



IHS Markit™

# Automotive Software: Trends, Importance & Opportunities

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# Who Is IHS Markit?

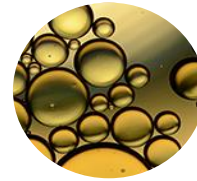
- ▶ Merger of IHS and Markit in July 2016
- ▶ Public company on NASDAQ: Symbol is INFO
- ▶ Market cap in \$16B range
- ▶ Over 12,500+ employees; Revenue \$3.4B+
- ▶ Industries IHS Markit serves:



Financial Markets



Energy



Chemical



**Automotive**



Aerospace,  
Defense & Security



Product Design

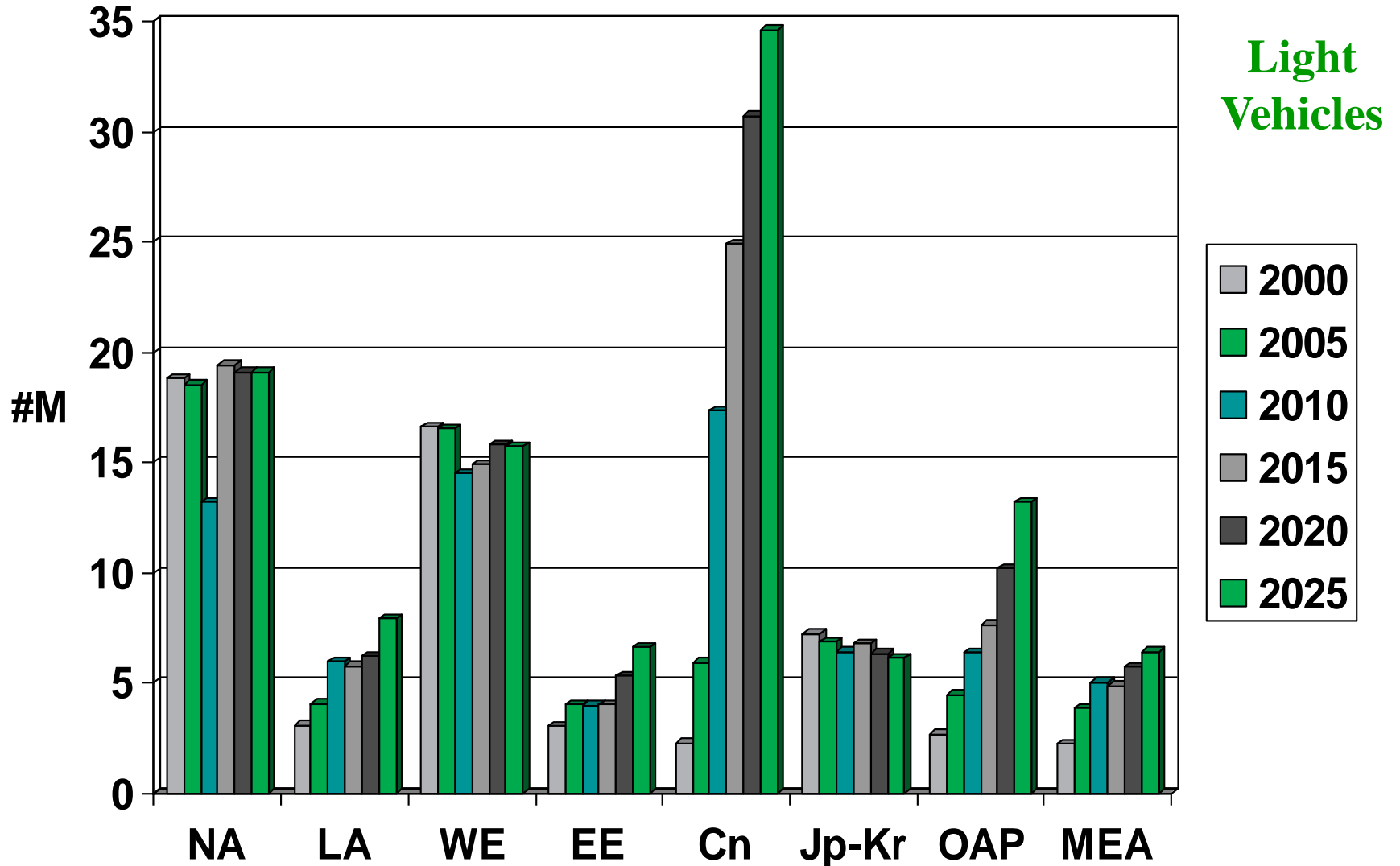


Technology, Media  
& Telecom



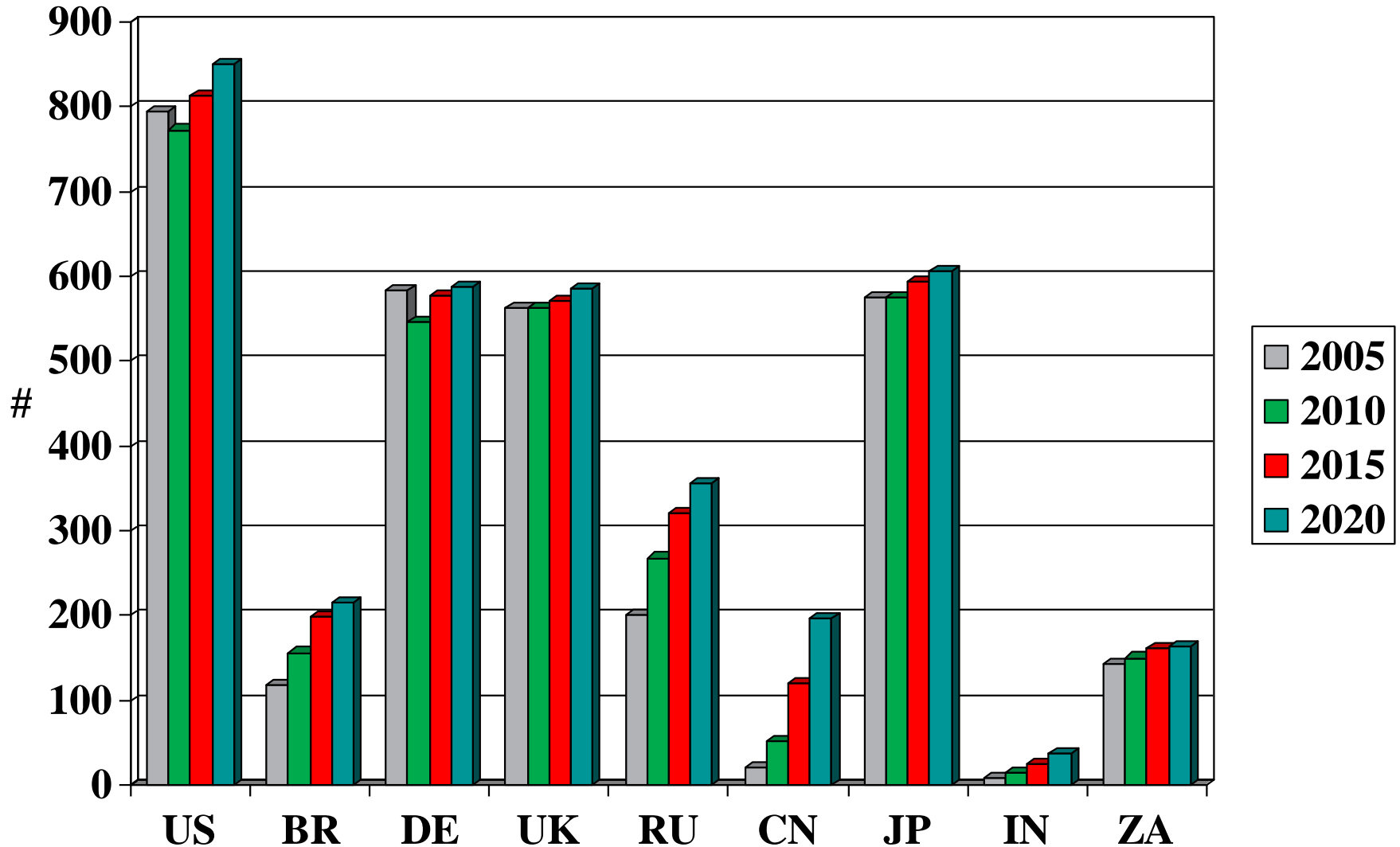
Maritime & Trade

# Regional Auto Sales (Millions)



LA=Latin America; WE=West Europe; EE=East Europe; CN=China; Jp-Kr=Japan-S. Korea; OAP=Other Asia; MEA=Middle East-Africa

# Motorization: Autos In-Use per 1,000 People



BR=Brazil; DE=Germany; RU=Russia; CN=China; Jp=Japan; IN=India; ZA=South Africa

# Automotive Technology Megatrends

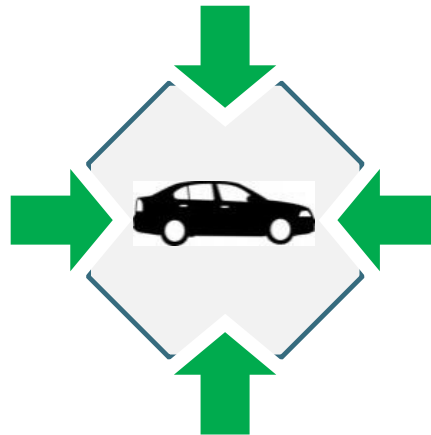
Implications for the Global Automotive Industry

**Impact of high-tech industry: Suppliers & competitors**

**ACES=Autonomous-Connected-Electric-Software**

4 technologies that opens auto industry to newcomers

**Autonomous Driving:**  
Major new opportunities  
Disruptive business models  
Vast MaaS prospects



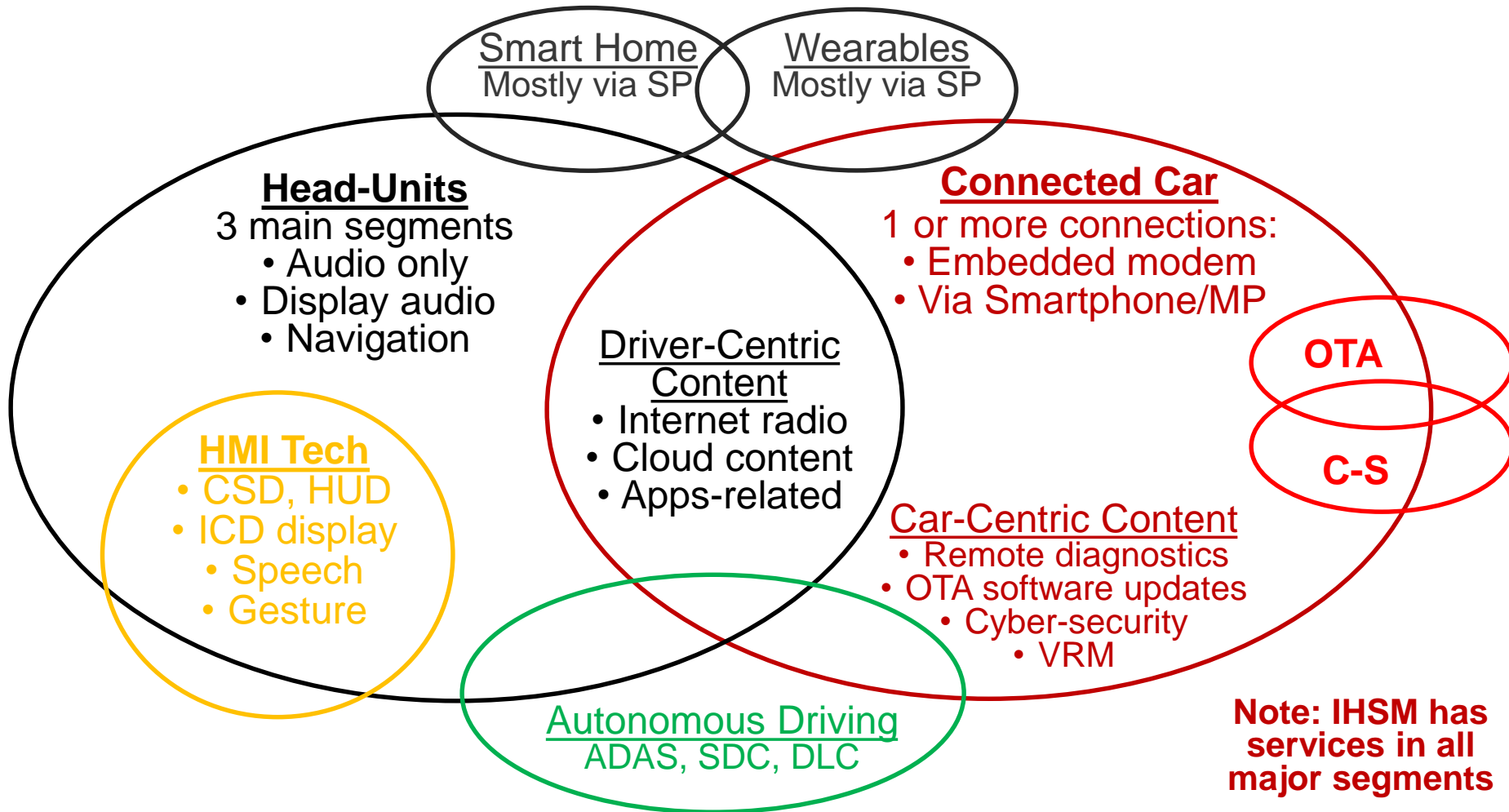
**Connected cars:**  
New products & competitors  
New content & cloud services  
Opportunities for newcomers

**Battery Electric Vehicles:**  
Newcomers: No ICE expertise needed  
Risk-takers with lots of \$  
Disruption as battery cost declines

**Software:**  
New products & opportunities  
Software & cloud platforms  
ACE opportunities newcomers

**ICE=Internal Combustion Engine; MaaS=Mobility-as-a-Service**

# Connected Car Segments



MP=Mobile Phone; SP=Smartphone; CSD=Center Stack Display; ICD=Instrument Cluster Display; HUD= Head-Up Display; VRM=Vehicle Relationship Management; SDC=Self-Driving Car; DLC=Driverless Car; OTA=Over-the-Air; C-S=Cyber-Security; SP=Smartphone

## 4 Factors Are Increasing High-Tech Impact

	Key Information	Comments
Software Complexity	<ul style="list-style-type: none"> <li>▶ Advanced OS for infotainment</li> <li>▶ Re-usable software platforms</li> <li>▶ Agile software development</li> <li>▶ Deep-learning software</li> <li>▶ Driverless car software</li> </ul>	<ul style="list-style-type: none"> <li>▶ Mostly high-tech expertise</li> <li>▶ Decades of use in high-tech</li> <li>▶ Pioneered by high-tech</li> <li>▶ High-tech industry leads</li> <li>▶ Google is leader; start-ups</li> </ul>
Connected Car Eco-System	<ul style="list-style-type: none"> <li>▶ Communication networks</li> <li>▶ Apps and content</li> <li>▶ Cloud content &amp; interactions</li> <li>▶ Remote software update</li> <li>▶ Cyber-security (HW &amp; SW)</li> </ul>	<ul style="list-style-type: none"> <li>▶ From telecom industry only</li> <li>▶ Android &amp; iPhone HMI wanted</li> <li>▶ Mostly Internet industry</li> <li>▶ Mostly high-tech expertise</li> <li>▶ High-tech expertise only</li> </ul>
Electric Vehicle	<ul style="list-style-type: none"> <li>▶ Electric motor skills are common</li> <li>▶ Battery is high-tech expertise</li> <li>▶ BEV opens door for new OEMs</li> </ul>	<ul style="list-style-type: none"> <li>▶ ICE dominated by auto OEMs</li> <li>▶ Minimal auto OEM advantages</li> <li>▶ ICE too costly for new OEMs</li> </ul>
Maturing High-Tech	<ul style="list-style-type: none"> <li>▶ New big opportunities needed</li> <li>▶ Want new segments to disrupt</li> </ul>	<ul style="list-style-type: none"> <li>▶ Slow growth in most segments</li> <li>▶ Few big high-tech opportunities</li> </ul>

ICE=Internal Combustion Engine; SW=Software

# Automotive Software Overview

**Software is pure digital and have different characteristics**

## Create

- Very expensive
- Long development
- Difficult testing
- New technologies
- Never bug-free

## Make

- No SW BoM cost
- Some royalty costs
- Mfg.=SW loading
- Loading flexibility

## Market/Sell

- SW=car features
- Features sell cars
- SW → connected car
- SW is upgradable
- SW → apps & cloud

## Car Use

- Bug-fixing needed
- SW maintenance
- Connected car growth
- OTA SW updates
- Cyber-security defense

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



# Software Life Stages

	Key Information	Comments
Software Design	<ul style="list-style-type: none"> <li>▶ SW architecture based on specs</li> <li>▶ Specify language, performance</li> </ul>	<ul style="list-style-type: none"> <li>▶ Effort is about <b>30%</b> of total</li> <li>▶ Key to get reliable program</li> </ul>
Software Coding	<ul style="list-style-type: none"> <li>▶ Program is coded as per design</li> <li>▶ Object oriented design needed</li> </ul>	<ul style="list-style-type: none"> <li>▶ Effort is about <b>30%</b> of total</li> <li>▶ Error check tools emerging</li> </ul>
Software Testing	<ul style="list-style-type: none"> <li>▶ Hardest part of development</li> <li>▶ Automated tools emerging</li> </ul>	<ul style="list-style-type: none"> <li>▶ Effort is about <b>40%</b> of total</li> <li>▶ Key to software reliability</li> </ul>
SW Release	<ul style="list-style-type: none"> <li>▶ Software is ready for deployment</li> </ul>	<ul style="list-style-type: none"> <li>▶ Usually gets a version #</li> </ul>
Software Mfg.	<ul style="list-style-type: none"> <li>▶ Object code loaded into memory</li> <li>▶ Wi-Fi loading emerging</li> </ul>	<ul style="list-style-type: none"> <li>▶ During car manufacturing</li> <li>▶ Wi-Fi provides flexibility</li> </ul>
Software Maintenance	<ul style="list-style-type: none"> <li>▶ Find and correct errors</li> <li>▶ Re-release program; Version #X</li> </ul>	<ul style="list-style-type: none"> <li>▶ Based on field usage</li> <li>▶ OTA update emerging</li> </ul>
Software Update	<ul style="list-style-type: none"> <li>▶ Update latest version</li> <li>▶ Repeat all steps above</li> </ul>	<ul style="list-style-type: none"> <li>▶ Improved functions</li> <li>▶ Usually for a new project</li> </ul>

OTA=Over-the-Air

# Software Life Cycle Example: Infotainment

Software Create Phase		
<u>SW Design</u> <ul style="list-style-type: none"> <li>• 30% of total</li> <li>• \$9M</li> </ul>	<u>SW Coding</u> <ul style="list-style-type: none"> <li>• 30% of total</li> <li>• \$9M</li> </ul>	<u>SW Testing</u> <ul style="list-style-type: none"> <li>• 40% of total</li> <li>• \$12M</li> </ul>
<p><b>Infotainment system development cost=\$30M</b>  <b>Around 3 year development time</b>  <b>Assume production volume of 200K units</b></p>		

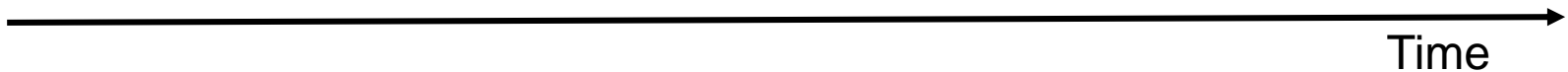
Production

- BoM=\$60 range
- Royalty & IP
- Total=\$12M
- 200K units

Use Phase

- Bug fixes: 2%/yr.
- \$0.6M/yr. for 5 yrs.
- Or \$3M total
- Bugs+Updates: 10%
- \$3M/yr. for 5 yrs.
- Or \$15M total
- SW recall estimate:
- \$200 per car or
- \$20M for 200K cars
- OTA: < \$10M

Note: Typical software development cost is up to **\$30 per line of code** and has not changed much in last 40 years



# Auto Software Complexity Path

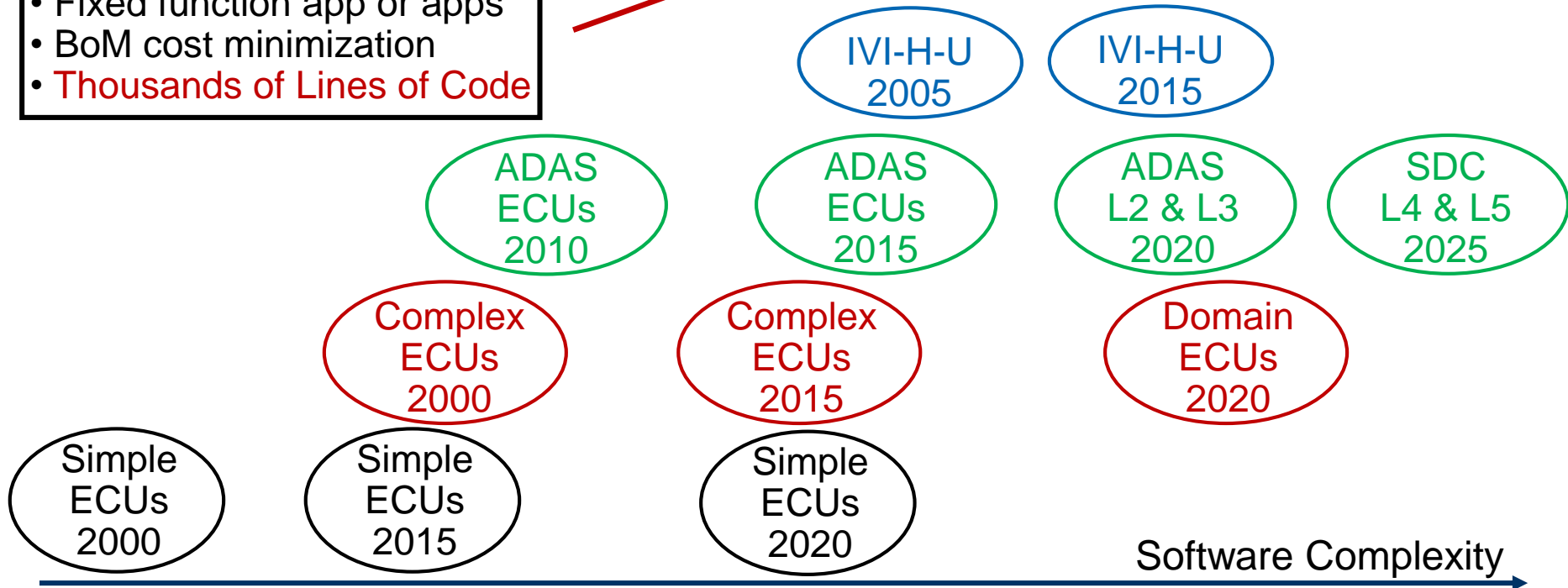
**“Embedded Controllers”**

- Simple SW control program
- Fixed middleware
- Fixed function app or apps
- BoM cost minimization
- **Thousands of Lines of Code**

10X-100X  
Complexity

**“Apps Computers”**

- Complex operating system
- Computer middleware
- Industry-specific middleware
- Multiple changeable apps
- **Millions of Lines of Code**



BoM=Bill of Material; SDC=Self-Driving Car; ECU=Electronic Control Unit; IVI=In-Vehicle Infotainment

# Google SDC-DLC Software

	Key Information	Comments
Estimated Status	<ul style="list-style-type: none"> <li>▶ Better than nearly all drivers—at least in fair weather driving</li> <li>▶ Fewer emergencies</li> <li>▶ Know common driver weaknesses</li> </ul>	<ul style="list-style-type: none"> <li>▶ Faster reaction time, never tired, never distracted, superior object tracking capabilities</li> <li>▶ From 2.5M miles in SDC mode</li> </ul>
Next Focus	<ul style="list-style-type: none"> <li>▶ Finding and learning the once in a million events (Edge cases)</li> </ul>	<ul style="list-style-type: none"> <li>▶ Google has active projects to identify such events</li> </ul>
Key Problems	<ul style="list-style-type: none"> <li>▶ Other drivers' perplexed reaction</li> <li>▶ Other cars run into SDC-DLCs</li> <li>▶ Computer ethics?</li> </ul>	<ul style="list-style-type: none"> <li>▶ SDC-DLC follow all laws!</li> <li>▶ SDC driving style too different</li> <li>▶ Different views on its impact</li> </ul>
Future Steps	<ul style="list-style-type: none"> <li>▶ More testing (Detroit likely)</li> <li>▶ Software qualification path</li> <li>▶ Driver license test for software</li> </ul>	<ul style="list-style-type: none"> <li>▶ Rain, snow &amp; bad weather</li> <li>▶ Government rules needed</li> <li>▶ Another set of rules needed</li> </ul>

## Key Questions:

How much better than average driver will DLC software need to be for deployment?  
 What is acceptable ratio for lives saved vs. lives lost due to imperfect software? **10?**

## Google-Waymo Disengagement Statistics: 2016

Disengagement Type	Number	Percent
Software discrepancy	51	41.1%
Unwanted vehicle maneuver	30	24.2%
Perception discrepancy	20	16.1%
Incorrect prediction of road user behavior	6	4.8%
Reckless road users	10	8.1%
Construction zone	2	1.6%
Emergency vehicle	2	1.6%
Debris in roadway	2	1.6%
Weather conditions	1	0.8%
<b>Total disengagements</b>	<b>124</b>	<b>100%</b>

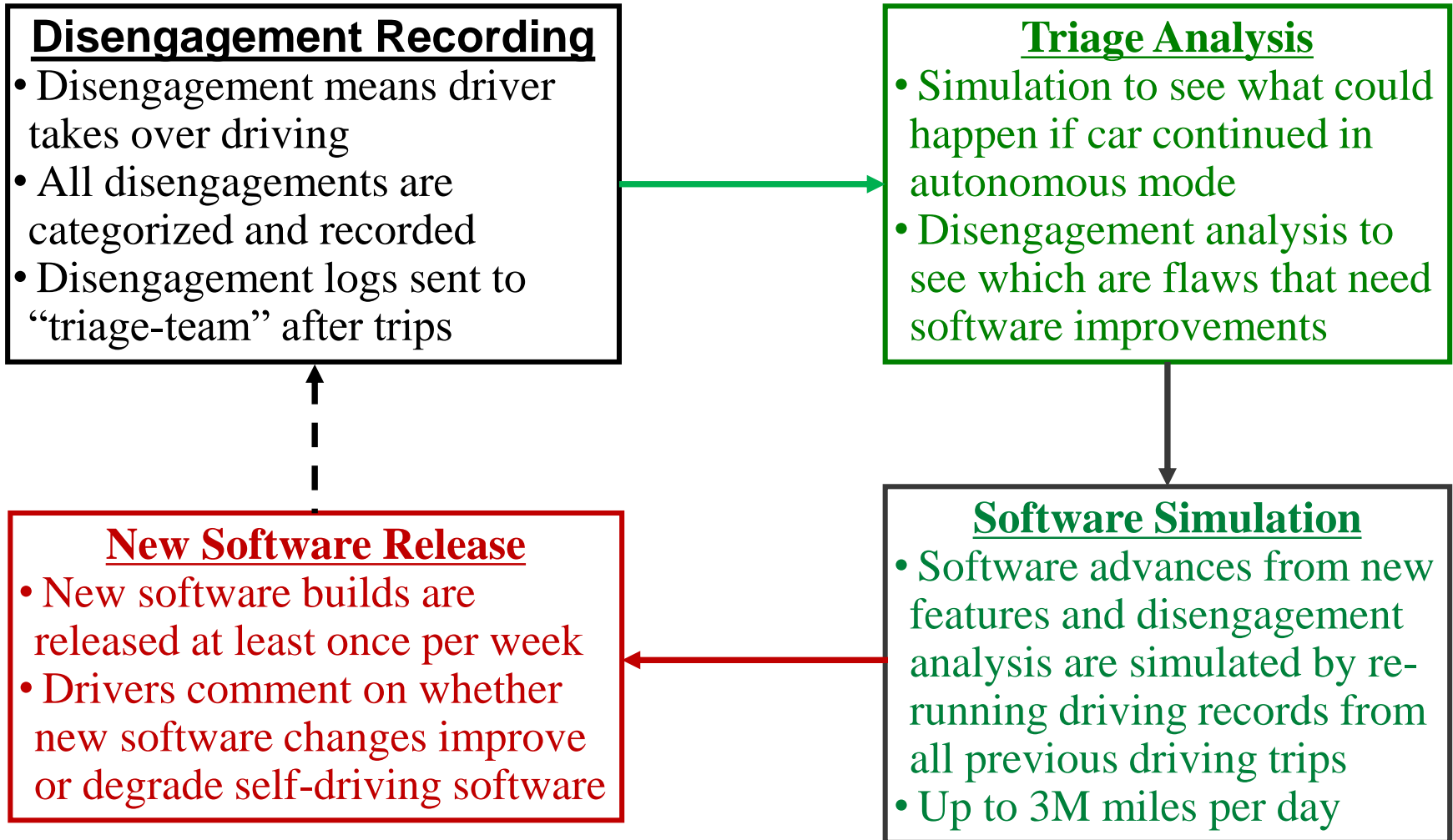
Source: Waymo via CA DMV

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- Google 2016 data: 636K miles; 124 disengagements → **5,128 miles per disengagement**
- Google 2015 data: 424K miles, 341 disengagements → **1,244 miles per disengagement**

Source: [https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/disengagement\\_report\\_2016](https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/disengagement_report_2016)

# Google's DLC Software Advances



# Automotive Software: Big Picture

## Software-Defined Car Era

- Driverless car fleet mobility
- Self-driving & driverless car software
- Always connected car software
- Cloud-centric software & service
- Cybersecurity & OTA updates

## Software Platform Era

- Software platform ecosystems
- Software development savings
- Software royalty opportunities
- Cloud & SW-service opportunities
- Software connections to many devices

## Embedded Software Era

- AUTOSAR as crowning success
- Auto industry proficiency
- Relatively small programs
- ECUs with embedded software

Past

Current

Future



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May 10, 2017



# Software Opportunity Perspectives

	Software Opportunities	Comments
Software Suppliers	<ul style="list-style-type: none"> <li>▶ Software royalties per car sold</li> <li>▶ SW development revenue</li> <li>▶ SW maintenance service</li> <li>▶ Services to connected cars</li> </ul>	<ul style="list-style-type: none"> <li>▶ \$1-3/car to \$20 range per car</li> <li>▶ SW “tailoring” to OEM auto model</li> <li>▶ Bug fixing and SW feature updates</li> <li>▶ OEM IT server software (SaaS)</li> </ul>
Tier 1 Suppliers	<ul style="list-style-type: none"> <li>▶ SW development revenue</li> <li>▶ SW maintenance service</li> <li>▶ Services to connected cars</li> <li>▶ SW expertise to retain business</li> <li>▶ Expertise to gain new business</li> </ul>	<ul style="list-style-type: none"> <li>▶ SW “tailoring” to OEM auto model</li> <li>▶ Bug fixing and SW feature updates</li> <li>▶ OEM IT server software (SaaS)</li> <li>▶ Retain HW manufacturing business</li> <li>▶ SW tech is key to win new business</li> </ul>
Auto OEMs	<ul style="list-style-type: none"> <li>▶ SW development savings</li> <li>▶ Operational cost savings</li> <li>▶ Cost avoidance</li> <li>▶ Software functional updates</li> <li>▶ New software capabilities</li> <li>▶ SW functionality sells cars</li> </ul>	<ul style="list-style-type: none"> <li>▶ Re-usable software platforms</li> <li>▶ Remote diagnostics, OTA, analytics</li> <li>▶ Cybersecurity: avoid recalls &amp; hacks</li> <li>▶ New revenue opportunity via OTA</li> <li>▶ To get new and/or retain customers</li> <li>▶ Competition requires new features</li> </ul>

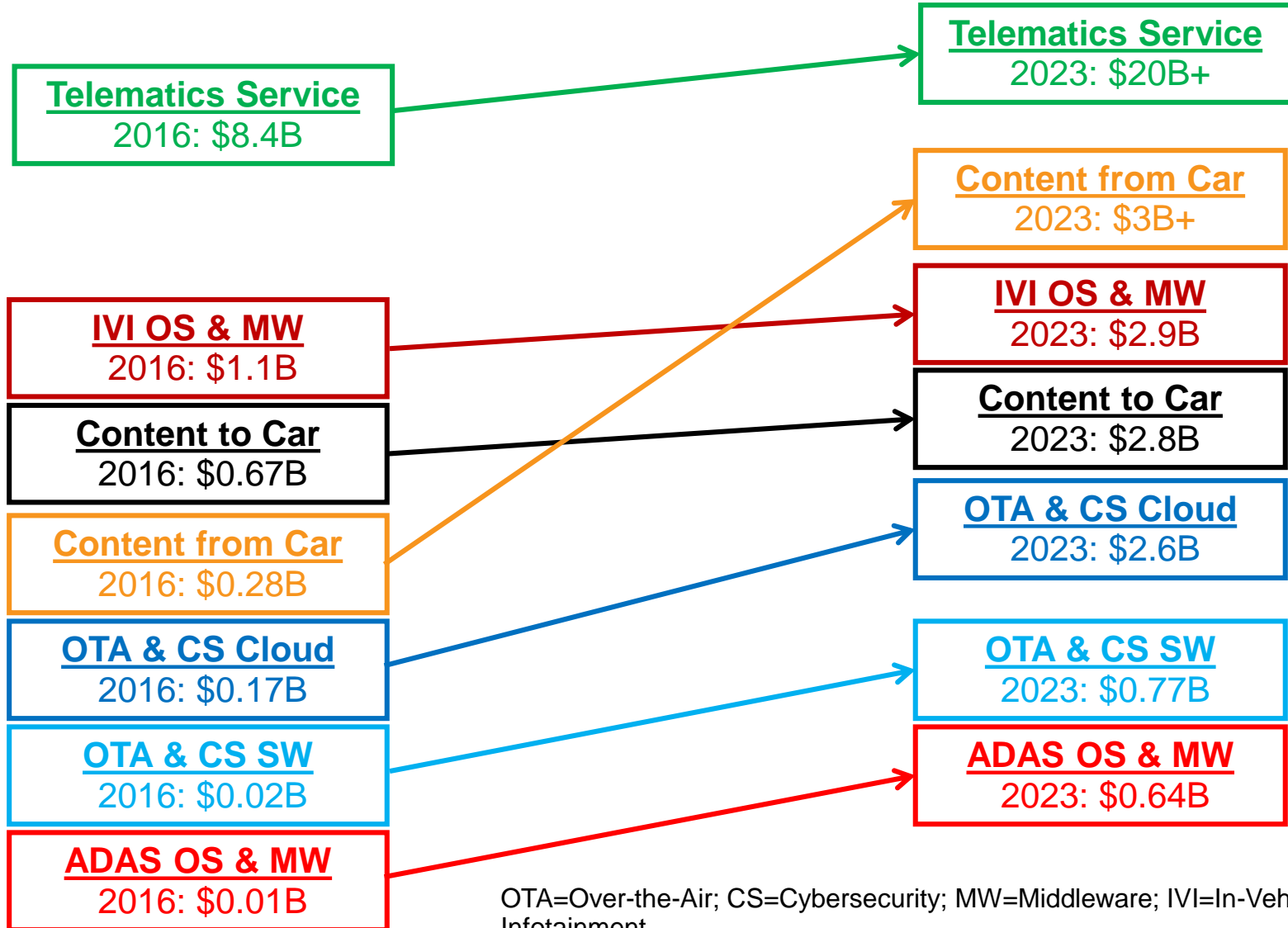
SaaS=Software-as-a-Service; OTA=Over-the-Air, SW=Software

# Software Suppliers' Opportunities

	Software Clients	SaaS & Cloud Software
Features	<ul style="list-style-type: none"> <li>▶ Software sold with cars</li> <li>▶ Many different segments</li> <li>▶ In every ECU: 1 or more</li> </ul>	<ul style="list-style-type: none"> <li>▶ Services to connected cars</li> <li>▶ Via in-car modem &amp; Smartphone</li> <li>▶ New segments emerging</li> </ul>
Connected Car & Infotainment	<ul style="list-style-type: none"> <li>▶ Operating system (OS)</li> <li>▶ OS &amp; auto middleware</li> <li>▶ Speech recognition</li> <li>▶ Navigation &amp; map database</li> <li>▶ OTA &amp; cybersecurity</li> </ul>	<ul style="list-style-type: none"> <li>▶ Telematics: car-centric</li> <li>▶ Telematics: driver-centric</li> <li>▶ Smartphone apps-based</li> <li>▶ Big data analytics</li> <li>▶ OTA &amp; cybersecurity SaaS</li> </ul>
ADAS & Autonomous Driving	<ul style="list-style-type: none"> <li>▶ Operating system (OS)</li> <li>▶ OS &amp; auto middleware</li> <li>▶ ADAS applications</li> <li>▶ OTA &amp; cybersecurity</li> <li>▶ SDC-DLC software</li> </ul>	<ul style="list-style-type: none"> <li>▶ Sensor big data analytics</li> <li>▶ OTA software update SaaS</li> <li>▶ Big data analytics; Cloud sensor fusion</li> <li>▶ Cybersecurity SaaS</li> <li>▶ Rapid functionality updates</li> </ul>
ECUs for Driving Control	<ul style="list-style-type: none"> <li>▶ AUTOSAR software</li> <li>▶ ECU applications</li> <li>▶ OTA &amp; cybersecurity</li> </ul>	<ul style="list-style-type: none"> <li>▶ Remote diagnostics analytics</li> <li>▶ Mostly OEM &amp; T1 opportunities</li> <li>▶ OTA &amp; cybersecurity SaaS</li> </ul>

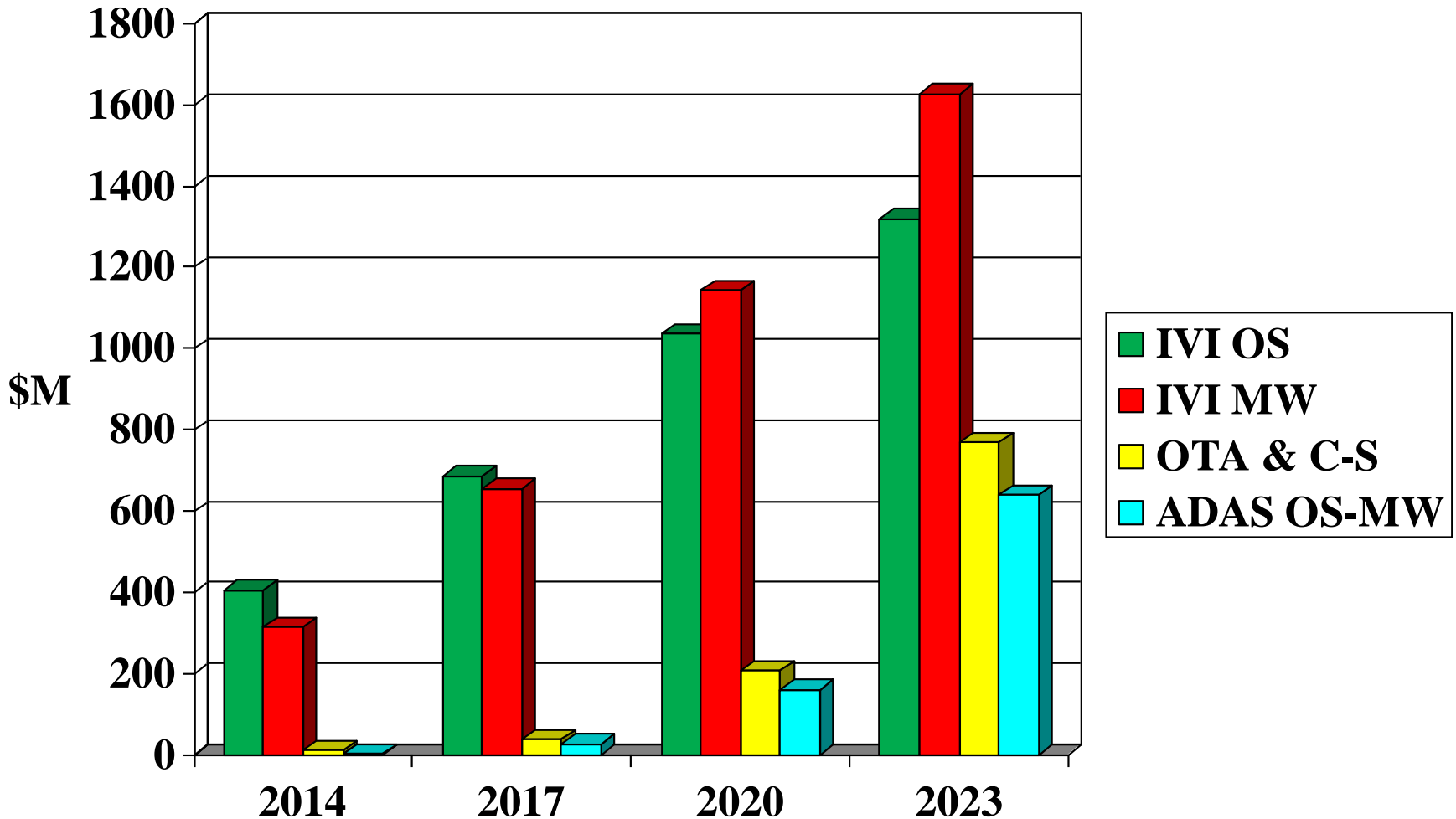
SaaS=Software-as-a-Service; OTA=Over-the-Air; SW=Software

# Auto Software & Service Opportunities: Big Picture



OTA=Over-the-Air; CS=Cybersecurity; MW=Middleware; IVI=In-Vehicle Infotainment

# Software Royalty Opportunity Scenario



# Auto Industry: Software Picture

## Software is pure digital and have different characteristics

### Create

- Very expensive
- Long development
- Difficult testing
- New technologies
- Never bug-free

### Make

- No SW BoM cost
- Some royalty costs
- Mfg.=SW loading
- Loading flexibility

### Market/Sell

- SW=car features
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### Car Use

- Bug-fixing needed
- SW maintenance
- Connected car growth
- OTA SW updates
- Cyber-security defense

## Software and apps impact all phases of most product

Good SW creation tools are required  
Better SW testing tools are needed

Minimal software cost for manufacturing  
SW make function can be re-done at low cost

New features are primarily via software  
Good/bad HMI is mostly based on software skills

High-tech influence  
Cyber-security threat  
SW recall growth  
SW features updates

### 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

### Re-usable software:

- Software platforms that are modified/updated for use with other car models
- Saves development cost and time and has fewer bugs. Benefits of platforms

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

# Automotive Software Opportunities

## For OEMs:

- Platforms: Development cost savings
- OTA-CS: Operational cost savings
- Connected car & Smartphone apps use
- Path to autonomous driving: SDC-DLC
- SW: Key to retain its auto leadership

## For Tier 1s:

- Platform: Development cost savings
- SW: Key to retain business
- SW: Key to get new business
- SW: Key to keep HW mfg. business
- SW expertise decides future success

## Automotive Software Market

- SW platforms → Dominant technology
- Standalone software → Cloud-centric
- Software as Product → Software as Service
- SW Dev. Method: Waterfall → Agile
- Connected SW: OTA, CS, BD Analytics
- Tech: Deep Learning & Cloud-based platforms

## For Software Suppliers:

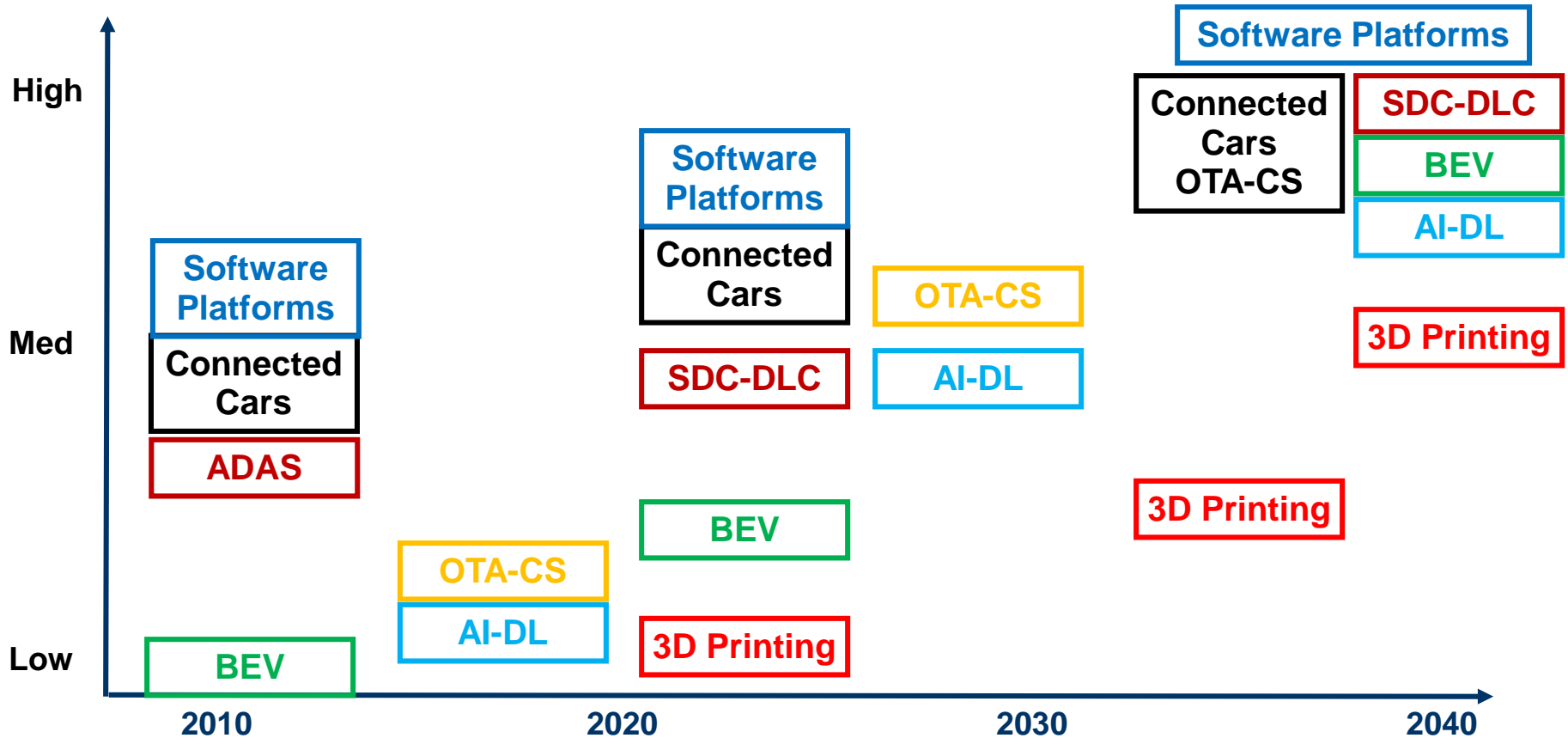
- Platform: Ecosystem & more business
- SW royalty: steady business model
- SW-cloud-service: better business model

## For High Tech:

- Auto SW: New opportunities
- Auto SW: Cloud-based SaaS
- SW: Business model disruption

OTA=Over-the-Air; CS=Cybersecurity; BD=Big Data; SW=Software; SaaS=Software-as-a-Service

# Technology Impact on Auto Industry



AI=Artificial Intelligence; DL=Deep Learning; BEV=Battery EV; CS=Cyber Security; OTA=Over-the-Air

**Takeaway:** Tremendous technology changes are impacting auto industry for decades to come

# 40 Year Forecast 😊

In 2057, if you live in an urban area, you will need to go to a driving track to drive your own car!

Just like you do with horses today.

**Egil Juliussen, Ph.D. Director of Research & Principal Analyst**



THANK YOU!

ありがとうございます

謝謝

감사합니다

धन्यवाद

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