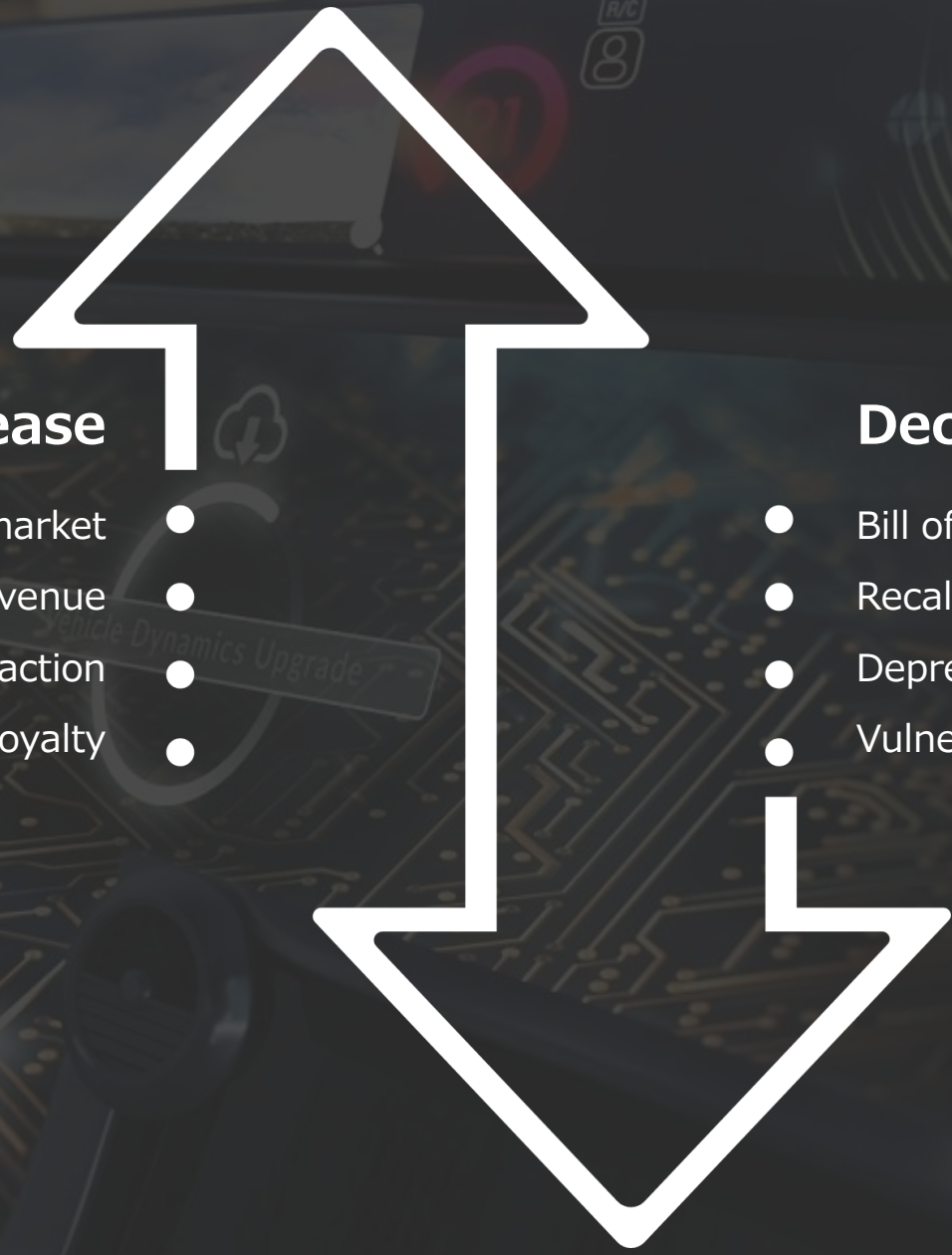
	# of stories	Trending companies	Top themes
C Connected		Apple, Android, BMW, GM, Mercedes-Benz, NIO, Honda	The impact of the tech sector continues to grow as OEMs battle with s/w sourcing decisions
A Autonomous		UNECE, Mercedes-Benz, Tesla, Stellantis	More OEMs announce plans for L3 autonomy just as pressure from regulators/press grows
S Shared		GM, Hyundai, Baidu, Pony.ai, Cruise, Argo AI	Robo-taxi programs transition from testing to operational services
E Electric		Mercedes-Benz, Stellantis, Tesla, Europcar, Audi, VinFast, Marelli, Ford, Volkswagen, Volvo	Demand for EV's outpaces supply as OEMs explore and invest in new business models
S Secure		CarConnectivity Consortium, Hyundai, Lexus, Tesla	More OEMs get involved in the development of the next-generation smartphone key

Legislative changes · M&A · New companies · New partnerships · New strategies · Product improvements · Product launches

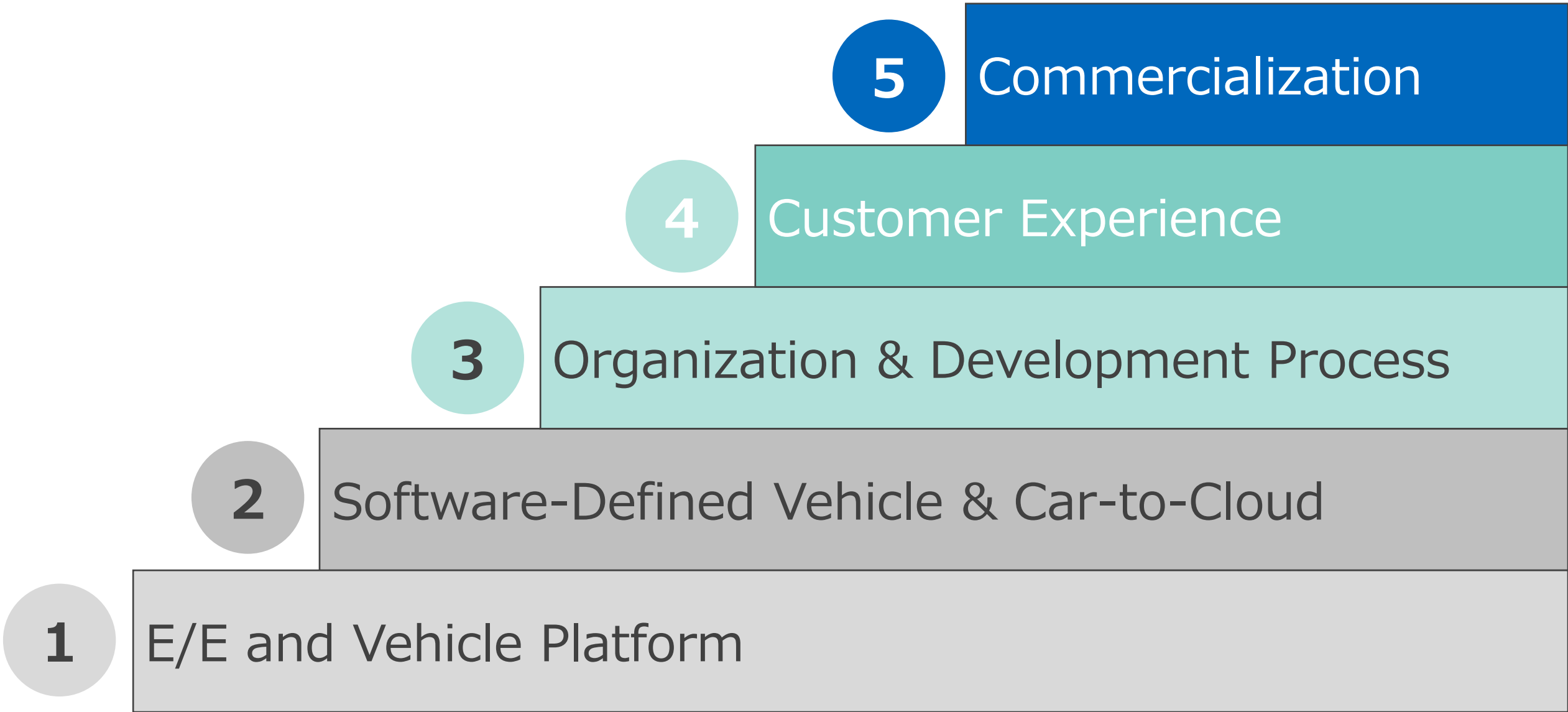
Source: SBD Automotive – Report 220 – Quarterly Wrap-Up (Q2 2022)

Software Defined Vehicles

What’s driving car makers forward?



The software-defined automaker’s hierarchy of needs



Focus today:


5
Commercialization
4
Customer Experience
3
Organization & Development Process
2
Software-Defined Vehicle & Car-to-Cloud
1
E/E and Vehicle Platform

What is Software Defined Vehicle?

Defining the software-defined vehicle

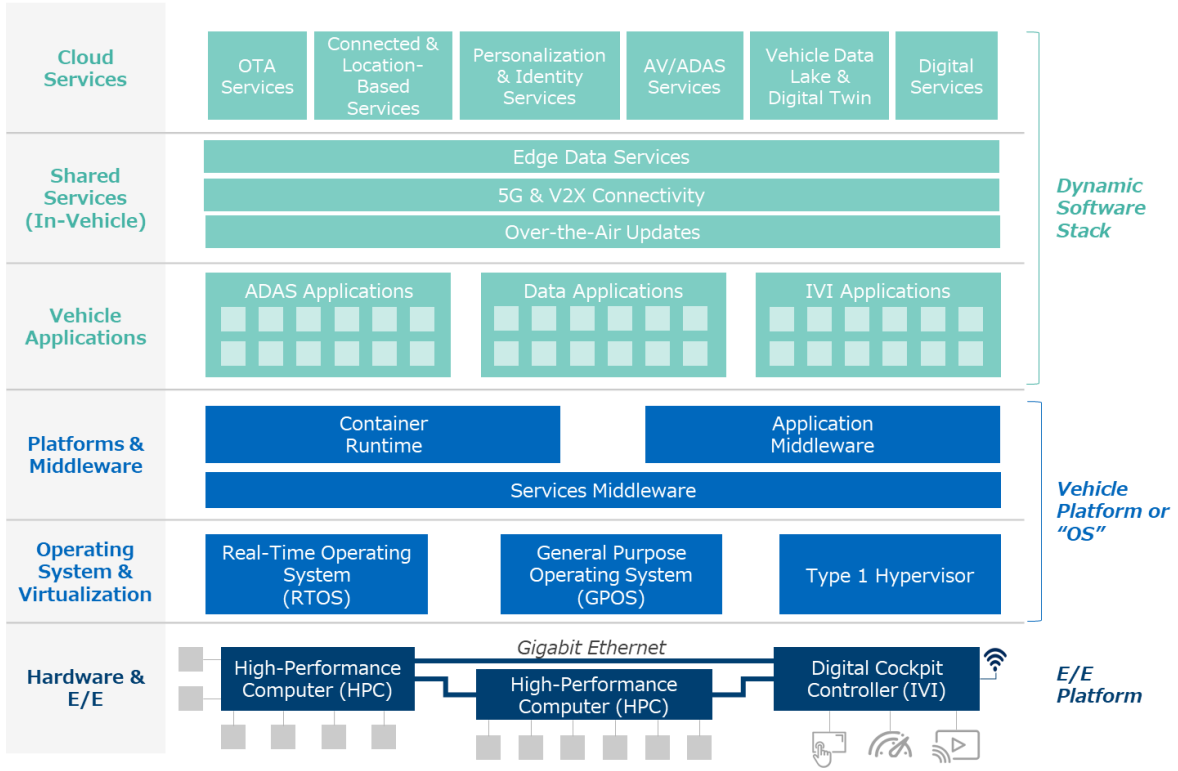
1. SDVs allow software to be **designed, developed and tested in a fully virtualized environment**, leveraging the scale of cloud services to simulate vehicle software

2. SDVs require **multiple layers of hardware and software across different domains** in order to implement this separation

3. SDVs allow OEMs to **dynamically implement new business models & customer experiences** much faster than before

4. SDVs create **significant disruption** in the traditional automotive electronics supply chain while creating **new "blue oceans"**

5. Much of the core SDV software stack is non-differentiating, making **standards & open-source software** attractive to OEMs



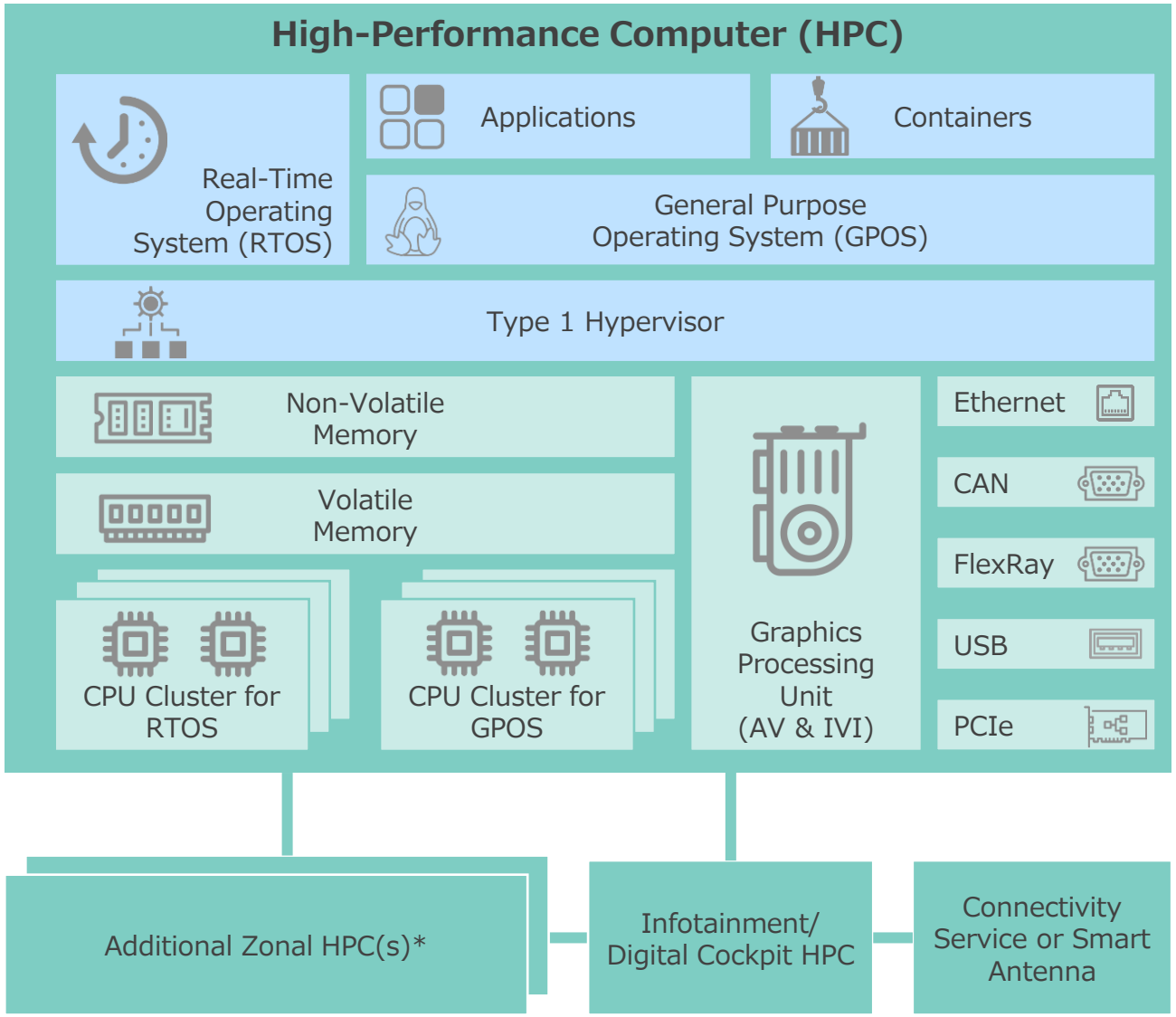
Source: SBD Automotive // The Software-Defined Vehicle (2021)

Vehicle 4.0: The evolution of the software-defined vehicle

Common evolution path for OEMs

	Definition	Characteristics	Technologies/Enablers
Vehicle 1.0 *Functional*	**Features developed & implemented in conjunction with underlying hardware**	No over-the-air updates	Microcontroller ECUs
		Tightly coupled ECUs	Real-time operating systems
		Basic infotainment services	CAN-based architecture
Vehicle 2.0 *Digital*	**Enhanced infotainment domain with apps, connectivity, and limited updateability**	Embedded or brought-in infotainment applications	Embedded 4G connectivity
		Limited software updates for infotainment	Cloud platform for content, services
		Limited driver personalization	Driver identity provider
Vehicle 3.0 *Updateable*	**Core domains (ADAS, digital cockpit, connectivity) implement abstracted software runtime & middleware**	Regular software updates for core functional domains	Ethernet E/E backbone
		Dynamic HMI for vehicle functions (voice, multiple screens, etc.)	Domain-based middleware
		OEM and/or 3rd party software applications	OEM-managed software development
Vehicle 4.0 *Software-Defined*	**Computing workloads can be dynamically shifted between vehicle computers & offboard infrastructure**	Redundant application processing across domains/zones	5G connectivity
		Continuous software delivery	Edge application runtime (i.e. edge containers)
		Dynamic data processing between vehicle, edge, & cloud	Homogenous computing platform between vehicle & cloud

High Performance Computer is a foundation for H/W abstraction



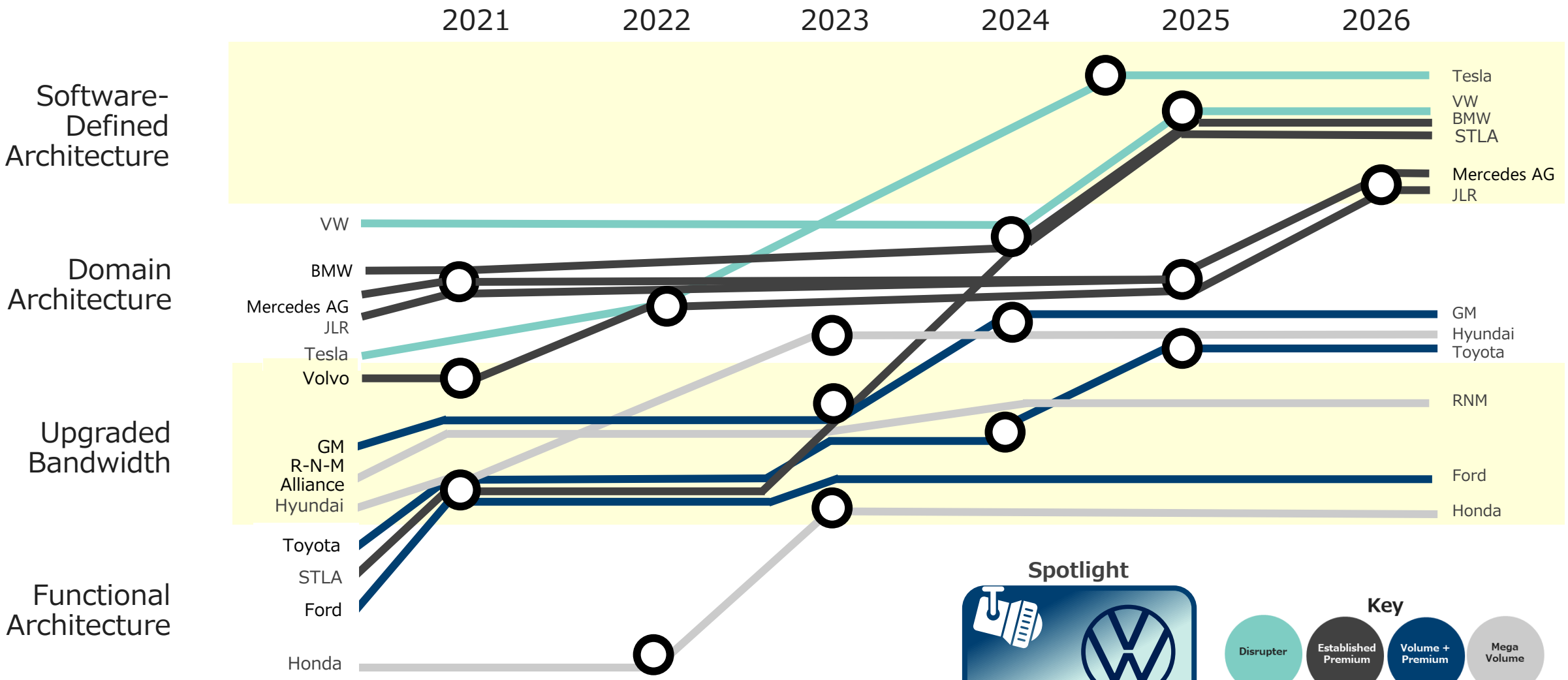
* In zonally configured E/E architectures

- **Applications & containers leverage services on the GPOS**
- **Simultaneous execution of real-time and general purpose operating systems** using CPU clusters
- **Type 1 hypervisor provides hardware-optimized virtualization services**

- **HPCs provide a variety of physical interfaces**
- **GPUs power the processing of camera & radar data** for ADAS/AV, and **rendering for digital cockpit** interfaces.
- **CPU clusters ensure redundant processing** for both RTOS and GPOS applications
- Multiple HPCs to provide **high availability, optimized, redundant AV services and digital cockpit application**

SDV needs overhaul in EE architecture as well as S/W structure

Vehicle platform engineering projects will take many years to reach maturity, scale within car parc

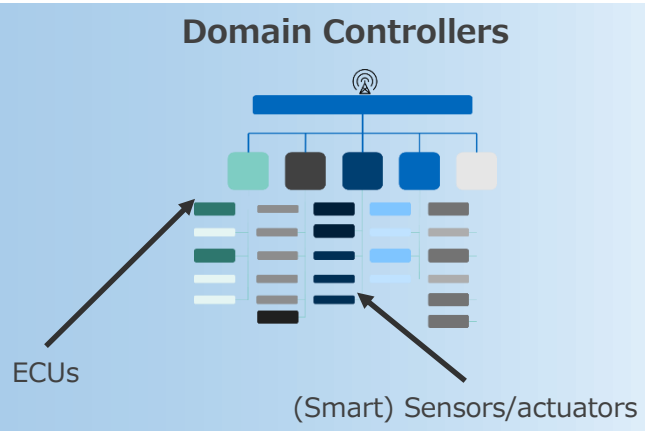


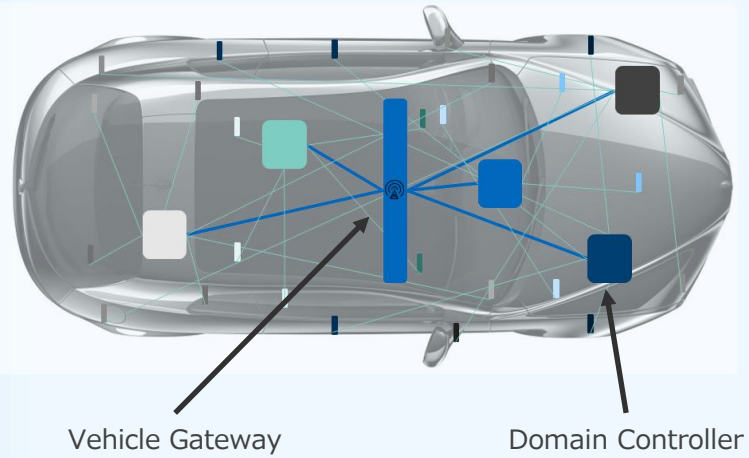
Source: SBD Automotive – Report 630 - *Evolution and technology drivers for next generation E/E-architectures*

SDV will be achieved on a centralized zonal EE architecture

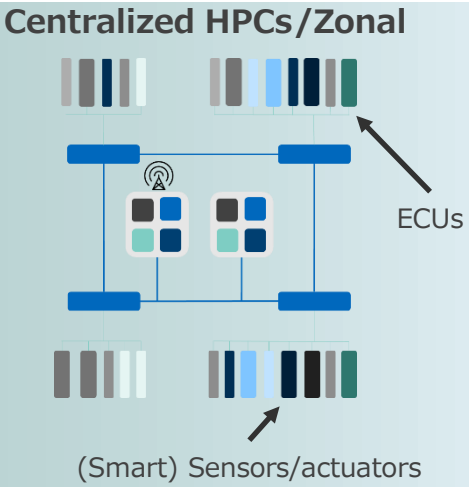
SoC scalability will drive consolidation and abstraction, enabling entry points for edge computing

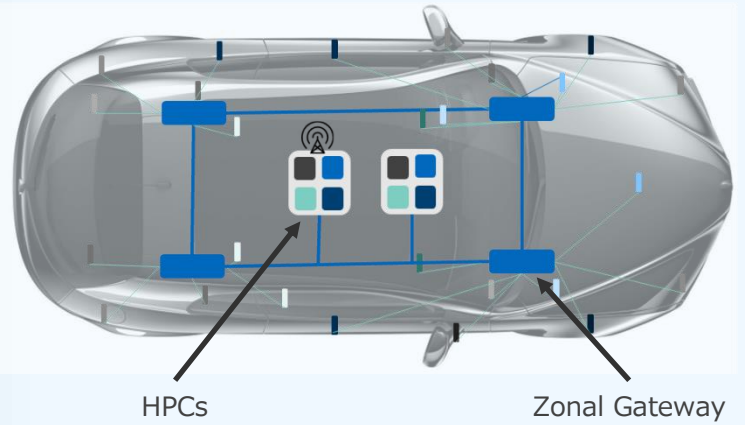
Domain Architecture





Centralized & Zonal Architecture



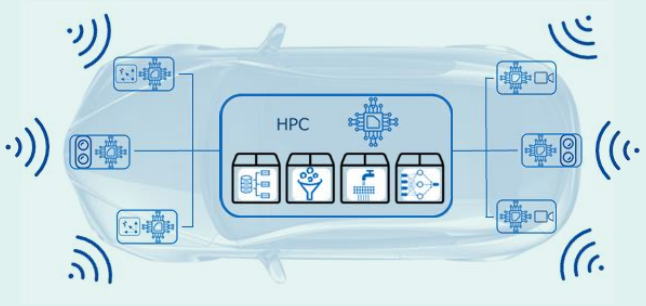


Source: SBD Automotive – Report 213 – *Advanced Computing*

Personalized, automated vehicles rely on cloud, edge

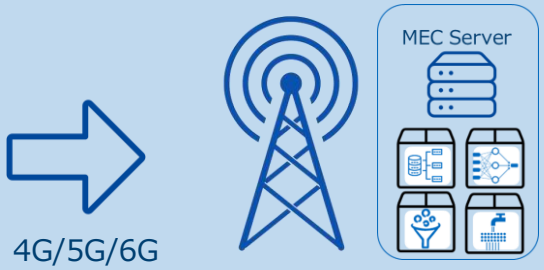
New commercialization opportunities require new car-to-cloud platform services to meet OEM needs

Far & In-Vehicle Embedded Edge



- Intelligent sensors
- Independent modules
- Containers
- Cloud-native apps
- Running in-vehicle via HPC

Network Edge

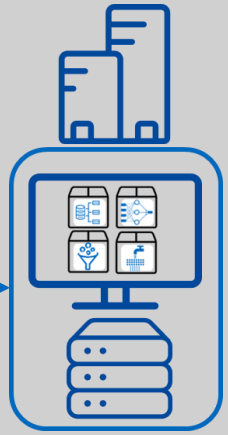


- Containers
- Cloud-native apps
- Running in network infrastructure

Cloud

- Containers or virtual machines
- (Usually) shared data center
- Supporting regional and global workloads

On Premise

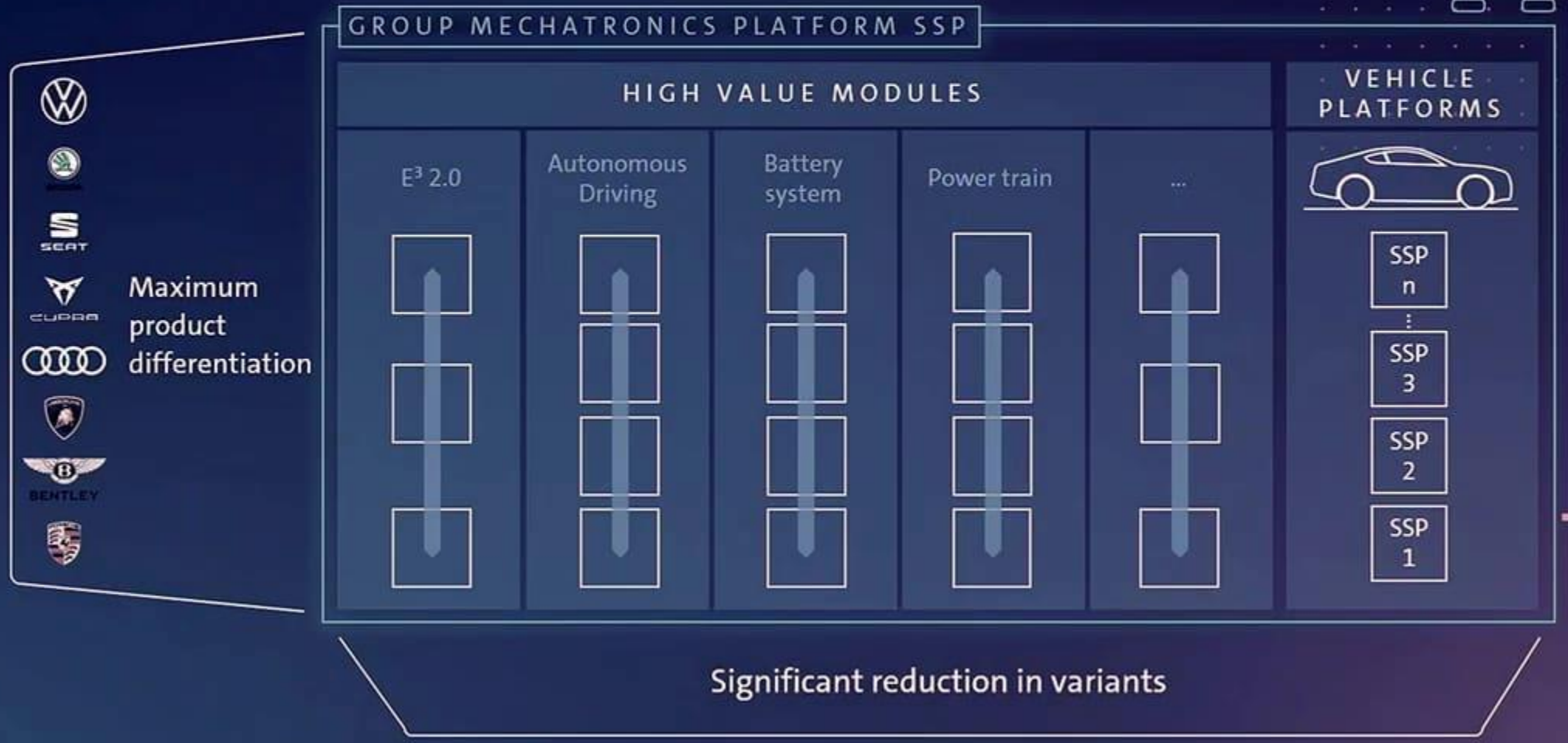


- Centralized
- Private to OEM
- Proprietary, mission-critical or sensitive data and workloads
- Dev environments

Source: SBD Automotive – Report 213 – *Advanced Computing*

VOLKSWAGEN
AKTIENGESELLSCHAFT

SSP comprises high value modules with dedicated variants to address all Group vehicles



Most automakers require multiple “stops” to SDV

Most OEMs can’t make the jump “straight” to SDV – it’s a more iterative engineering journey

Vehicle 1.0	Vehicle 2.0	Vehicle 3.0	Vehicle 4.0
Functional	**Digital**	**Updateable**	**Software-defined**
“New feature? Let’s add a new box	*“Let’s focus on digitizing our IVI*	*“Let’s keep the car fresh*	*“Let’s fully decouple SW from HW*

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Ford

RENAULT NISSAN MITSUBISHI

DAIMLER

TESLA

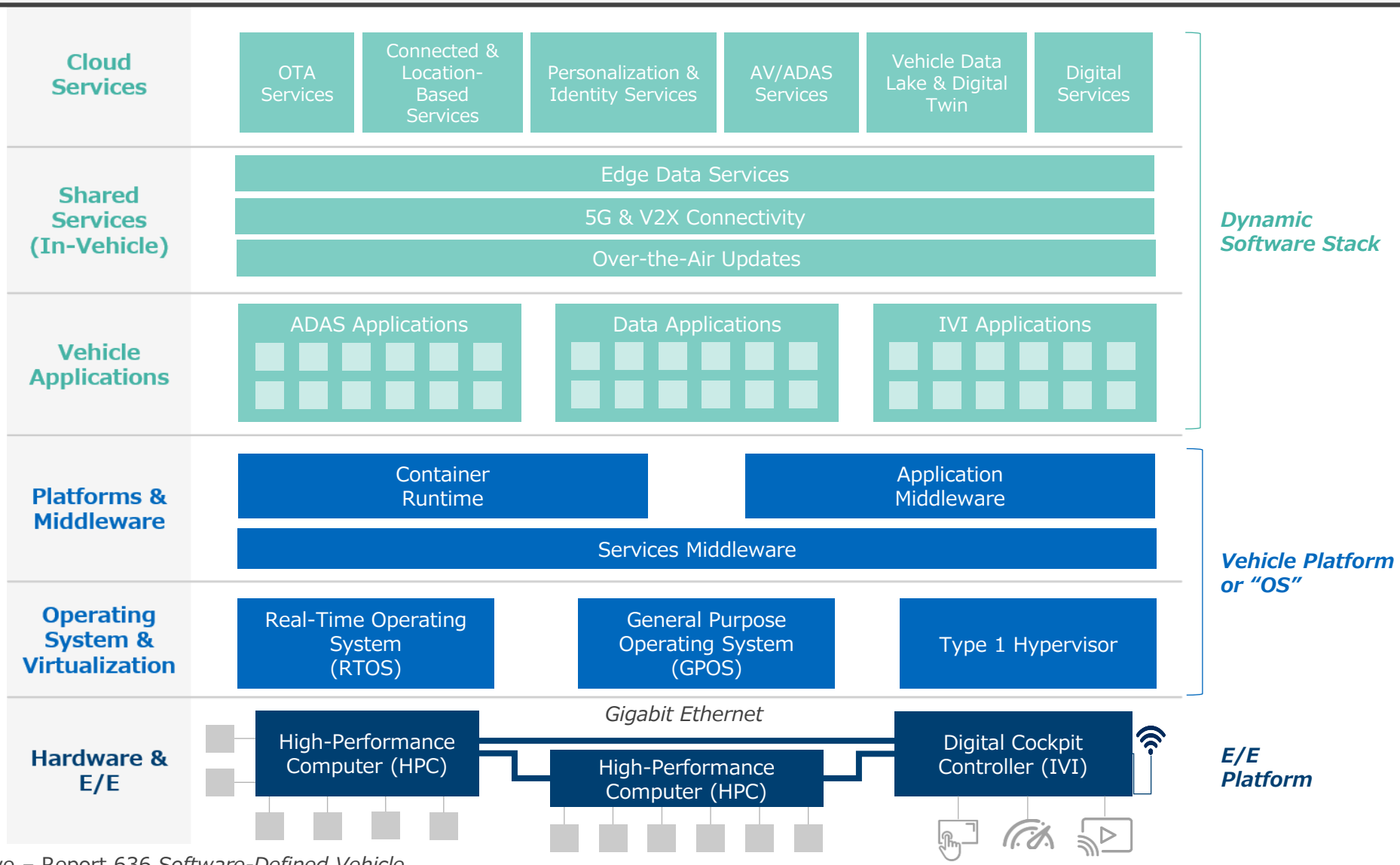
XPENG

Source: SBD Automotive – Report 636 – *The Software-Defined Vehicle*

Challenges to OEMs

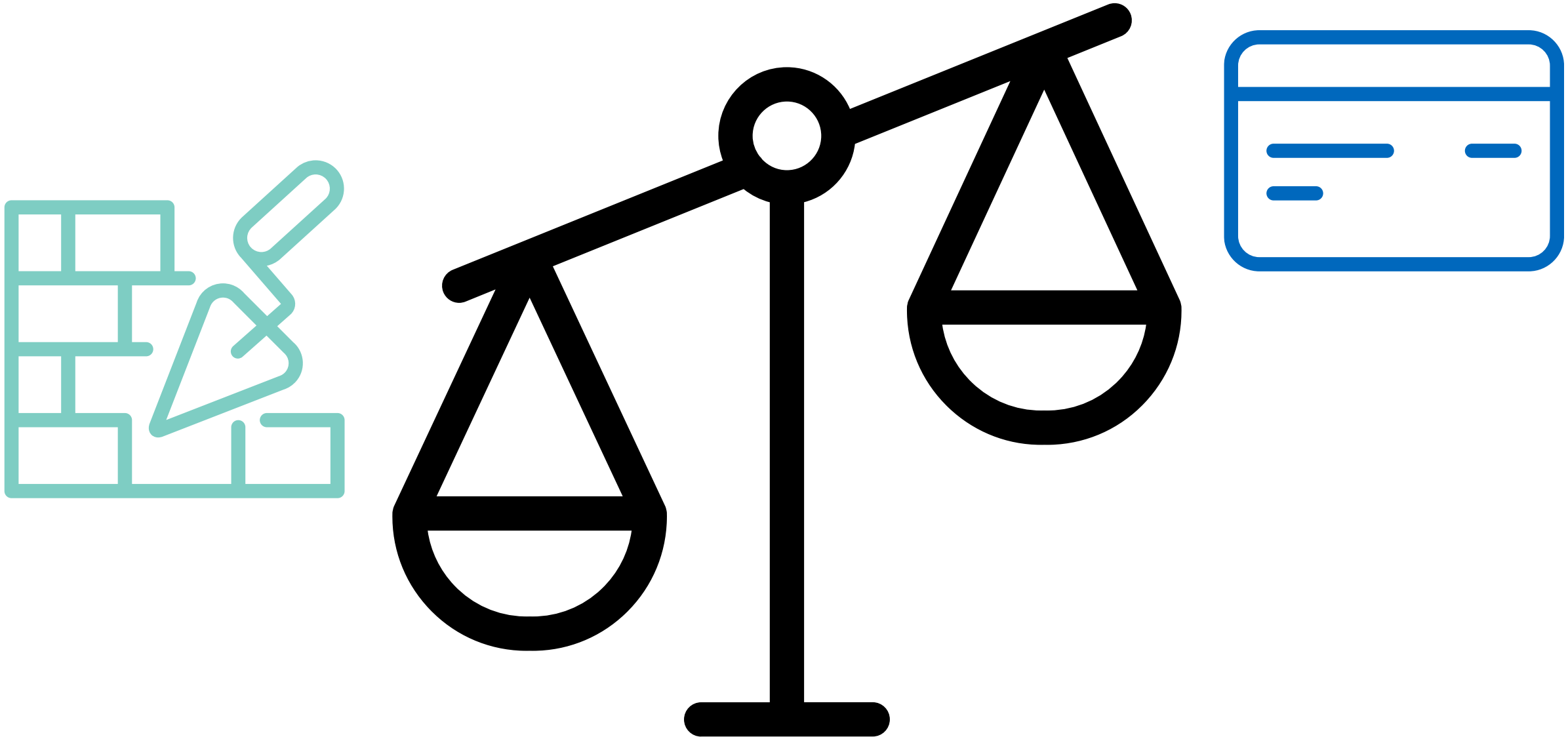
SDV architecture starts with abstraction from car to cloud

Some OEMs pursue “Vehicle.OS” which hold most of software stack



Source: SBD Automotive – Report 636 *Software-Defined Vehicle*

Key consideration: Build OR Buy?



Software sourcing strategies differ, limited by recruitment

Top SW Spenders	▼Outsourced Insourced▼
1. Volkswagen Group	
2. Toyota Group	
3. Stellantis	
4. Mercedes-Benz Group	
5. BMW Group	
6. Renault-Nissan-Mitsubishi	
7. General Motors Group	
8. Hyundai Group	
9. Ford Group	
10. Honda Group	
11. Tesla Motors	
12. Tata Motors Group	

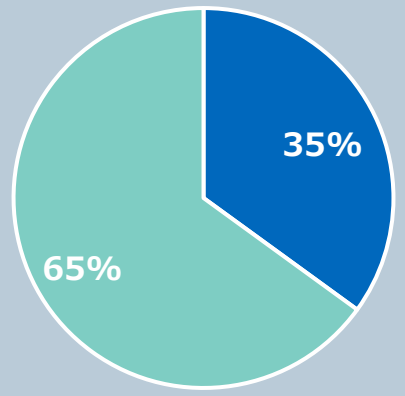
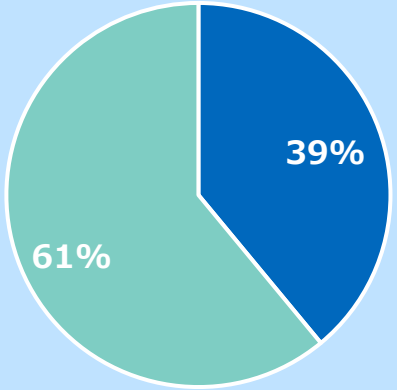
Source: SBD Automotive – Report 220 – *Quarterly Wrap-Ups (Q2 2022)*

Developer ecosystems, communities, and tools are the "secret sauce" to OEM-cloud partnership

"Our #1 barrier to achieving greater in-house software development goals is **recruitment**."

Software Director at Major OEM

Hidden cost of SDV – OPEX of non-differentiating S/W

	Volume OEM	Tier 1
10 year TCO ($Million)	100 +	140+
Breakdown by expense		
Key contributing factors	• High volume = outsized OPEX • Software revenue margin expected to be high due to small sales margin	• Multi-tenancy drives high OPEX • More feature-rich to support multiple OEMs

Source: The Hidden Costs of Software-Defined Vehicles (SBD)

Whatever approach OEM take, everything cannot be under control

	 **Integration Approach** Leveraging 3rd party software vendors	 **Long-Term Approach** Careful investment for reduced risk	 **Fast Development Approach** Immediate investment & re-organization
Cost	**Low**	**Low**	**High**
Time to Market	**Fast**	**Slow**	**Fast**
Intellectual Property Control	**Poor**	**Strong**	**Strong**

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OSS as key accelerator

OSS as the engine of SDV

OSS is not a panacea, but it will continue to grow in relevance

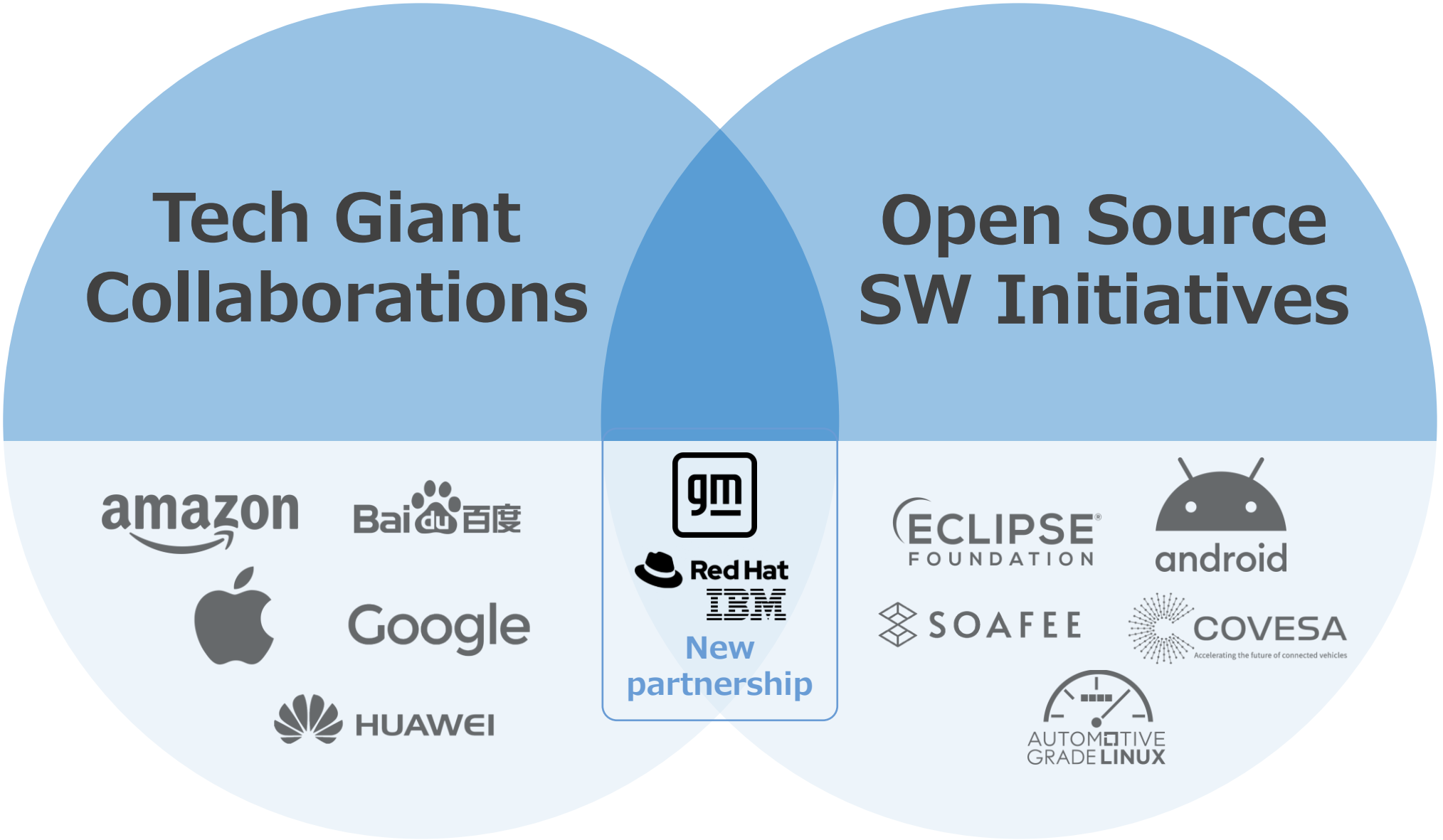
OSS is attractive to OEMs because:

- ✓ **Customization** for size/scale/context
- ✓ **Access** to development ecosystems, skillsets
- ✓ Lowering **cost of development** by:
  - ✓ Investing in mutually beneficial OSS
  - ✓ Eliminating licensing fees
- ✓ Reduction of **risk** via software supplier lock-in
- ✓ Alignment with hardware/chipset architecture creates **efficient optimization** effort

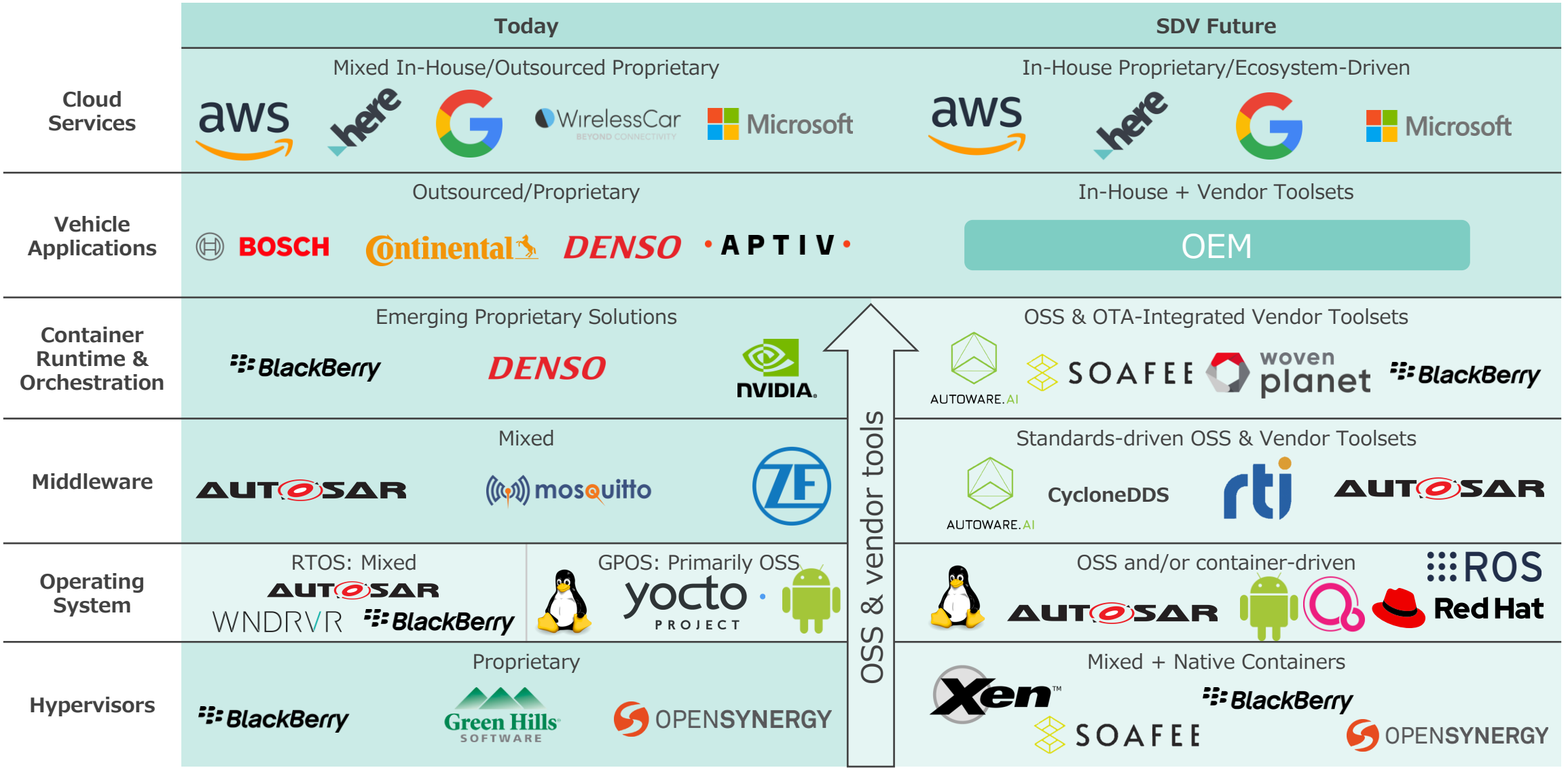
But OEMs will still need licensed software because:

- ✓ Developing **ASIL-C/D** software is difficult and expensive
- ✓ **Stricter regulations** will create demand for complexity abstraction
- ✓ **Different components and domains** have different requirements
- ✓ **Virtualization in mixed criticality environments** remains a linchpin to SDVs
- ✓ Outsourcing **management of upstream security threats** & **license compliance** remains attractive

OEMs leveraging Tech Giants & OSS to accelerate transformation



Key effect of SDV adoption: bottom-up commodification



Different approaches take different tool / supplier relationships

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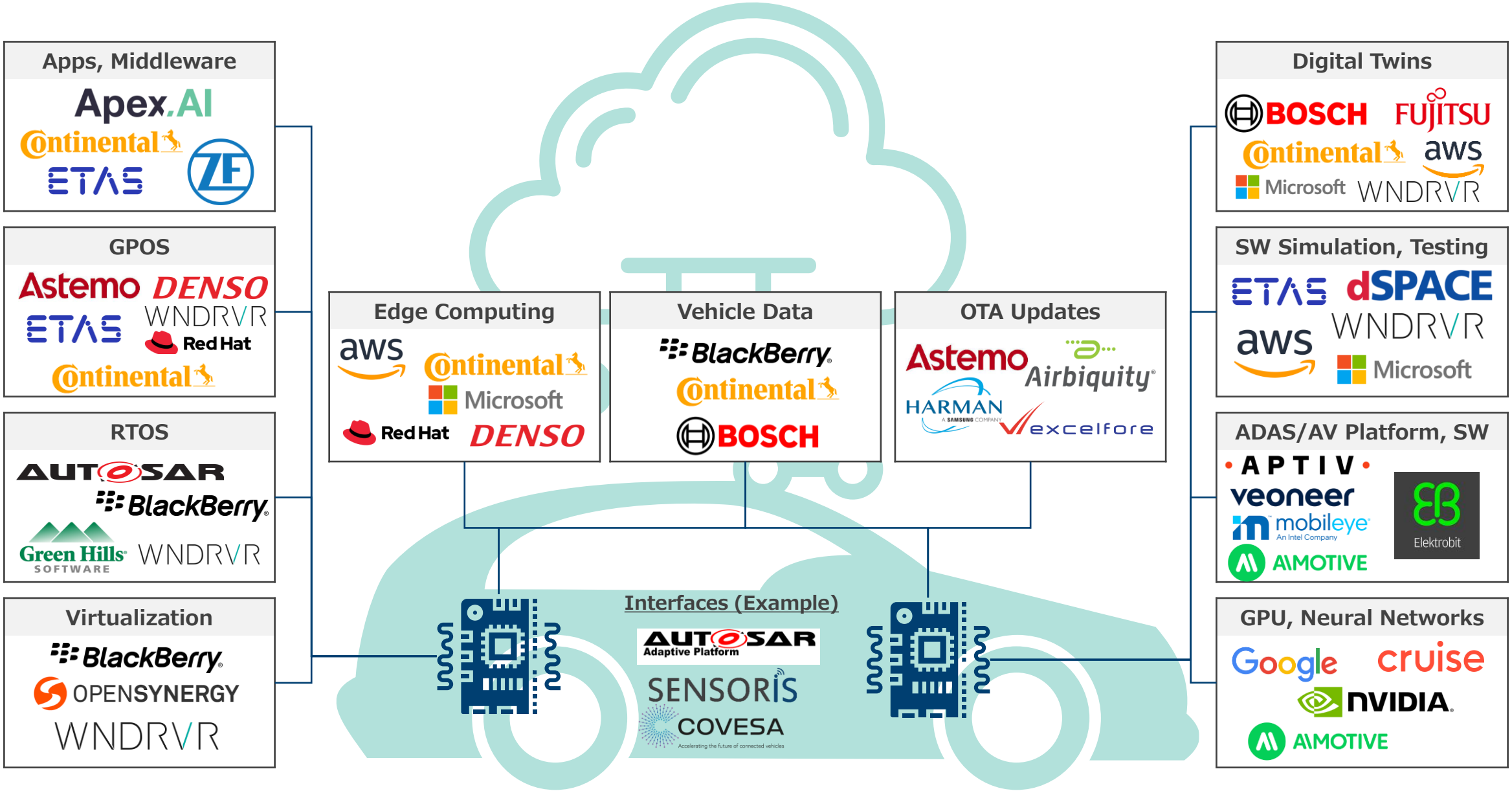
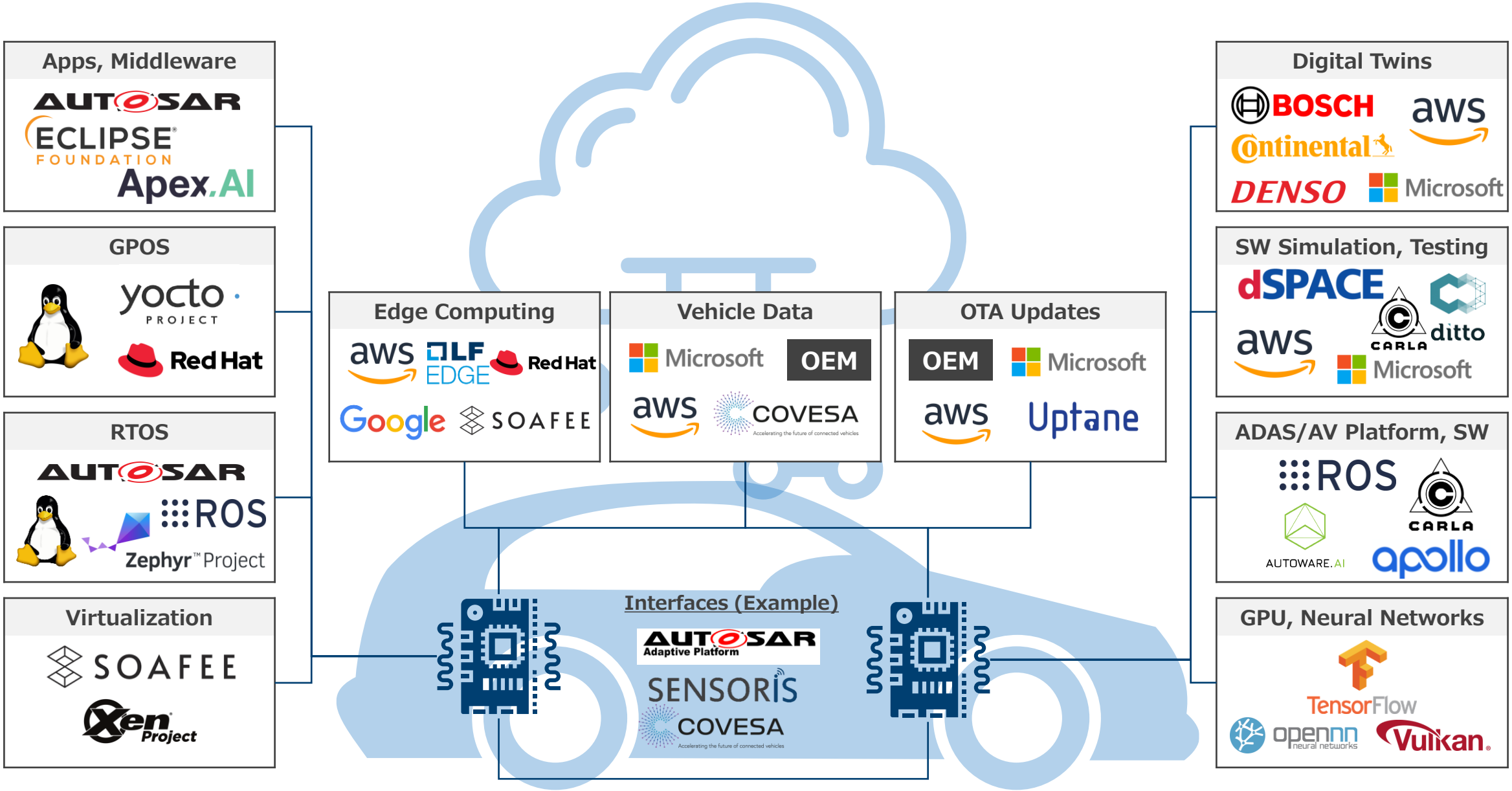
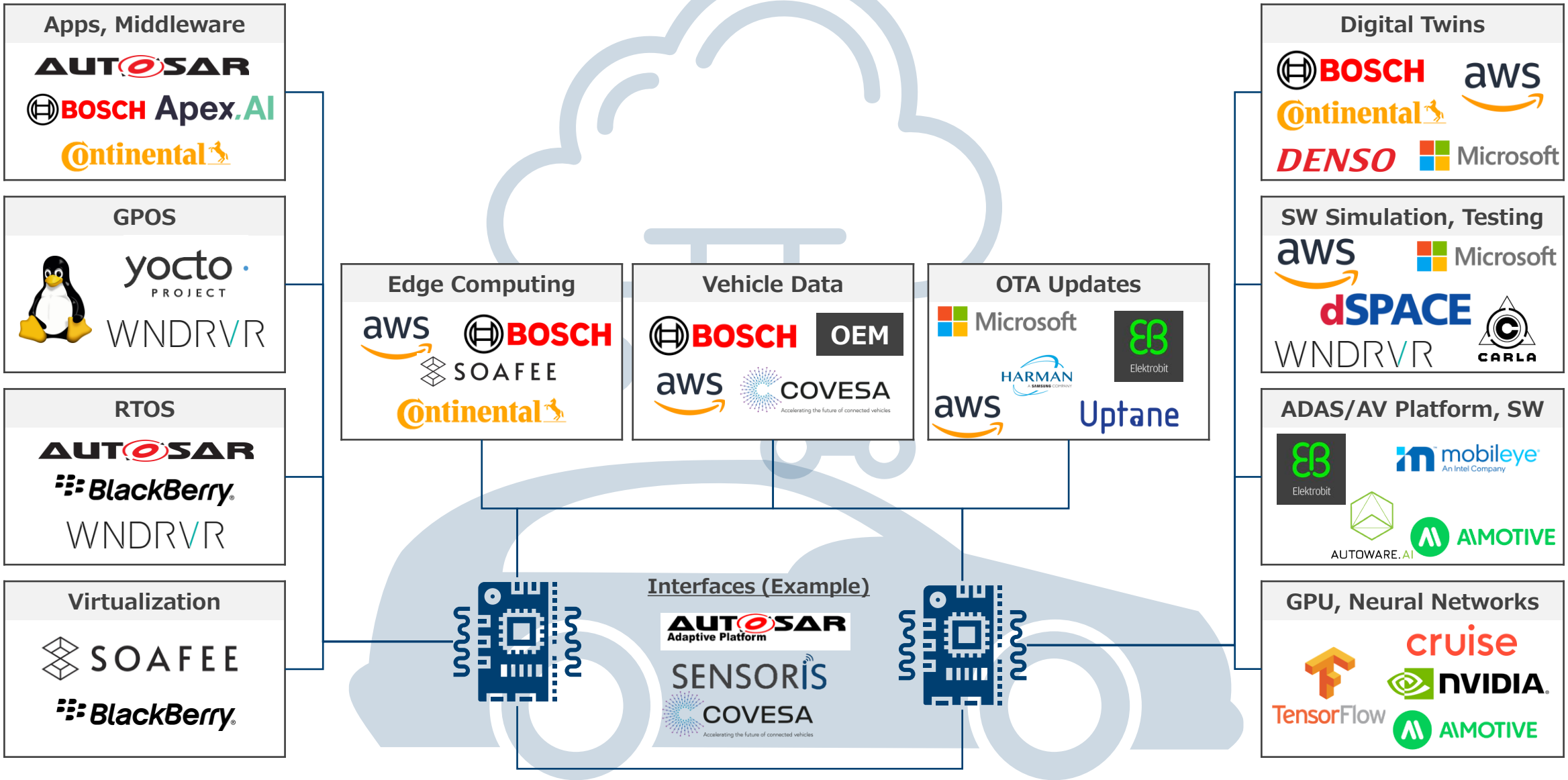
Integration Approach – Visualized



Long-Term Approach - Visualized



Fast Development Approach - Visualized



Final thoughts

1. SDV require overhaul of EE architecture and S/W architecture
2. Major challenge comes as a combination of organizational, technical and strategic challenges
3. Plenty of opportunities for OSS lie in SDV, but choice depends on OEMs' sourcing strategy

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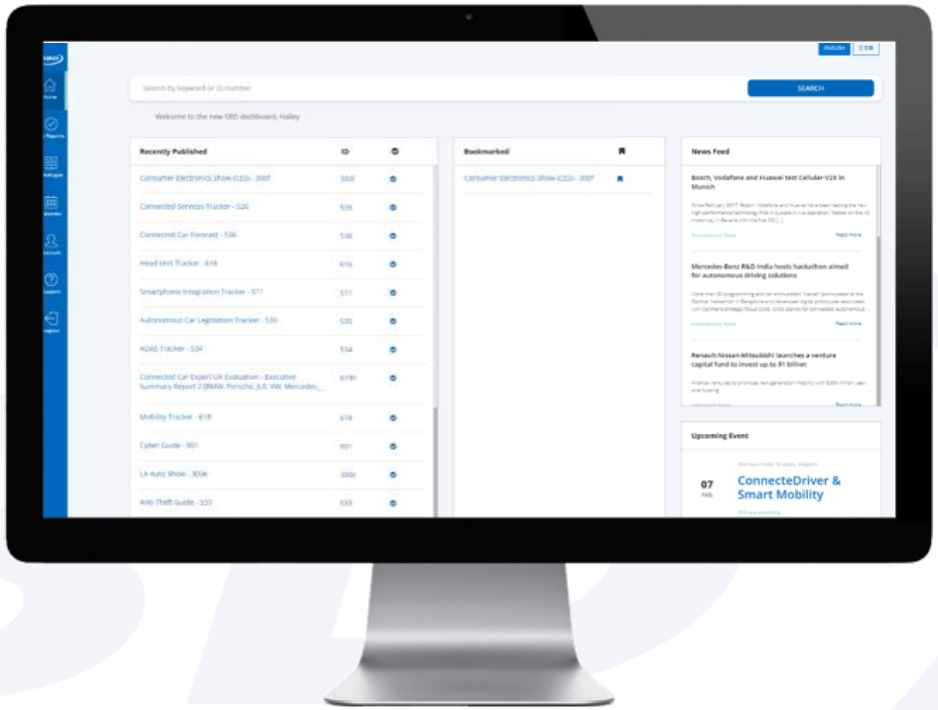

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