Connected Cars: Perspectives to 2025

IHS Automotive Technology

April 27, 2016

Egil Juliussen, Ph.D.
Director Research & Principal Analyst
Egil.Juliussen@IHS.com
Connected Cars: Perspectives to 2025

- Auto Sales and Motorization
- Infotainment: Growing Platform Importance
- Connected Cars: Opportunities & Threats
- Self-driving Cars vs. Driverless Cars: Revolution
- Summary Perspectives

Egil Juliussen, Ph.D. Director Research & Principal Analyst
Auto Sales by Region

Yearly Auto Sales

N. America
S. America
W. Europe
E/C Europe
China
Jp-Kr
India
O. A-P
ME/A

IHS March 2016 light vehicle forecast

SOURCE: IHS Automotive
Motorization: Autos In-Use per 1,000 People

SOURCE: IHS Automotive
Connected Cars: Perspectives to 2025

- Auto Sales and Motorization
- Infotainment: Growing Platform Importance
- Connected Cars: Opportunities & Threats
- Self-driving Cars vs. Driverless Cars: Revolution
- Summary Perspectives

Egil Juliussen, Ph.D. Director Research & Principal Analyst
Semiconductor Chip Advances: Auto Impact

Capabilities

Chip advances will have tremendous auto impact even if annual chip improvements slow down!

2015 Auto Impact
- Moore’s Law: 1X
- DRAM: 512 Mbit
- NAND: 16 Gbit
- MCU Speed: 1X

2020 Auto Impact
- Moore’s Law: 16X
- DRAM: 8 Gbit
- NAND: 256 Gbit
- MCU Speed: 3.5X

2025 Auto Impact
- Moore’s Law: 128X
- DRAM: 64 Gbit
- NAND: 2 Tbit
- MCU Speed: 12X

2030 Auto Impact
- Moore’s Law: 1024X
- DRAM: 256 Gbit
- NAND: 16 Tbit
- MCU Speed: 108X

2035 Auto Impact
- Moore’s Law: 81924X
- DRAM: 2 Tbit
- NAND: 256 Tbit
- MCU Speed: 108X

Take-away:
Automotive System on Chips (SoC) will have amazing capabilities in a decade or two. Future software will take full advantage of such capabilities!
Auto Industry and Software Impact

Every company has a structure similar to phases shown below:

<table>
<thead>
<tr>
<th><strong>Create</strong></th>
<th><strong>Make</strong></th>
<th><strong>Market</strong></th>
<th><strong>Product Use</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Product idea</td>
<td>Factory control</td>
<td>Product marketing</td>
<td>Payment systems</td>
</tr>
<tr>
<td>Technology R&amp;D</td>
<td>Parts management</td>
<td>Product sales</td>
<td>Customer support</td>
</tr>
<tr>
<td>Product design</td>
<td>Supplier mgmt.</td>
<td>Distribution channels</td>
<td>Warranty &amp; repair</td>
</tr>
<tr>
<td>Product testing</td>
<td>Inventory mgmt.</td>
<td>Delivery logistics</td>
<td>Repeat customers</td>
</tr>
</tbody>
</table>

Software and apps impact all phases of most product

<table>
<thead>
<tr>
<th><strong>Create</strong></th>
<th><strong>Make</strong></th>
<th><strong>Market</strong></th>
<th><strong>Car Use</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Very expensive</td>
<td>No SW BoM cost</td>
<td>SW=features</td>
<td>Bug-fixing needed</td>
</tr>
<tr>
<td>Long development</td>
<td>Some royalty costs</td>
<td>Features sell cars</td>
<td>SW maintenance</td>
</tr>
<tr>
<td>Difficult testing</td>
<td>Mfg.=SW loading</td>
<td>SW is upgradable</td>
<td>Connected car growth</td>
</tr>
<tr>
<td>Never bug-free</td>
<td>Loading flexibility</td>
<td>Upgradable features</td>
<td>OTA SW updates</td>
</tr>
</tbody>
</table>

**Take-away: Lower software development cost is key:**
- Re-usable software platforms are needed to lower development costs
- Over-the-air software updates needed for bug fixes & cyber-security

BoM=Bill of Material; SW=Software; OTA=Over-the-Air

SOURCE: IHS Automotive
Infotainment: Connected Car vs. Head-Unit

**Head-Units**
3 main segments
- Audio only
- Display audio
- Navigation

**Connected Car**
1 or more connections:
- Embedded modem
- Via Smartphone/MP

**Driver-Centric Content**
- Internet radio
- Cloud content
- Apps

**Car-Centric Content**
- Remote diagnostics
- OTA software updates
- Cyber-security
- VRM

**HMI Tech**
- CSD, HUD
- ICD display
- Speech
- Gesture

**Autonomous Driving**
- ADAS, SDC, DLC

**Smart Home**
Mostly via SP

**Wearables**
Mostly via SP

SOURCE: IHS Automotive

MP=Mobile Phone; SP=Smartphone; VRM=Vehicle Relationship Management; SDC=Self-Driving Car; DLC=Driverless Car; OTA=Over-the-Air; C-S=Cyber-Security
Infotainment Apps: Big Picture

- **IVI Apps**
  - Downloaded apps
  - Driver chosen
  - Travel & LBS
  - Eco apps
  - Social network apps
  - Entertainment apps
  - Car-centric apps
  - OBDII-based apps
  - UBI apps

- **Integrated SP Apps**
  - Apps integration
  - OEM chosen

- **Current Standards**
  - Apple CarPlay
  - Android Auto
  - Baidu CarLife
  - Ford AppLink-SDL
  - MirrorLink
  - SofTec
  - Others

- **Smartphone Apps & Content Platforms**
  - Android
  - iPhone
  - Win Phone 10

- **Integrated SP Apps**
  - OEM chosen

- **IVI Apps**
  - Built-in apps
  - OEM chosen

- **Music apps**
- **Navi-LBS apps**
- **Telematics apps**
- **Search apps**
- **CRM apps**
- **Remote diagnostics**
- **OBDII-based apps**
- **SP remote control**

- **IVI HMI Software Platform**
  - Auto OEM specific

- **IVI Software Platform**
  - OS Kernel & Middleware

- **Hardware Abstraction Layer?**
  - Equivalent to BIOS in PCs

- **IVI Hardware Platform**
  - Atom, ARM, MIPS, others?

- **IVI HMI Hardware**
  - Input, Output & Control

- **Smartphone Apps & Content Platforms**
  - Android
  - iPhone
  - Win Phone 10

- **Current Standards**
  - Apple CarPlay
  - Android Auto
  - Baidu CarLife
  - Ford AppLink-SDL
  - MirrorLink
  - SofTec
  - Others

- **Travel & LBS**
- **Eco apps**
- **Social network apps**
- **Entertainment apps**
- **Car-centric apps**
- **OBDII-based apps**
- **UBI apps**

- **QNX**
- **GENIVI Linux**
- **Other Linux**
- **Microsoft**

- **Music apps**
- **Navi-LBS apps**
- **Telematics apps**
- **Search apps**
- **CRM apps**
- **Remote diagnostics**
- **OBDII-based apps**
- **SP remote control**

- **OS Kernel & Middleware**

- **Auto OEM specific**

- **Equivalent to BIOS in PCs**

- **Atom, ARM, MIPS, others?**

- **Input, Output & Control**

SOURCE: IHS Automotive
Head-Unit System Trends

- **No-Brand Audio**
  - 2015 share: 34%
  - 2021 share: 14%

- **Display Audio**
  - 2015 share: 23%
  - 2021 share: 36%

- **Navi & Audio**
  - 2015 share: 22%
  - 2021 share: 31%

- **Branded Audio**
  - 2015 share: 11%
  - 2021 share: 13%

- **No OEM H-U**
  - 2015 share: 10%
  - 2021 share: 5%

- **Audio & Video**
  - 2015 share: 0.4%
  - 2021 share: 0.3%

Navi & LBS are key SP Apps

SOURCE: IHS Automotive Infotainment Portal
## Smartphone Apps Integration: Status

<table>
<thead>
<tr>
<th></th>
<th>CarPlay</th>
<th>Android Auto</th>
<th>MirrorLink</th>
<th>AppLink-SDL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OEMs Brands</strong></td>
<td>16 OEMs 24 Brands</td>
<td>16 OEMs 42 Brands</td>
<td>6 OEMs 12 Brands</td>
<td>2 OEMs 3 Brands</td>
</tr>
<tr>
<td><strong>Key OEMs with Availability</strong></td>
<td>BMW, Daimler, FCA, GM, Honda, Hyundai, Mazda, Mitsubishi, Nissan, PSA, Renault, Subaru, Suzuki, Volkswagen, Volvo</td>
<td>BMW, Daimler, FCA, GM, Honda, Hyundai, Mazda, Mitsubishi, Nissan, PSA, Renault, Subaru, Suzuki, Volkswagen, Volvo</td>
<td>Daimler GM Honda PSA Toyota Volkswagen</td>
<td>Ford Toyota</td>
</tr>
<tr>
<td><strong>Car Models</strong></td>
<td>116</td>
<td>122</td>
<td>66</td>
<td>28</td>
</tr>
<tr>
<td><strong>SP OS</strong></td>
<td>iOS</td>
<td>Android</td>
<td>Android, Symbian</td>
<td>iOS, Android</td>
</tr>
<tr>
<td><strong>Apps</strong></td>
<td>30</td>
<td>55</td>
<td>12</td>
<td>12+</td>
</tr>
</tbody>
</table>

SDL=Smart Device Link; SP=Smartphone; OS=Operating System
Smartphone Apps Integration: Enabled Autos

Global Cumulative Enabled Car Sales

- MirrorLink
- Apple CarPlay
- Android Auto
- Ford AppLink

Others not included: Baidu CarLife; Abalta Weblink, Airbiquity Choreo, Nuance Dragon Drive Link, SofTec, UIEvolution Cloud Connect, VNC

SOURCE: IHS Automotive
Software Apps & Service Portal
Connected Cars: Perspectives to 2025

- Auto Sales and Motorization
- Infotainment: Growing Platform Importance
- Connected Cars: Opportunities & Threats
- Self-driving Cars vs. Driverless Cars: Revolution
- Summary Perspectives

Egil Juliussen, Ph.D. Director Research & Principal Analyst
Connected Car Technologies Overview

Cellular Systems
- Analog-1G
- 2G-2.5G
- 3G-3.5G
- 4G LTE
- 4.5G LTE Advanced
- 5G

Short-Range Wireless Tech
- Bluetooth
- Bluetooth Smart 4.1, 4.2
- Wi-Fi: IEEE 802a/b/g/n
- NFC
- Keyless RF
- IEEE 802ac/ad

Broadcast Signals
- AM Radio
- FM Radio
- GPS
- Digital Radio: HD; DAB-DMB
- Satellite Radio
- Mobile TV

White Space
Unused TV Spectrum
DSRC-V2X
5.9 GHz band

SOURCE: IHS Automotive

Mobile TV mostly in Japan, Korea & China; Satellite Radio mostly in N. America

© 2016 IHS
# Connected Car Trends: U.S. & EU

<table>
<thead>
<tr>
<th></th>
<th>U.S. Trends</th>
<th>EU Trends</th>
</tr>
</thead>
</table>
| **Embedded Telematics** | ▶ Leading technology  
▶ Remote diagnostic most valuable  
▶ LTE deployment going fast | ▶ Waiting for eCall to fire up  
▶ Mostly for high-end autos  
▶ eCall main app initially |
| **Smartphone Telematics** | ▶ Ford success, followed by others  
▶ Will leverage phone projection | ▶ Limited success so far  
▶ Success via phone projection |
| **Embedded & Smartphone** | ▶ Growing rapidly  
▶ Long-term winner | ▶ Emerging in most countries  
▶ Long-term winner |
| **Phone Projection** | ▶ Very important in next 5 years  
▶ CarPlay & Android Auto to lead  
▶ Qs: MirrorLink? AppLink-SDL? | ▶ Very important in next 5 years  
▶ CarPlay & AA to lead  
▶ Qs: MirrorLink? SofTec? |
| **OTA SW Update** | ▶ Emerging for telematics  
▶ Infotainment OTA is next  
▶ Core ECU OTA emerging | ▶ Emerging for telematics  
▶ Mostly luxury brands  
▶ May lag U.S. by 2-4 years |
| **Cyber Security** | ▶ Finally getting attention  
▶ OEMs scrambling to catch up  
▶ Laws & regulation on the way | ▶ Strong R&D, little deployment  
▶ Orderly deployment coming  
▶ Laws & regulation expected |

AA=Android Auto; OTA=Over-the-Air

SOURCE: IHS Automotive
Software Apps & Service Portal
# Connected Car Trends: U.S. & A-P

<table>
<thead>
<tr>
<th></th>
<th>U.S. Trends</th>
<th>AP Trends</th>
</tr>
</thead>
</table>
| **Embedded Telematics** | ▶ Leading tech approach  
▶ Remote diagnostic most valuable  
▶ LTE deployment coming fast | ▶ Leading approach in China  
▶ Weak in most other regions  
▶ LTE emerging first in China |
| **Smartphone Telematics** | ▶ Ford success, followed by others  
▶ Will leverage phone projection | ▶ Leading approach in Japan  
▶ Future growth in China |
| **Embedded & SP**     | ▶ Growing rapidly  
▶ Long-term winner | ▶ Grows with Smartphone  
▶ Long-term winner in most areas |
| **Phone Projection**  | ▶ Very important in next 5 years  
▶ CarPlay & Android Auto to lead  
▶ Qs: MirrorLink? AppLink-SDL? | ▶ CP & AA important in Jp & Kr  
▶ CarLife important in China  
▶ China Qs: Local AA? ML? SDL? |
| **OTA SW Update**     | ▶ Emerging for telematics  
▶ Infotainment OTA is next  
▶ Core ECU OTA emerging | ▶ OTA to be important in Jp & Kr  
▶ Cn: GM, BMW etc. to lead  
▶ AP may lag U.S. by 3-5 years |
| **Cyber Security**    | ▶ Finally getting attention  
▶ OEMs scrambling to catch up  
▶ Laws & regulation on the way | ▶ Getting attention in Jp & Kr  
▶ Need attention in Cn & In  
▶ Laws & regulation expected |

© 2016 IHS

SOURCE: IHS Automotive  
Software Apps & Service Portal
Connected Car Trends

**No Telematics**
- 2015 share: 45%

**Phone HFI Only**
- 2015 share: 27%

**Embedded Telematics**
- 2015 share: 12%

**CE Telematics**
- 2015 share: 10%

**Hybrid Telematics**
- 2015 share: 7%

**Hybrid Telematics**
- 2021 share: 30%

**No Telematics**
- 2021 share: 25%

**CE Telematics**
- 2021 share: 18%

**Embedded Telematics**
- 2021 share: 16%

**Phone HFI Only**
- 2021 share: 11%

CE Telematics use mobile phone for connection
Global yearly sales share

SOURCE: IHS Automotive
*Infotainment Portal*
Connected Car Attach Rate

Includes connected car services via embedded modem, Smartphone & both

© 2016 IHS

SOURCE: IHS Automotive
Infotainment Portal
GM’s USA deployment of LTE will kick-start market: GM volume will lower auto-grade LTE chip price

SOURCE: IHS Automotive
## Who Benefits from Connected Cars?

<table>
<thead>
<tr>
<th>Segment</th>
<th>Benefit Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>OEMs</td>
<td>▶ Cost savings: Remote diagnostics &amp; <strong>Remote software upgrades</strong></td>
</tr>
<tr>
<td></td>
<td>▶ New revenue from future functional software upgrades</td>
</tr>
<tr>
<td>Suppliers</td>
<td>▶ Revenue from communication &amp; HMI hardware</td>
</tr>
<tr>
<td></td>
<td>▶ Revenue from connected car software: middleware &amp; apps</td>
</tr>
<tr>
<td>TSPs</td>
<td>▶ Revenue from safety &amp; car-centric services: Base service</td>
</tr>
<tr>
<td></td>
<td>▶ Revenue from infotainment-centric services: New opportunities</td>
</tr>
<tr>
<td>MNOs</td>
<td>▶ Revenue from growing amount of data to and from the car</td>
</tr>
<tr>
<td></td>
<td>▶ Revenue from being a TSP and/or content provider</td>
</tr>
<tr>
<td>Content Providers</td>
<td>▶ Many entertainment categories: music &amp; audio as leaders</td>
</tr>
<tr>
<td></td>
<td>▶ Many information categories: LBS-relates as leader</td>
</tr>
<tr>
<td></td>
<td>▶ Many new categories emerging</td>
</tr>
<tr>
<td>Car Data Consumption</td>
<td>▶ Mostly TSP-centric data, traffic info &amp; insurance-centric data</td>
</tr>
<tr>
<td></td>
<td>▶ Many new categories emerging: OBDII data, V2X &amp; others</td>
</tr>
<tr>
<td>Driver &amp; Passengers</td>
<td>▶ Cost savings similar to OEMs, higher resale value w/RD history</td>
</tr>
<tr>
<td></td>
<td>▶ Connected car apps value: cost savings, safety &amp; convenience</td>
</tr>
<tr>
<td></td>
<td>▶ Access to vast infotainment content portfolios</td>
</tr>
</tbody>
</table>

HMI=Human Machine Interface; TSP=Telematics Service Provider; MNO=Mobile Network Operator

SOURCE: IHS Automotive
Automotive Software Mega-Trends

External Factors

- SP, PC & CE Products
- Semiconductor Chip Advances
- Software Recalls
- Cyber-Security Threats

Emerging Solutions

- SP Apps Integration
- Connected Car
- Hardware Modularity
- ECU Domains
- HSM MCUs
- ISO 26262 Software
- Software Platforms
- Open Source SW
- OTA SW Updates
- Layers: SW Security

Internal Factors

- Software Reliability
- SW Life-Cycle Costs
- Time to Market
- Feature Obsolescence
- Autonomous Driving Tech

SP=Smartphone; CE=Consumer Electronics; HSM=Hardware Security Module; SW=Software; OTA=Over The Air

SOURCE: IHS Automotive
Software Apps & Service Portal
Auto Software Complexity Path

"Embedded Controllers"
- Simple SW control program
- Fixed middleware
- Fixed function app or apps
- BoM cost minimization
- LoC* counted in thousands

“Apps Computers”
- Complex operating system
- Computer middleware
- Industry-specific middleware
- Multiple changeable apps
- LoC* counted in millions

10X-100X Complexity

Simple ECU 2000

Complex ECU 2000

Complex ECU 2015

Complex ECU 2015

ADI ECUs 2015

IVI H-U 2005

IVI H-U 2015

IVI H-U 2020

ADAS L2 & L3 2020

ADAS L4 & L5 2025

Domain ECU 2020

Simple ECU 2000

Simple ECU 2015

Source: IHS Automotive

LoC=Lines of Code; SDC=Self-Driving Car
Infotainment OS Trends

IVI OS Market Share

ALL H-U & Telematics Linux versions included

© 2016 IHS

WE-QNX
WE-Linux
USA-QNX
USA-Linux
China-QNX
China-Linux
WW-QNX
WW-Linux

WE=Western Europe; WW=Worldwide

SOURCE: IHS Automotive
OTA Software Update Evolution

Core ECU SW Update
- Re-flashing At Dealers
- Dealer Re-flash Recall-Centric
- OTA Tesla
- “VPN” OTA & Cyber-Security

Infotainment SW Update
- Re-flashing At Dealers
- Apps OTA
- Feature & OS FOTA
- OTA & Cyber-Security

Smartphones
- iPhone-Android OTA
- OS & Apps Update
- OTA & Cyber-Security

PCs
- SW Patches Magnetic Media
- OTA Windows XP
- Monthly OTA: OS & Apps Security-Centric


OTA=Over The Air

SOURCE: IHS Automotive
Software Apps & Service Portal
## OTA Software Update Advantages

<table>
<thead>
<tr>
<th></th>
<th>Key Information</th>
<th>Other Information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost Savings</strong></td>
<td>▶ Dealer cost is $70-100 per software update event</td>
<td>▶ OTA could save 50%</td>
</tr>
<tr>
<td></td>
<td>▶ Lower notification costs</td>
<td>▶ IT investment delays ROI</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▶ Electronic notification</td>
</tr>
<tr>
<td><strong>Time Savings</strong></td>
<td>▶ Quicker preparation time</td>
<td>▶ No dealer appointment</td>
</tr>
<tr>
<td></td>
<td>▶ Less notification time</td>
<td>▶ No mailing expected</td>
</tr>
<tr>
<td><strong>Recall Completion</strong></td>
<td>▶ 70% dealer recall completion</td>
<td>▶ Many unsafe cars on road</td>
</tr>
<tr>
<td></td>
<td>▶ OTA should do much better</td>
<td>▶ OTA completion? 90%+</td>
</tr>
<tr>
<td><strong>Future Business</strong></td>
<td>▶ Value of functional updates</td>
<td>▶ Mostly aftermarket now</td>
</tr>
<tr>
<td></td>
<td>▶ A portion will pay for this</td>
<td>▶ Future OEM revenue stream</td>
</tr>
</tbody>
</table>

SOURCE: IHS Automotive Software Apps & Service Portal
## OTA Software Update Segments

<table>
<thead>
<tr>
<th>What Is Updated</th>
<th>OEM Deployment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Infotainment Apps</strong></td>
<td>Head-unit apps</td>
</tr>
<tr>
<td></td>
<td>Telematics apps</td>
</tr>
<tr>
<td></td>
<td>Toyota, Chrysler</td>
</tr>
<tr>
<td></td>
<td>Chrysler brands, Infiniti</td>
</tr>
<tr>
<td><strong>Infotainment Software</strong></td>
<td>Telematics software</td>
</tr>
<tr>
<td></td>
<td>Head-unit software</td>
</tr>
<tr>
<td></td>
<td>Including operating system</td>
</tr>
<tr>
<td></td>
<td>BMW, GM, M-B, Ford</td>
</tr>
<tr>
<td></td>
<td>Mercedes-Benz</td>
</tr>
<tr>
<td></td>
<td>Emerging now</td>
</tr>
<tr>
<td><strong>Core Auto ECUs</strong></td>
<td>Powertrain ECU software</td>
</tr>
<tr>
<td></td>
<td>Chassis ECU software</td>
</tr>
<tr>
<td></td>
<td>Convenience ECU software</td>
</tr>
<tr>
<td></td>
<td>Public: Tesla* since 2012</td>
</tr>
<tr>
<td></td>
<td>Emerging: 2017+</td>
</tr>
<tr>
<td></td>
<td>Required: 2020+</td>
</tr>
<tr>
<td><strong>Navigation Map</strong></td>
<td>Map software</td>
</tr>
<tr>
<td></td>
<td>POI database</td>
</tr>
<tr>
<td></td>
<td>Autonomous Driving Map</td>
</tr>
<tr>
<td></td>
<td>Japan OEMs in Japan; BMW, Audi, Tesla &amp; others</td>
</tr>
<tr>
<td></td>
<td>Future AD Map required</td>
</tr>
</tbody>
</table>

*Tesla added hardware for L2-L3 autonomy in model D in November 2014, but software & apps where downloaded in October 2015. Adds new level of future proofing!
Over-the-Air Software Update Forecast

OTA Auto Sales

- Infotainment SW
- HU Apps
- Map Updates
- TCU Software
- Core ECU SW

TCU=Telematics Control Unit

© 2016 IHS

SOURCE: IHS Automotive
Auto Cyber-Security: Complacency → Action

**Age of Cyber-Security**
- Check current systems
- Weakness identification
- Any apps & content
- Best practice → standards
- Every RFQ with cyber-security
- Product portfolio growth
- OEM-T1 expertise acquisition

**Complacency Stage**
- No need for security
- No actual breaches
- Too expensive
- Will not happen to us

**Proof of Concept Stage**
- White-hat hackers
- Skills & expertise needed
- Wired connection hacking
- Wireless hacking events

**Mass Deployment**
- First for connected cars
- New system architecture
- Next for control ECUs
- New innovative products
- Combined with OTA

SOURCE: IHS Automotive
Infotainment Portal
Connected Cars: Perspectives to 2025

- Auto Sales and Motorization
- Infotainment: Growing Platform Importance
- Connected Cars: Opportunities & Threats
- Self-driving Cars vs. Driverless Cars: Revolution
- Summary Perspectives

Egil Juliussen, Ph.D. Director Research & Principal Analyst
Current State of the Art & Announced Plans

IHS Level 4: Fully autonomous with driver controls
IHS Level 5: Fully autonomous without driver controls

SOURCE: IHS Automotive
# 2 Autonomous Driving Strategies

<table>
<thead>
<tr>
<th>Focus:</th>
<th>Level 4 Vehicles</th>
<th>Level 5 Vehicles</th>
</tr>
</thead>
</table>
| **Autonomy Levels** | • Self-driving car mode  
  • Human driving mode | • Driverless car mode only  
  • No driving controls |
| **Business Models** | • Traditional car ownership  
  • Car-as-a-Product (CaaP) | • Car-as-a-Service (CaaS)  
  • Some car ownership |
| **Proponents** | • Mercedes-Benz  
  • Other luxury brands  
  • Volume OEMs | • Google, Uber, Lyft, Didi, Ola  
  • Fleet operators (taxi etc.)  
  • Some OEMs (Ford, GM) |
| **Advantages** | • Fewer accidents  
  • Time, space & privacy*  
  • Evolution from ADAS | • Fewer accidents  
  • Mobility to anyone  
  • Mobility to anything |
| **Implications** | • Driver license for HDC  
  • Some degree of CaaS? | • No driver license needed  
  • CaaS for nearly all people |
| **Summary** | • Cars to make drivers better | • Cars are better than drivers |

* Mercedes-Benz SDC positioning

SOURCE: IHS Automotive  
Autonomous Driving Portal
# Google SDC & DLC Success

<table>
<thead>
<tr>
<th>Key Information</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Highway Testing-L4</strong></td>
<td><img src="image" alt="L4 Cars since 2009" /> <img src="image" alt="L4: Now driving assertively" /> <img src="image" alt="Driven 880K+ miles" /> <img src="image" alt="Inch forward at 4-way stops" /></td>
</tr>
<tr>
<td><strong>L4 City Testing</strong></td>
<td><img src="image" alt="L4: Mostly in Mt. View, CA" /> <img src="image" alt="L4: Started in Austin, TX" /> <img src="image" alt="Driven 620K+ miles" /> <img src="image" alt="July 2015 (12 cars in Dec)" /></td>
</tr>
<tr>
<td><strong>L5 Pod Testing</strong></td>
<td><img src="image" alt="Initially restricted area tests" /> <img src="image" alt="June start in Mt. View (L4 mode)" /> <img src="image" alt="In Google’s restricted areas" /> <img src="image" alt="Sep 2015 start in Austin, TX" /></td>
</tr>
<tr>
<td><strong>Restricted Testing</strong></td>
<td><img src="image" alt="NASA Moffett Field (1,000 acres)" /> <img src="image" alt="Castle AF Base, Merced, CA" /> <img src="image" alt="60 year lease: Google projects" /> <img src="image" alt="L4 &amp; L5 tests on 100 acres" /></td>
</tr>
<tr>
<td><strong>Vehicles (Mar 31, 2016)</strong></td>
<td><img src="image" alt="23 Lexus RX450h SUVs" /> <img src="image" alt="33 Pod cars (L5 or L4 mode)" /> <img src="image" alt="Total self-driving miles: 1.5M" /> <img src="image" alt="SDC simulation &amp; modeling" /> <img src="image" alt="Mt. View-15; Austin-7; Kirkland-1" /> <img src="image" alt="Mt. View-24; Austin-7; Kirkland-2" /> <img src="image" alt="Self-driving miles/week: 12-15K" /> <img src="image" alt="3M miles/day; test new SW" /></td>
</tr>
<tr>
<td><strong>Next Steps</strong></td>
<td><img src="image" alt="Seattle-area &amp; Detroit-area tests" /> <img src="image" alt="Cooperative driving situations" /> <img src="image" alt="Lower crashes by other drivers" /> <img src="image" alt="Rain, snow &amp; bad weather" /> <img src="image" alt="4-way stops is first step" /> <img src="image" alt="SDC external info? What else?" /></td>
</tr>
</tbody>
</table>

**SOURCE:** IHS Automotive
# Google SDC-DLC Software

<table>
<thead>
<tr>
<th>Key Information</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Estimated Status</strong></td>
<td>Better than nearly all drivers—at least in fair weather driving&lt;br&gt;Lesser emergencies&lt;br&gt;Know common driver weaknesses</td>
</tr>
<tr>
<td><strong>Next Focus</strong></td>
<td>Finding and learning the once in a million events</td>
</tr>
<tr>
<td><strong>Key Problems</strong></td>
<td>Other drivers’ negative reaction&lt;br&gt;Other cars run into SDC-DLCs&lt;br&gt;Computer ethics?</td>
</tr>
<tr>
<td><strong>Next Steps</strong></td>
<td>Cooperative driving situations&lt;br&gt;Lower crashes by other drivers&lt;br&gt;Bad weather testing &amp; learning</td>
</tr>
</tbody>
</table>

**Key Question:**
How much better than the best drivers will DLC software need to be for deployment?
<table>
<thead>
<tr>
<th>Mobility Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Key Information</strong></td>
</tr>
<tr>
<td><strong>Car Sharing</strong></td>
</tr>
<tr>
<td>▶ Smartphone apps centric</td>
</tr>
<tr>
<td>▶ DLC lowers operating cost</td>
</tr>
<tr>
<td>▶ DLC fleets for car-sharing</td>
</tr>
<tr>
<td><strong>Other Information</strong></td>
</tr>
<tr>
<td>▶ Convenience &amp; availability</td>
</tr>
<tr>
<td>▶ No driver costs</td>
</tr>
<tr>
<td>▶ Likely first SDC deployment</td>
</tr>
<tr>
<td><strong>Car Ownership</strong></td>
</tr>
<tr>
<td>▶ Fewer cars/household when SDCs are fully available</td>
</tr>
<tr>
<td>▶ Higher miles per car year</td>
</tr>
<tr>
<td><strong>Other Information</strong></td>
</tr>
<tr>
<td>▶ USA currently: 2.1 cars/HH</td>
</tr>
<tr>
<td>▶ USA projected: 1.2 w/SDCs*</td>
</tr>
<tr>
<td>▶ Quicker replacement rate</td>
</tr>
<tr>
<td><strong>Car-as-a-Service Potential</strong></td>
</tr>
<tr>
<td>▶ Worldwide population</td>
</tr>
<tr>
<td>▶ People with driver license</td>
</tr>
<tr>
<td>▶ People w/o driver license</td>
</tr>
<tr>
<td>▶ Urban population</td>
</tr>
<tr>
<td>▶ Seniors (65+ years old)</td>
</tr>
<tr>
<td>▶ Youth (Under 18 years old)</td>
</tr>
<tr>
<td><strong>Other Information</strong></td>
</tr>
<tr>
<td>▶ 2015: 7.32B → 2035: 8.74B</td>
</tr>
<tr>
<td>▶ 2015: 1.13B → 2035: 1.9B</td>
</tr>
<tr>
<td>▶ 2015: 6.2B → 2035: 6.8B</td>
</tr>
<tr>
<td>▶ 2015: 4.1B → 2035: 5.7B</td>
</tr>
<tr>
<td>▶ 2015: 604M → 2035: 1.12B</td>
</tr>
<tr>
<td>▶ 2015: 2.26B → 2035: 2.36B</td>
</tr>
<tr>
<td><strong>Mass Transit</strong></td>
</tr>
<tr>
<td>▶ SDC for last mile service</td>
</tr>
<tr>
<td>▶ SDV for new mass transit</td>
</tr>
<tr>
<td>▶ SDV as mass transit</td>
</tr>
<tr>
<td><strong>Other Information</strong></td>
</tr>
<tr>
<td>▶ To fill mass transit gaps</td>
</tr>
<tr>
<td>▶ Less cost than mass transit</td>
</tr>
<tr>
<td>▶ Current system competition</td>
</tr>
</tbody>
</table>

* UMTRI study, February 2015
Connected Cars: Perspectives to 2025

- Auto Sales and Motorization
- Infotainment: Growing Platform Importance
- Connected Cars: Opportunities & Threats
- Self-driving Cars vs. Driverless Cars: Revolution
- Summary Perspectives

Egil Juliussen, Ph.D. Director Research & Principal Analyst
New Auto Industry Competition

Current Competition

- OS & MW
- OTA SW Update
- ADAS SW
- Ride Sharing: Smartphone App-based
- Phone Projection CarPlay, AA, ML
- Virtual Mobility Telecommuting. E-commerce, etc.

Future Competition

- SDC & DLC SW SDC Maps
- New EV-based Auto OEMs
- DLC-based CaaS Fleets
- Mobility Service for Non-Driver & Packages

Auto Industry
- Infotainment
- Cloud Content
- Connected Car
- Software-centric
- ADAS → SDC
- Mobility-centric
- ICE → EV

OS=Operating System; MW=Middleware; OTA=Over-the-Air; ICE=Internal Combustion Engine; SW=Software; SDC=Self-Driving Car; DLC=Driverless Car; CaaS=Car-as-a-Service; AA=Android Auto; ML=MirrorLink

SOURCE: IHS Automotive
Connected Car by 2020+

OBDII Device W/wo Wireless

AM Device(s) W/wo Wireless

Wi-Fi, BT 3G to 4G

Wi-Fi, BT 3G to 4G

Core Auto ECUs

Infotainment ECUs

Devices in & around Car

Wearable Devices

Cloud Content

Data Plan & Embedded 4.5G

BT 4.2

BT Smart 4.2

Wi-Fi or USB

Tablet-based RSE

Smartphone Apps

Integration & Data Plan

• Software upgrades via Ethernet network to all ECUs in car?
• Secure, ECU software distribution system

Embedded links: from shared to separate

© 2016 IHS Automotive
Connected cars are the halfway point on a journey from simple and rare telematics use, to self-driving cars with required, multiple and constant connections over secure wireless links.

**Telematics**
- 1G Analog
- Speed: Kbps
- Safety-Security
- Available: Rare

**LTE Connected**
- 4G LTE: Mbps
- Multiple connections
- Apps & cloud content
- Connections: Common

**Connected SDC-DLC**
- 5G: Gbps
- Secure connections
- Any apps & content
- Connections: Required
- Car-as-a-Service

Connected cars create new challenges: cyber-security.

Kbps-Mbps-Gbps=Kilo-Mega-Giga bits per second; SDC=Self-Driving Car; DLC=Driverless Car

SOURCE: IHS Automotive
Software-Defined Car Evolution

The car is the most complex product in volume production!

- Analog Car Era
  - Analog control systems

- Analog-Digital Car Era
  - Digital control system growth
  - ECU

- Digital Car Era
  - Platform architecture
  - Re-usable software
  - AUTOSAR
  - Remote Diagnostics
  - Software APIs

- Connected Car
  - Remote SW Upgrades
  - Software security

- Self-Driving Car
  - Software-defined car
  - Car-as-a-Service

Next 20 Year HW Improvements
- MCU performance: 400 times
- Memory chip: 32,000 times

Tesla is first SW-defined car

SOURCE: IHS Automotive
Questions?

Egil Juliussen, Ph.D. Research Director, Principal Analyst, IHS Automotive Technology
April 27, 2016
egil.juliussen@ihs.com