The Software Defined Vehicle and OSS

OSS as an emerging key enabler to build SDV

AGL members F2F meeting

October 19, 2022
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Senior Consulting Specialist – Automotive Software
SBD Automotive
Nagoya, JP

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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

**Traditional paradigm**
- Buy it
- Drive it
- Fill it up
- Get there

**New paradigm**
- Use it
- Be driven
- Charge it
- Enjoy the ride

**Technology trends**
- Sensors
- Connectivity
- Computing

**Consumer habits**
- Urbanization
- Digitization
- Mobility

**New regulations**
- Privacy
- Security
- Environmental

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

**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

<table>
<thead>
<tr>
<th># of stories</th>
<th>Trending companies</th>
<th>Top themes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>C</strong></td>
<td>Connected</td>
<td>The impact of the tech sector continues to grow as OEMs battle with s/w sourcing decisions</td>
</tr>
<tr>
<td><img src="" alt="Connected" /></td>
<td><img src="#" alt="Apple" /> <img src="#" alt="Android" /> <img src="#" alt="Mercedes-Benz" /> <img src="#" alt="BMW" /> <img src="#" alt="NIO" /> <img src="#" alt="Honda" /> <img src="#" alt="Mercedes-Benz" /></td>
<td></td>
</tr>
<tr>
<td><strong>A</strong></td>
<td>Autonomous</td>
<td>More OEMs announce plans for L3 autonomy just as pressure from regulators/press grows</td>
</tr>
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<td><img src="" alt="Autonomous" /></td>
<td><img src="#" alt="UNECE" /> <img src="#" alt="Mercedes-Benz" /> <img src="#" alt="STELLANTIS" /> <img src="#" alt="Tesla" /></td>
<td></td>
</tr>
<tr>
<td><strong>S</strong></td>
<td>Shared</td>
<td>Robo-taxi programs transition from testing to operational services</td>
</tr>
<tr>
<td><img src="" alt="Shared" /></td>
<td><img src="#" alt="GM" /> <img src="#" alt="Hyundai" /> <img src="#" alt="Baidu" /> <img src="#" alt="Pony.ai" /> <img src="#" alt="Cruise" /> <img src="#" alt="Argo" /></td>
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</tr>
<tr>
<td><strong>E</strong></td>
<td>Electric</td>
<td>Demand for EV’s outpaces supply as OEMs explore and invest in new business models</td>
</tr>
<tr>
<td><img src="" alt="Electric" /></td>
<td><img src="#" alt="Mercedes-Benz" /> <img src="#" alt="STELLANTIS" /> <img src="#" alt="Europcar" /> <img src="#" alt="O迪" /> <img src="#" alt="Ford" /> <img src="#" alt="Volvo" /></td>
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<tr>
<td><strong>S</strong></td>
<td>Secure</td>
<td>More OEMs get involved in the development of the next-generation smartphone key</td>
</tr>
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<td><img src="#" alt="Secure" /></td>
<td><img src="#" alt="CARCONNECTIVITY" /> <img src="#" alt="consortium" /> <img src="#" alt="Lexus" /> <img src="#" alt="Hyundai" /></td>
<td></td>
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</tbody>
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Source: SBD Automotive – Report 220 – Quarterly Wrap-Up (Q2 2022)
Software Defined Vehicles

What’s driving car makers forward?

Increase
- Speed-to-market
- Aftersales revenue
- Customer satisfaction
- Brand loyalty

Decrease
- Bill of materials
- Recall rate
- Depreciation
- Vulnerabilities
The software-defined automaker’s hierarchy of needs

1. E/E and Vehicle Platform
2. Software-Defined Vehicle & Car-to-Cloud
3. Organization & Development Process
4. Customer Experience
5. Commercialization
The software-defined automaker’s hierarchy of needs

Focus today:

1. E/E and Vehicle Platform
2. Software-Defined Vehicle & Car-to-Cloud
3. Organization & Development Process
4. Customer Experience
5. Commercialization
What is Software Defined Vehicle?
SDVs allow software to be designed, developed and tested in a fully virtualized environment, leveraging the scale of cloud services to simulate vehicle software.

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

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

SDVs create significant disruption in the traditional automotive electronics supply chain while creating new “blue oceans”.

Much of the core SDV software stack is non-differentiating, making standards & open-source software attractive to OEMs.
## Vehicle 4.0: The evolution of the software-defined vehicle

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

- 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

Additional Zonal HPC(s)*

Additional Zonal HPC(s)* in zonally configured E/E architectures

* In zonally configured E/E architectures
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

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

**GROUP MECHATRONICS PLATFORM SSP**

**HIGH VALUE MODULES**

- E³ 2.0
- Autonomous Driving
- Battery system
- Power train

**VEHICLE PLATFORMS**

- SSP n
- SSP 3
- SSP 2
- SSP 1

Maximum product differentiation

Significant reduction in variants
Most automakers require multiple “stops” to SDV

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

<table>
<thead>
<tr>
<th>Vehicle 1.0</th>
<th>Vehicle 2.0</th>
<th>Vehicle 3.0</th>
<th>Vehicle 4.0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functional</strong></td>
<td><strong>Digital</strong></td>
<td><strong>Updateable</strong></td>
<td><strong>Software-defined</strong></td>
</tr>
<tr>
<td>New feature? Let’s</td>
<td>Let’s focus on</td>
<td>Let’s keep the car</td>
<td>Let’s fully decouple</td>
</tr>
<tr>
<td>add a new box</td>
<td>digitizing our IVI</td>
<td>fresh</td>
<td>SW from HW</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Cloud Services</th>
<th>OTA Services</th>
<th>Connected &amp; Location-Based Services</th>
<th>Personalization &amp; Identity Services</th>
<th>AV/ADAS Services</th>
<th>Vehicle Data Lake &amp; Digital Twin</th>
<th>Digital Services</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Shared Services (In-Vehicle)</th>
<th>Edge Data Services</th>
<th>5G &amp; V2X Connectivity</th>
<th>Over-the-Air Updates</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Vehicle Applications</th>
<th>ADAS Applications</th>
<th>Data Applications</th>
<th>IVI Applications</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Platforms &amp; Middleware</th>
<th>Container Runtime</th>
<th>Application Middleware</th>
<th>Services Middleware</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Operating System &amp; Virtualization</th>
<th>Real-Time Operating System (RTOS)</th>
<th>General Purpose Operating System (GPOS)</th>
<th>Type 1 Hypervisor</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Hardware &amp; E/E</th>
<th>High-Performance Computer (HPC)</th>
<th>Gigabit Ethernet</th>
<th>High-Performance Computer (HPC)</th>
<th>Digital Cockpit Controller (IVI)</th>
</tr>
</thead>
</table>

Source: SBD Automotive – Report 636 Software-Defined Vehicle
Key consideration: Build OR Buy?
# Software Sourcing Strategies Differ, Limited by Recruitment

## Top SW Spenders

<table>
<thead>
<tr>
<th>Rank</th>
<th>Company</th>
<th>Outsourced</th>
<th>Insourced</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Volkswagen Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Toyota Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Stellantis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Mercedes-Benz Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>BMW Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Renault-Nissan-Mitsubishi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>General Motors Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Hyundai Group</td>
<td></td>
<td></td>
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<tr>
<td>9</td>
<td>Ford Group</td>
<td></td>
<td></td>
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<tr>
<td>10</td>
<td>Honda Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Tesla Motors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Tata Motors Group</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

Source: SBD Automotive – Report 220 – Quarterly Wrap-Ups (Q2 2022)
### Hidden cost of SDV – OPEX of non-differentiating S/W

#### Key contributing factors

<table>
<thead>
<tr>
<th></th>
<th>Volume OEM</th>
<th>Tier 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>10 year TCO ($Million)</strong></td>
<td>100 +</td>
<td>140+</td>
</tr>
<tr>
<td><strong>Breakdown by expense</strong></td>
<td>65% OPEX, 35% CAPEX</td>
<td>61% OPEX, 39% CAPEX</td>
</tr>
<tr>
<td><strong>Key contributing factors</strong></td>
<td>High volume = outsized OPEX</td>
<td>Multi-tenancy drives high OPEX</td>
</tr>
<tr>
<td></td>
<td>Software revenue margin expected to be high due to small sales margin</td>
<td>More feature-rich to support multiple OEMs</td>
</tr>
</tbody>
</table>

Source: The Hidden Costs of Software-Defined Vehicles (SBD)
Whatever approach OEM take, everything cannot be under control.

<table>
<thead>
<tr>
<th></th>
<th>Integration Approach</th>
<th>Long-Term Approach</th>
<th>Fast Development Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>Low</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td><strong>Time to Market</strong></td>
<td>Fast</td>
<td>Slow</td>
<td>Fast</td>
</tr>
<tr>
<td><strong>Intellectual Property Control</strong></td>
<td>Poor</td>
<td>Strong</td>
<td>Strong</td>
</tr>
</tbody>
</table>
OSS as key accelerator
OSS as the engine of SDV
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

<table>
<thead>
<tr>
<th>Today</th>
<th>SDV Future</th>
</tr>
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<tbody>
<tr>
<td>Cloud Services</td>
<td>Mixed In-House/Outsourced Proprietary</td>
</tr>
<tr>
<td><img src="image1" alt="AWS" /></td>
<td><img src="image1" alt="AWS" /></td>
</tr>
<tr>
<td><img src="image1" alt="Here" /></td>
<td><img src="image1" alt="Here" /></td>
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<tr>
<td><img src="image1" alt="Google" /></td>
<td><img src="image1" alt="Google" /></td>
</tr>
<tr>
<td><img src="image1" alt="WirelessCar" /></td>
<td><img src="image1" alt="Microsoft" /></td>
</tr>
<tr>
<td><img src="image1" alt="SDV Future Cloud Services - Mixed In-House/Outsourced Proprietary" /></td>
<td><img src="image1" alt="SDV Future Cloud Services - In-House Proprietary/Ecosystem-Driven" /></td>
</tr>
<tr>
<td>Vehicle Applications</td>
<td>Outsourced/Proprietary</td>
</tr>
<tr>
<td><img src="image1" alt="Bosch" /></td>
<td><img src="image1" alt="Continental" /></td>
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<tr>
<td><img src="image1" alt="SDV Future Vehicle Applications - Outsourced/Proprietary" /></td>
<td><img src="image1" alt="SDV Future Vehicle Applications - In-House + Vendor Toolsets" /></td>
</tr>
<tr>
<td>Container Runtime &amp; Orchestration</td>
<td>Emerging Proprietary Solutions</td>
</tr>
<tr>
<td><img src="image1" alt="BlackBerry" /></td>
<td><img src="image1" alt="Denso" /></td>
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<td><img src="image1" alt="SDV Future Container Runtime &amp; Orchestration - Emerging Proprietary Solutions" /></td>
<td><img src="image1" alt="SDV Future Container Runtime &amp; Orchestration - OSS &amp; OTA-Integrated Vendor Toolsets" /></td>
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<tr>
<td>Middleware</td>
<td>Mixed</td>
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<tr>
<td><img src="image1" alt="AUTOSAR" /></td>
<td><img src="image1" alt="mosquitto" /></td>
</tr>
<tr>
<td><img src="image1" alt="SDV Future Middleware - Mixed" /></td>
<td><img src="image1" alt="SDV Future Middleware - Standards-driven OSS &amp; Vendor Toolsets" /></td>
</tr>
<tr>
<td>Operating System</td>
<td>RTOS: Mixed</td>
</tr>
<tr>
<td><img src="image1" alt="AUTOSAR" /></td>
<td><img src="image1" alt="yocto" /></td>
</tr>
<tr>
<td><img src="image1" alt="WNDRVR" /></td>
<td><img src="image1" alt="BlackBerry" /></td>
</tr>
<tr>
<td>Hypervisors</td>
<td>Proprietary</td>
</tr>
<tr>
<td><img src="image1" alt="BlackBerry" /></td>
<td><img src="image1" alt="Green Hills Software" /></td>
</tr>
<tr>
<td><img src="image1" alt="SDV Future Hypervisors - Proprietary" /></td>
<td><img src="image1" alt="SDV Future Hypervisors - Mixed + Native Containers" /></td>
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Different approaches take different tool / supplier relationships

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Long-Term Approach - Visualized

Apps, Middleware
- Autosar
- Eclipse Foundation
- Apex.AI

GPOS
- yocto Project
- Red Hat

RTOS
- Autosar
- ROS
- Zephyr Project

Virtualization
- SOAFEE
- Xen Project

Edge Computing
- AWS
- DLF
- Red Hat

Vehicle Data
- Microsoft
- COVESa

OTA Updates
- OEM
- Uptane

Interfaces (Example)
- AUTOSAR
- SENSORiS
- COVESa

Digital Twins
- BOSCH
- Continental
- DENSO
- Microsoft

SW Simulation, Testing
- dSPACE
- CARLA
- ditto
- Microsoft

ADAS/AV Platform, SW
- ROS
- CARLA
- AUTOWARE.AI
- apollo

GPU, Neural Networks
- TensorFlow
- OpenNN
- openNN
- Vulikan
Fast Development Approach - Visualized

Apps, Middleware
- AUTOSAR
- BOSCH Apex.AI
- Continental
- SOAFEE
- BlackBerry

GPOS
- yocto
- WNDRV

RTOS
- AUTOSAR
- BlackBerry

Virtualization
- SOAFEE
- BlackBerry

Edge Computing
- BOSCH
- SoaFEE
- Continental
- AWS

Vehicle Data
- BOSCH
- Continental
- AWS
- COVESA

OTA Updates
- Microsoft
- BB
- Uptane

Digital Twins
- BOSCH
- Continental
- AWS
- DENSO
- Microsoft

SW Simulation, Testing
- AWS
- Microsoft
- dSPACE
- WNDRV
- CARLA

ADAS/AV Platform, SW
- BB
- Mobileye
- AIMOTIVE

GPU, Neural Networks
- Cruise
- NVIDIA
- Tensorflow
- AIMOTIVE

Interfaces (Example)
- AUTOSAR
- SENSORiS
- COVESA

OEM
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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- 24-hour access & self-registration
- Bookmark your favorite reports
- Configure your notification preferences
- Market news Feed and event overview

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