

# Connected Cars: Perspectives to 2025

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IHS Automotive Technology

[ihs.com](http://ihs.com)

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**IHS AUTOMOTIVE**  
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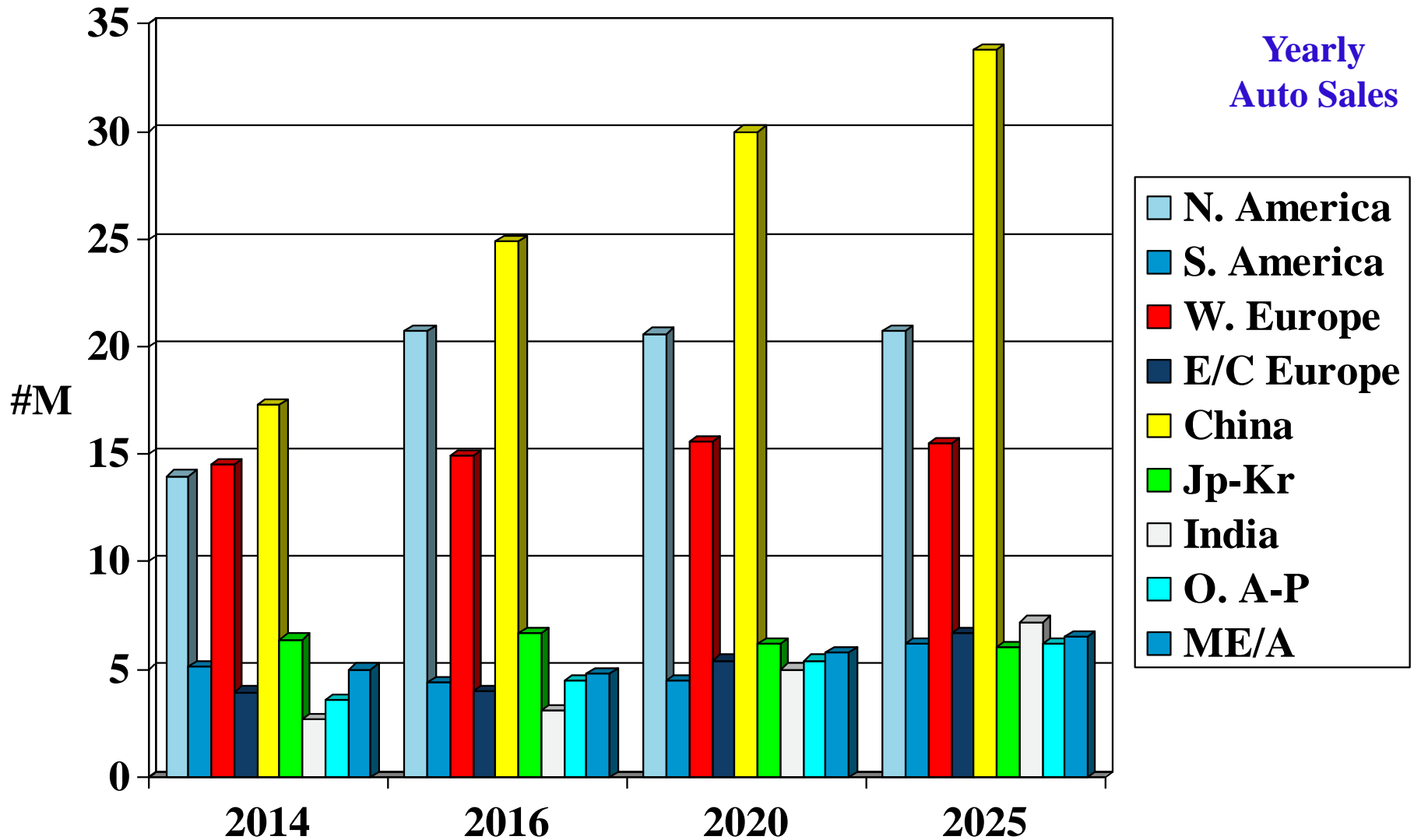


# Connected Cars: Perspectives to 2025

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

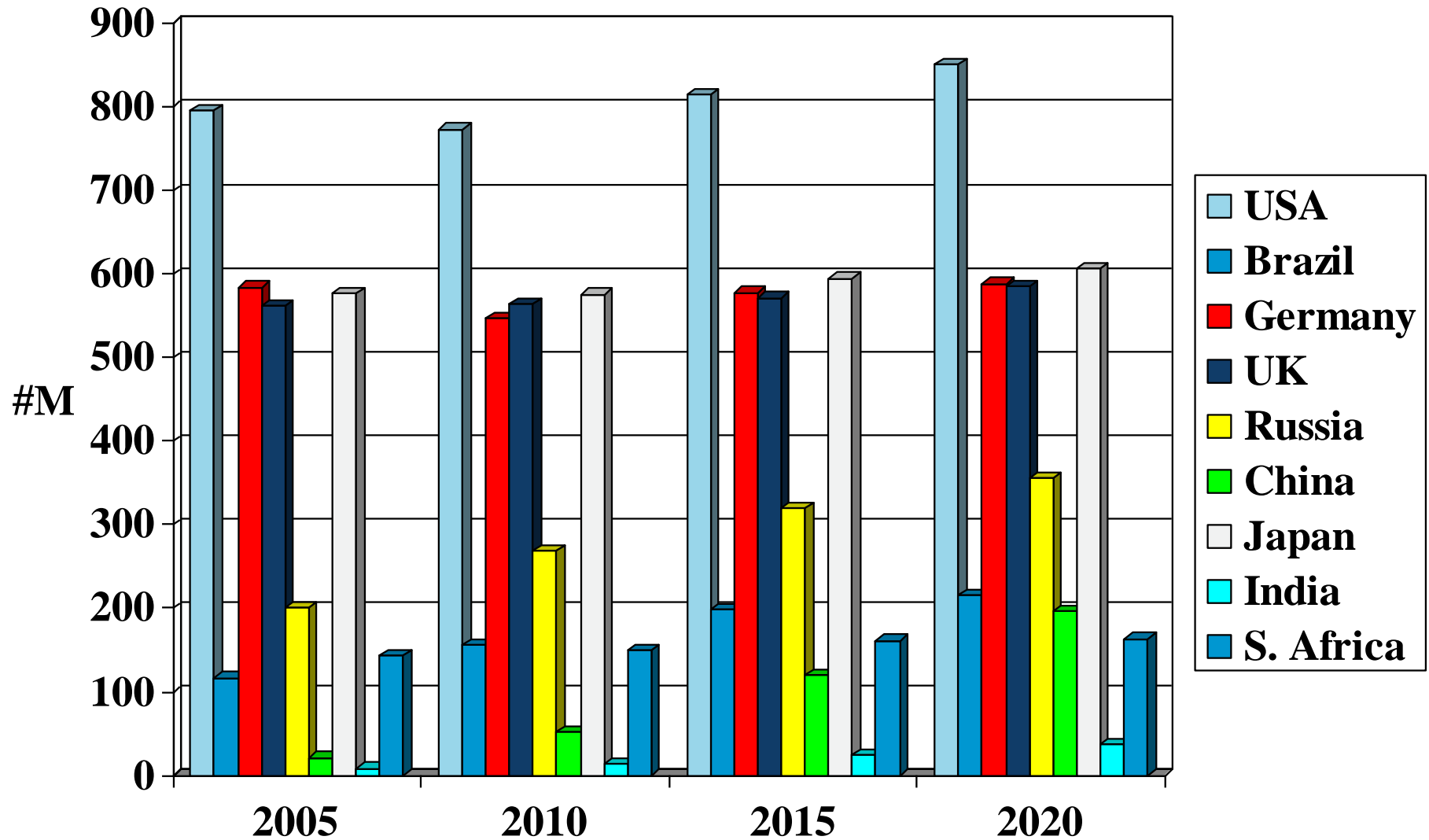
**Egil Juliussen, Ph.D. Director Research & Principal Analyst**

# Auto Sales by Region



IHS March 2016 light vehicle forecast

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



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# 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: 36X

### 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:

## Create

- Product idea
- Technology R&D
- Product design
- Product testing

## Make

- Factory control
- Parts management
- Supplier mgmt.
- Inventory mgmt.

## Market

- Product marketing
- Product sales
- Distribution channels
- Delivery logistics

## Product Use

- Payment systems
- Customer support
- Warranty & repair
- Repeat customers

**Software and apps impact all phases of most product**

## Create

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

## Make

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

## Market

- SW=features
- Features sell cars
- SW is upgradable
- Upgradable features

## Car Use

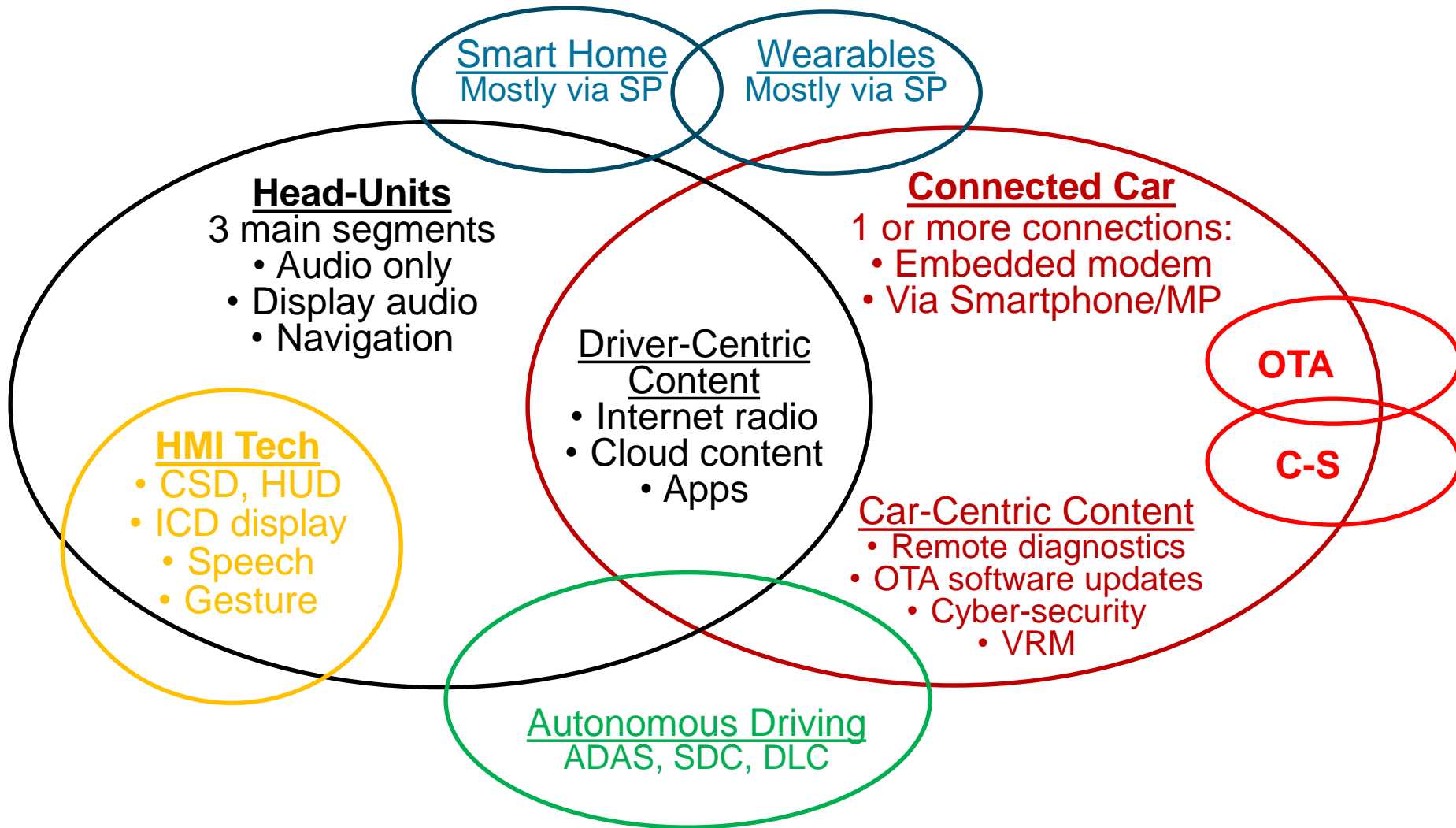
- Bug-fixing needed
- SW maintenance
- Connected car growth
- OTA SW updates

**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

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

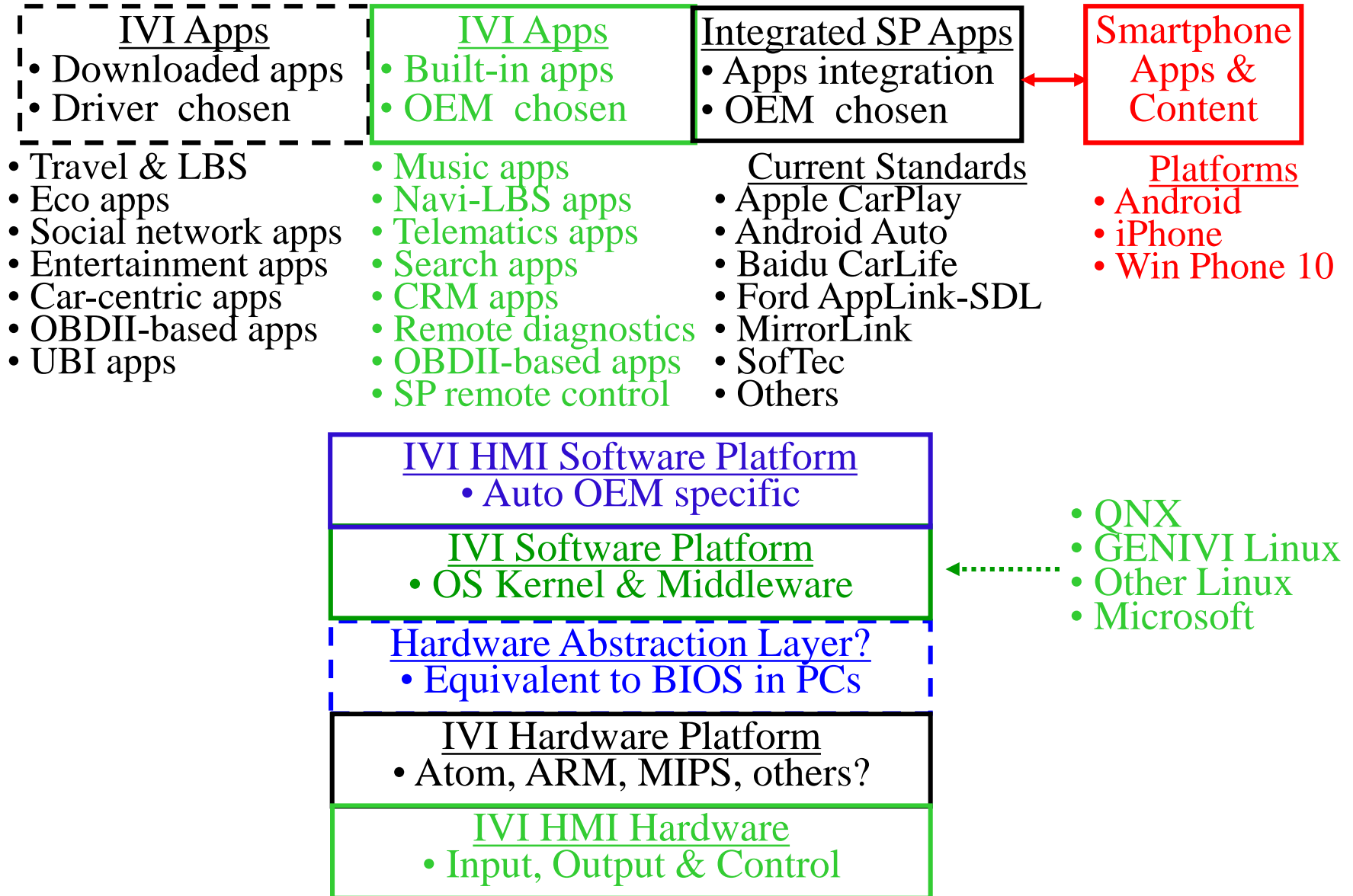
# Infotainment: Connected Car vs. Head-Unit



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



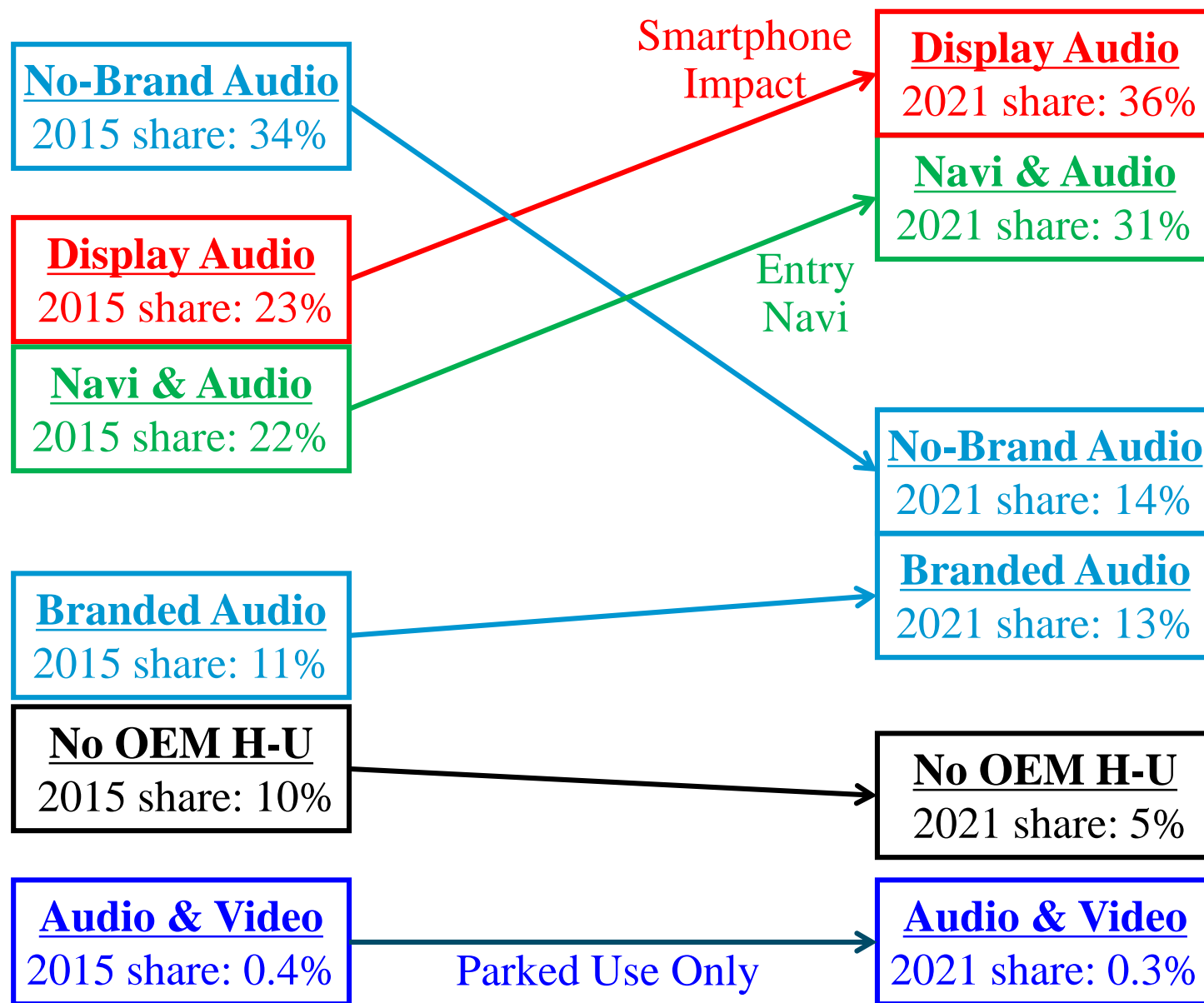
# Infotainment Apps: Big Picture



# Head-Unit System Trends



Navi & LBS  
are key SP  
Apps



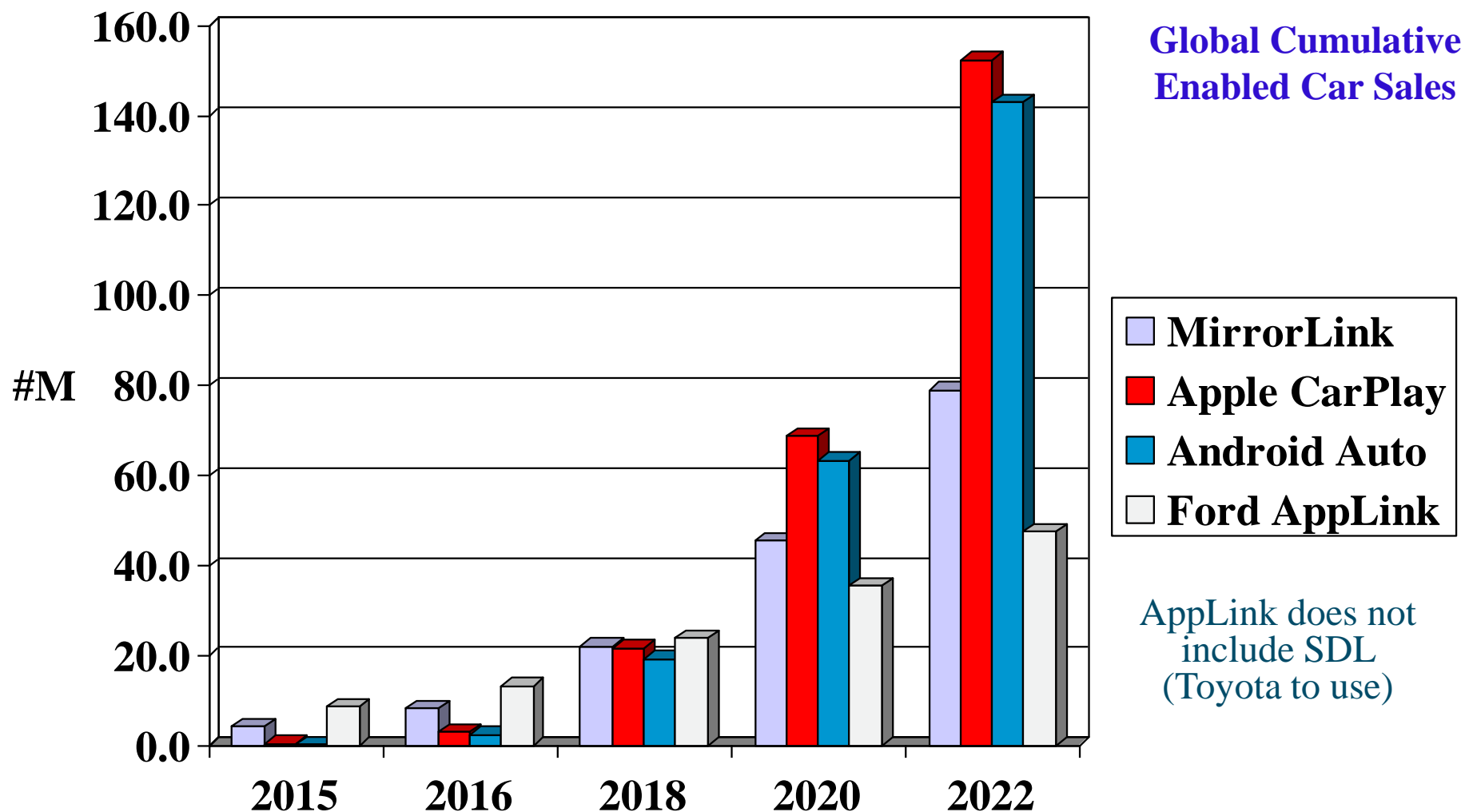
# Smartphone Apps Integration: Status



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

SDL=Smart Device Link; SP=Smartphone; OS=Operating System

# Smartphone Apps Integration: Enabled Autos



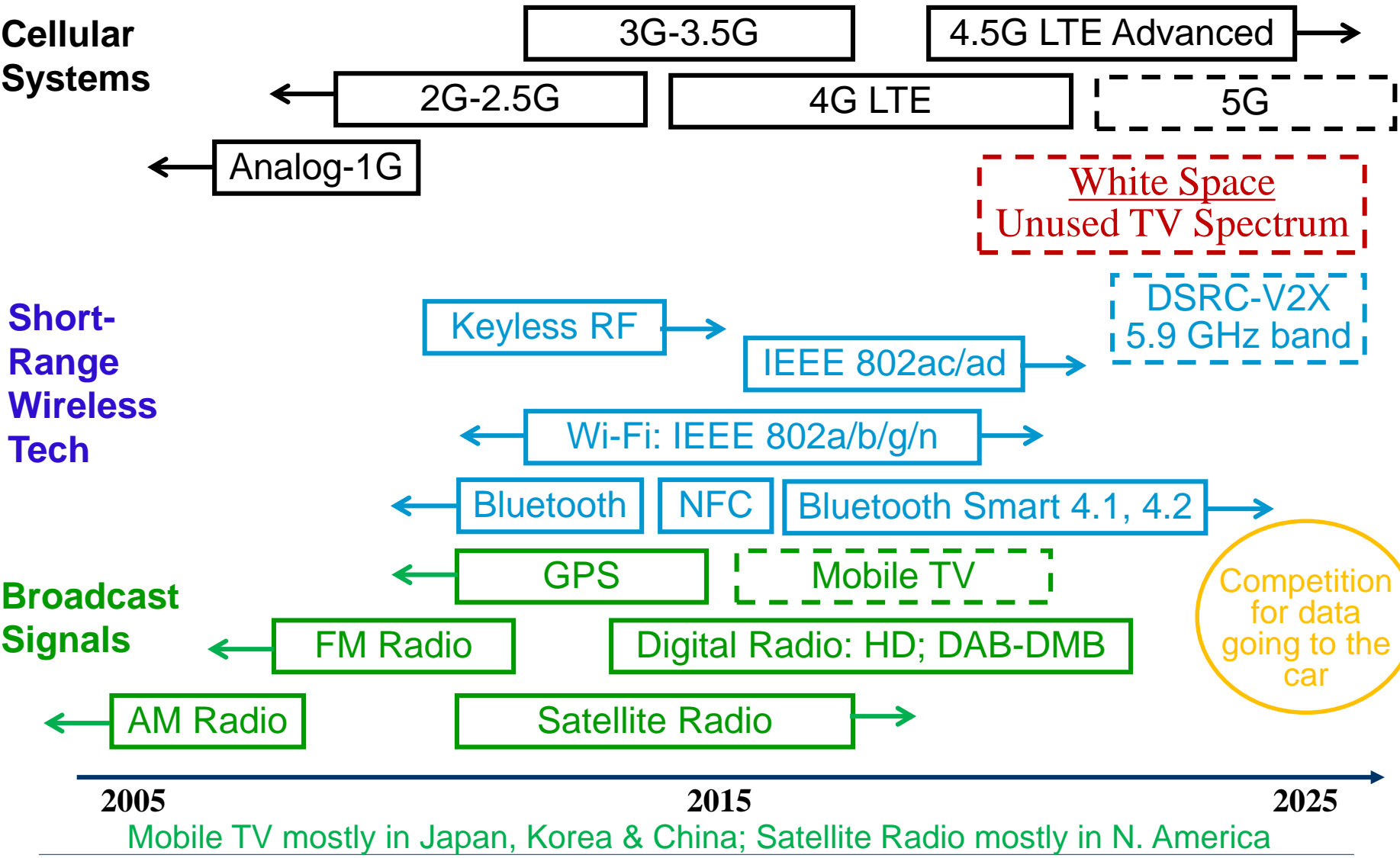
**Others not included: Baidu CarLife; Abalta Weblink, Airbiquity Choreo, Nuance Dragon Drive Link, SofTec, UIEvolution Cloud Connect, VNC**

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# Connected Car Technologies Overview



# Connected Car Trends: U.S. & EU



	U.S. Trends	EU Trends
Embedded Telematics	<ul style="list-style-type: none"> <li>▶ Leading technology</li> <li>▶ Remote diagnostic most valuable</li> <li>▶ LTE deployment going fast</li> </ul>	<ul style="list-style-type: none"> <li>▶ Waiting for eCall to fire up</li> <li>▶ Mostly for high-end autos</li> <li>▶ eCall main app initially</li> </ul>
Smartphone Telematics	<ul style="list-style-type: none"> <li>▶ Ford success, followed by others</li> <li>▶ Will leverage phone projection</li> </ul>	<ul style="list-style-type: none"> <li>▶ Limited success so far</li> <li>▶ Success via phone projection</li> </ul>
Embedded & Smartphone	<ul style="list-style-type: none"> <li>▶ Growing rapidly</li> <li>▶ Long-term winner</li> </ul>	<ul style="list-style-type: none"> <li>▶ Emerging in most countries</li> <li>▶ Long-term winner</li> </ul>
Phone Projection	<ul style="list-style-type: none"> <li>▶ Very important in next 5 years</li> <li>▶ CarPlay &amp; Android Auto to lead</li> <li>▶ Qs: MirrorLink? AppLink-SDL?</li> </ul>	<ul style="list-style-type: none"> <li>▶ Very important in next 5 years</li> <li>▶ CarPlay &amp; AA to lead</li> <li>▶ Qs: MirroLink? SofTec?</li> </ul>
OTA SW Update	<ul style="list-style-type: none"> <li>▶ Emerging for telematics</li> <li>▶ Infotainment OTA is next</li> <li>▶ Core ECU OTA emerging</li> </ul>	<ul style="list-style-type: none"> <li>▶ Emerging for telematics</li> <li>▶ Mostly luxury brands</li> <li>▶ May lag U.S. by 2-4 years</li> </ul>
Cyber Security	<ul style="list-style-type: none"> <li>▶ Finally getting attention</li> <li>▶ OEMs scrambling to catch up</li> <li>▶ Laws &amp; regulation on the way</li> </ul>	<ul style="list-style-type: none"> <li>▶ Strong R&amp;D, little deployment</li> <li>▶ Orderly deployment coming</li> <li>▶ Laws &amp; regulation expected</li> </ul>

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

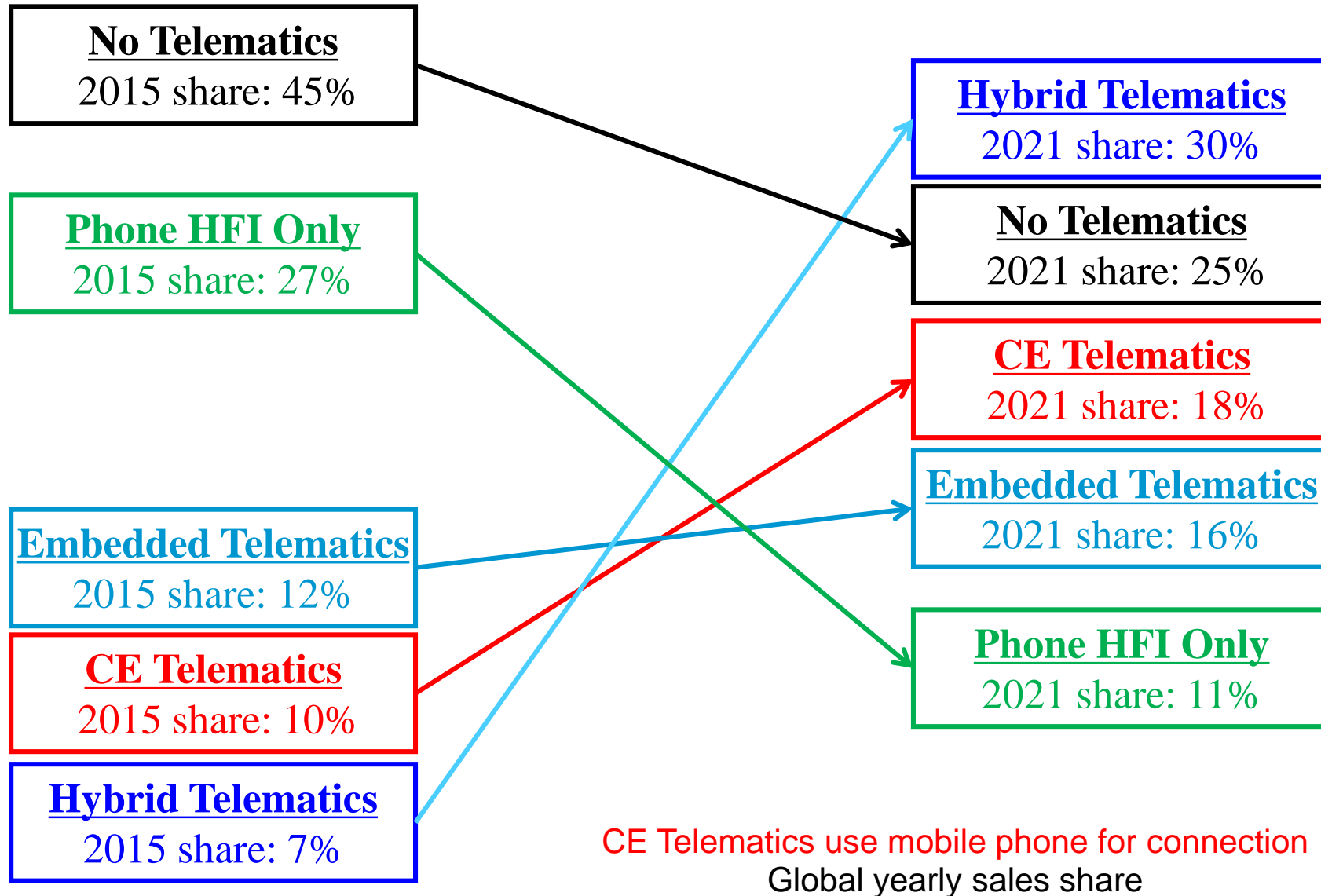
# Connected Car Trends: U.S. & A-P



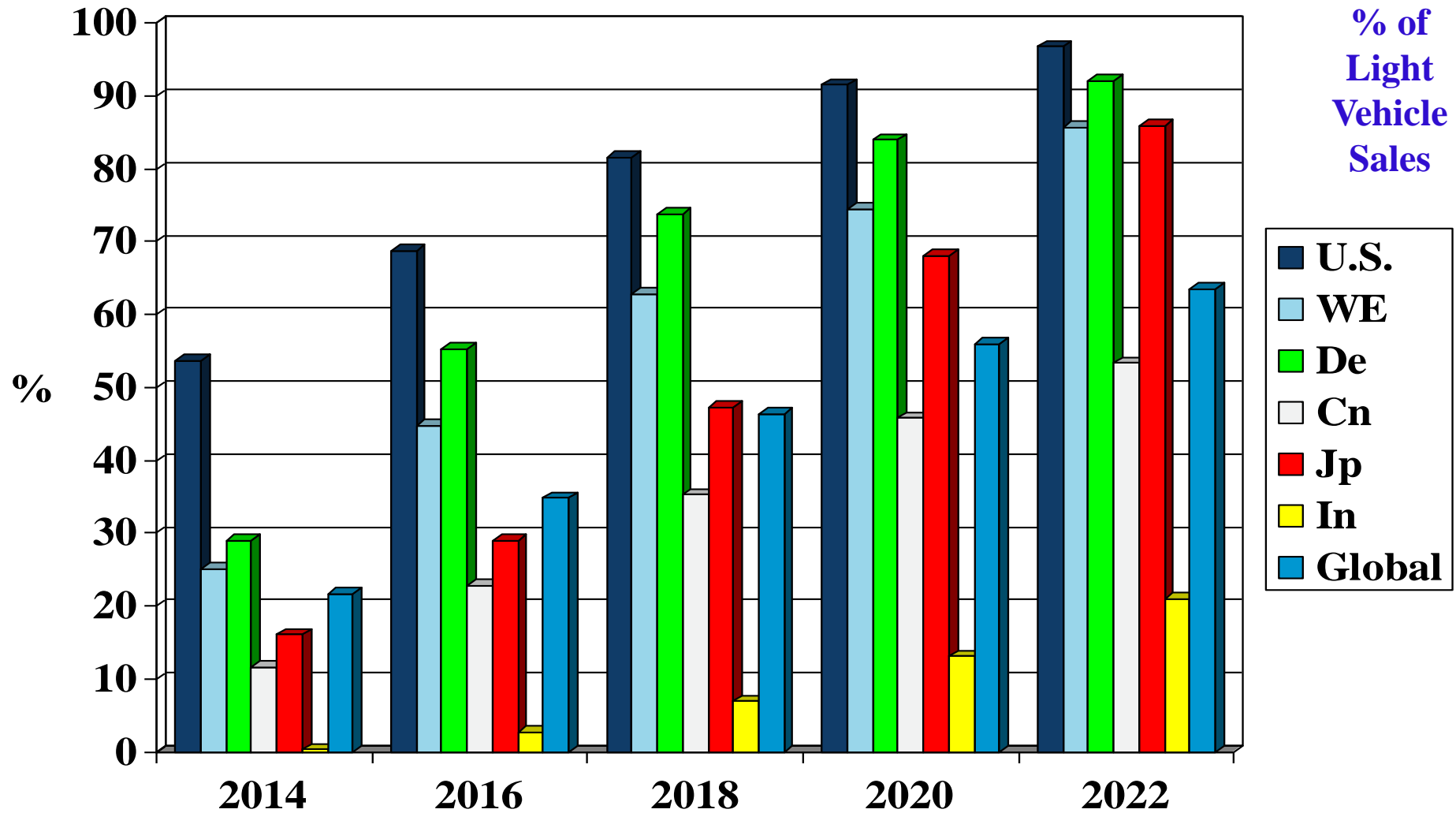
	U.S. Trends	AP Trends
Embedded Telematics	<ul style="list-style-type: none"> <li>▶ Leading tech approach</li> <li>▶ Remote diagnostic most valuable</li> <li>▶ LTE deployment coming fast</li> </ul>	<ul style="list-style-type: none"> <li>▶ Leading approach in China</li> <li>▶ Weak in most other regions</li> <li>▶ LTE emerging first in China</li> </ul>
Smartphone Telematics	<ul style="list-style-type: none"> <li>▶ Ford success, followed by others</li> <li>▶ Will leverage phone projection</li> </ul>	<ul style="list-style-type: none"> <li>▶ Leading approach in Japan</li> <li>▶ Future growth in China</li> </ul>
Embedded & SP	<ul style="list-style-type: none"> <li>▶ Growing rapidly</li> <li>▶ Long-term winner</li> </ul>	<ul style="list-style-type: none"> <li>▶ Grows with Smartphone</li> <li>▶ Long-term winner in most areas</li> </ul>
Phone Projection	<ul style="list-style-type: none"> <li>▶ Very important in next 5 years</li> <li>▶ CarPlay &amp; Android Auto to lead</li> <li>▶ Qs: MirrorLink? AppLink-SDL?</li> </ul>	<ul style="list-style-type: none"> <li>▶ CP &amp; AA important in Jp &amp; Kr</li> <li>▶ CarLife important in China</li> <li>▶ China Qs: Local AA? ML? SDL?</li> </ul>
OTA SW Update	<ul style="list-style-type: none"> <li>▶ Emerging for telematics</li> <li>▶ Infotainment OTA is next</li> <li>▶ Core ECU OTA emerging</li> </ul>	<ul style="list-style-type: none"> <li>▶ OTA to be important in Jp &amp; Kr</li> <li>▶ Cn: GM, BMW etc. to lead</li> <li>▶ AP may lag U.S. by 3-5 years</li> </ul>
Cyber Security	<ul style="list-style-type: none"> <li>▶ Finally getting attention</li> <li>▶ OEMs scrambling to catch up</li> <li>▶ Laws &amp; regulation on the way</li> </ul>	<ul style="list-style-type: none"> <li>▶ Getting attention in Jp &amp; Kr</li> <li>▶ Need attention in Cn &amp; In</li> <li>▶ Laws &amp; regulation expected</li> </ul>



# Connected Car Trends

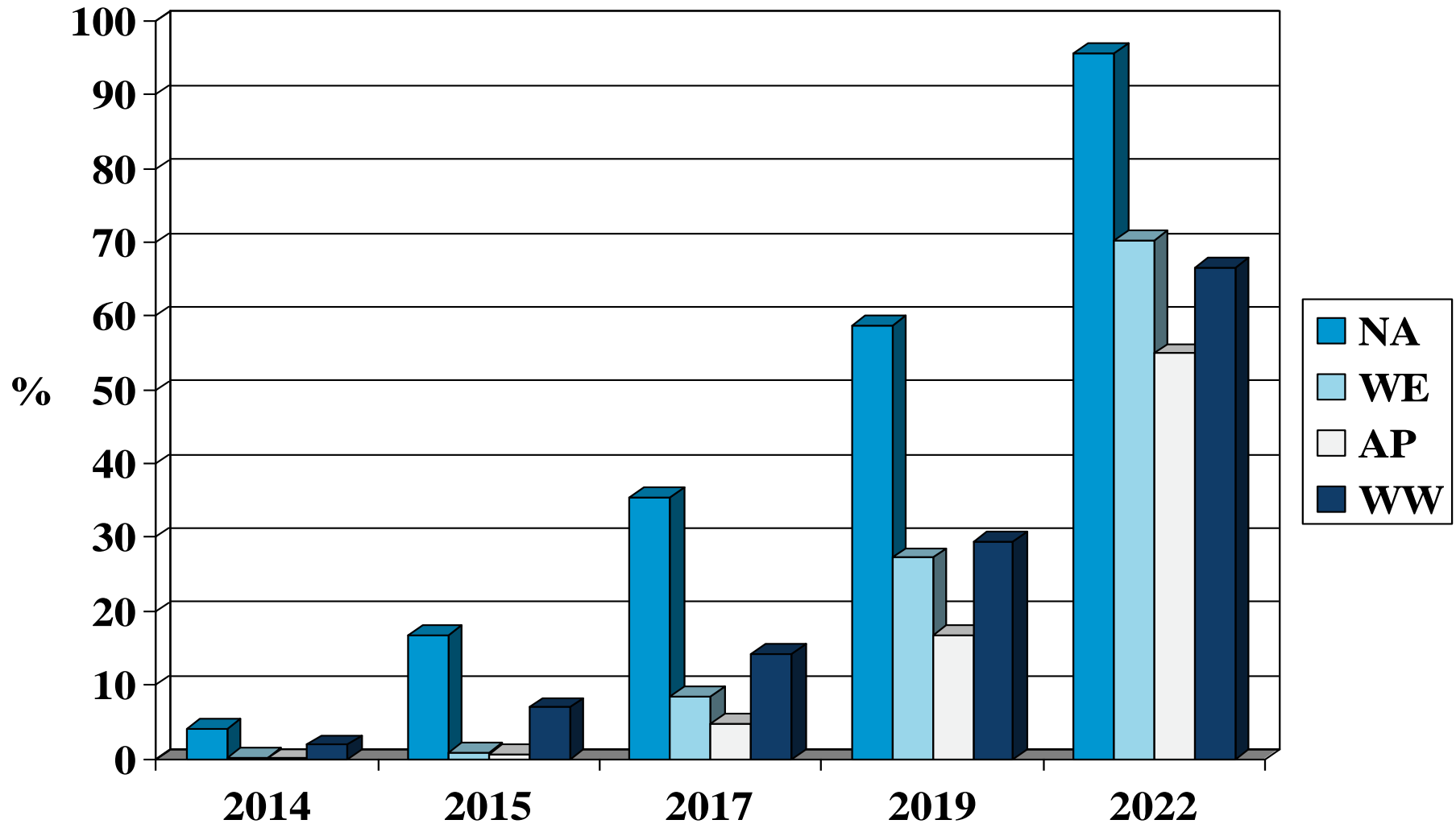


# Connected Car Attach Rate



**Includes connected car services via embedded modem, Smartphone & both**

# LTE Share: Embedded Telematics Sales



GM's USA deployment of LTE will kick-start market: GM volume will lower auto-grade LTE chip price

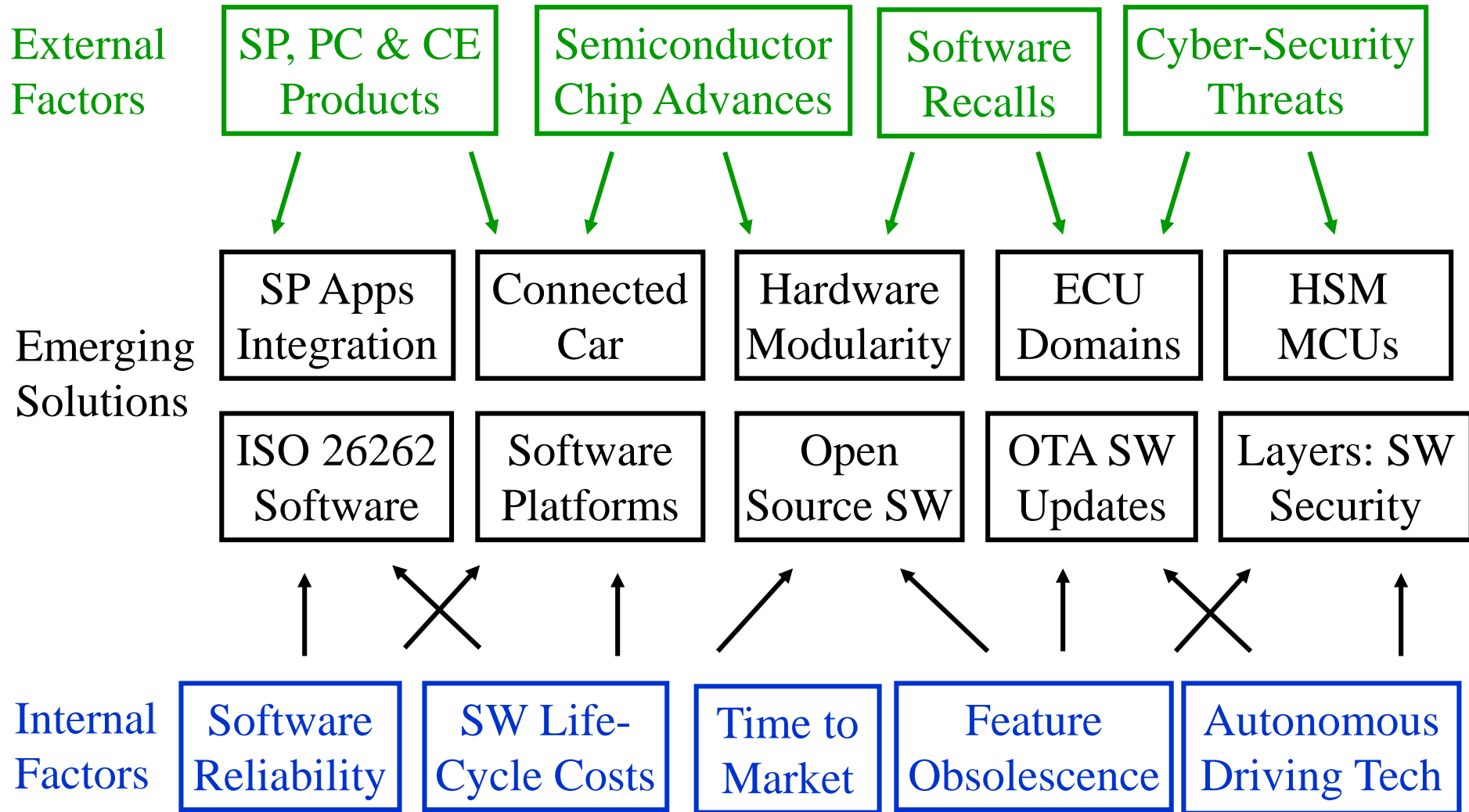
# Who Benefits from Connected Cars?



Segment	Benefit Areas
OEMs	<ul style="list-style-type: none"><li>▶ Cost savings: Remote diagnostics &amp; Remote software upgrades</li><li>▶ New revenue from future functional software upgrades</li></ul>
Suppliers	<ul style="list-style-type: none"><li>▶ Revenue from communication &amp; HMI hardware</li><li>▶ Revenue from connected car software: middleware &amp; apps</li></ul>
TSPs	<ul style="list-style-type: none"><li>▶ Revenue from safety &amp; car-centric services: Base service</li><li>▶ Revenue from infotainment-centric services: New opportunities</li></ul>
MNOs	<ul style="list-style-type: none"><li>▶ Revenue from growing amount of data to and from the car</li><li>▶ Revenue from being a TSP and/or content provider</li></ul>
Content Providers	<ul style="list-style-type: none"><li>▶ Many entertainment categories: music &amp; audio as leaders</li><li>▶ Many information categories: LBS-relates as leader</li><li>▶ Many new categories emerging</li></ul>
Car Data Consumption	<ul style="list-style-type: none"><li>▶ Mostly TSP-centric data, traffic info &amp; insurance-centric data</li><li>▶ Many new categories emerging: OBDII data, V2X &amp; others</li></ul>
Driver & Passengers	<ul style="list-style-type: none"><li>▶ Cost savings similar to OEMs, higher resale value w/RD history</li><li>▶ Connected car apps value: cost savings, safety &amp; convenience</li><li>▶ Access to vast infotainment content portfolios</li></ul>

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

# Automotive Software Mega-Trends



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

# Auto Software Complexity Path



## “Embedded Controllers”

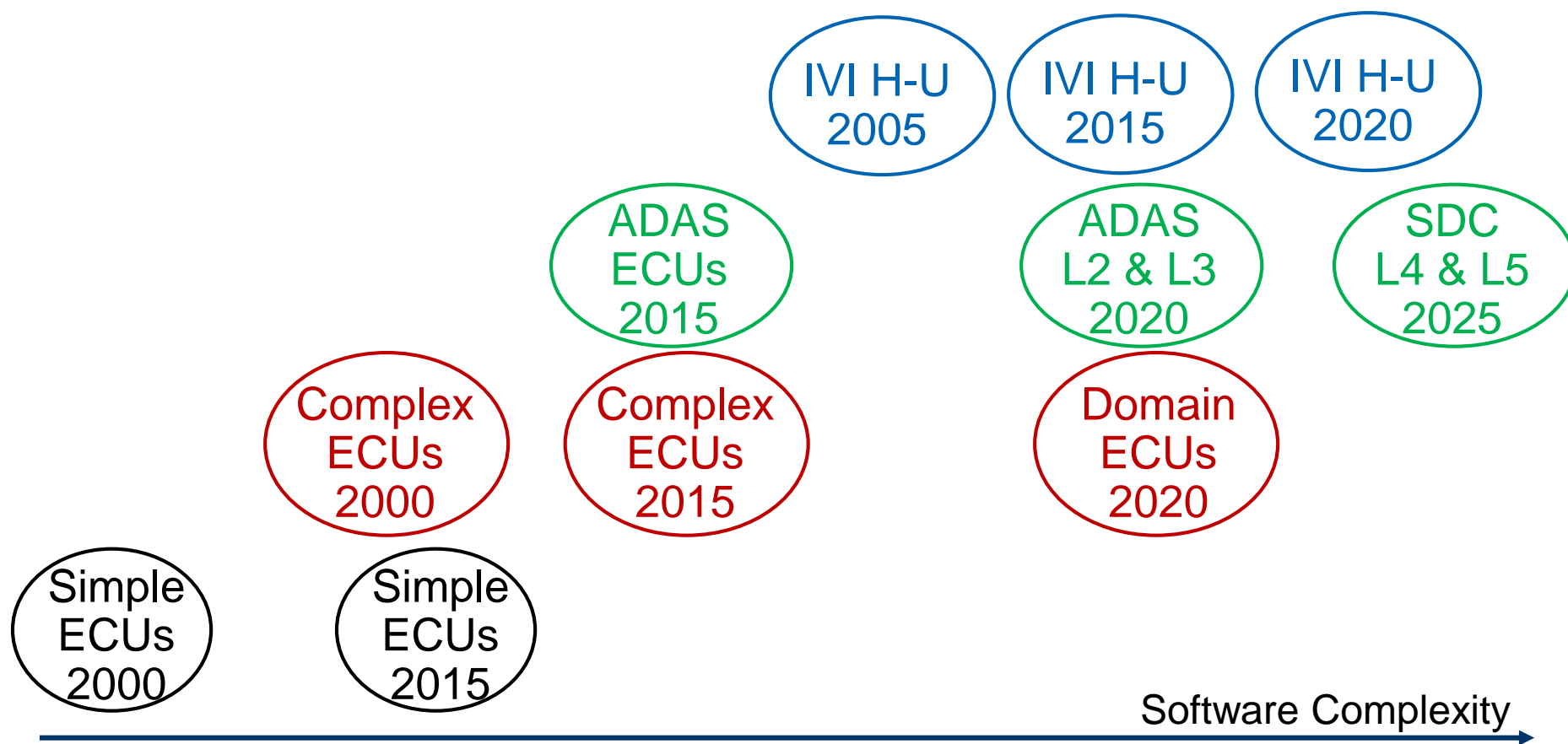
- Simple SW control program
- Fixed middleware
- Fixed function app or apps
- BoM cost minimization
- LoC\* counted in **thousands**

10X-100X Complexity

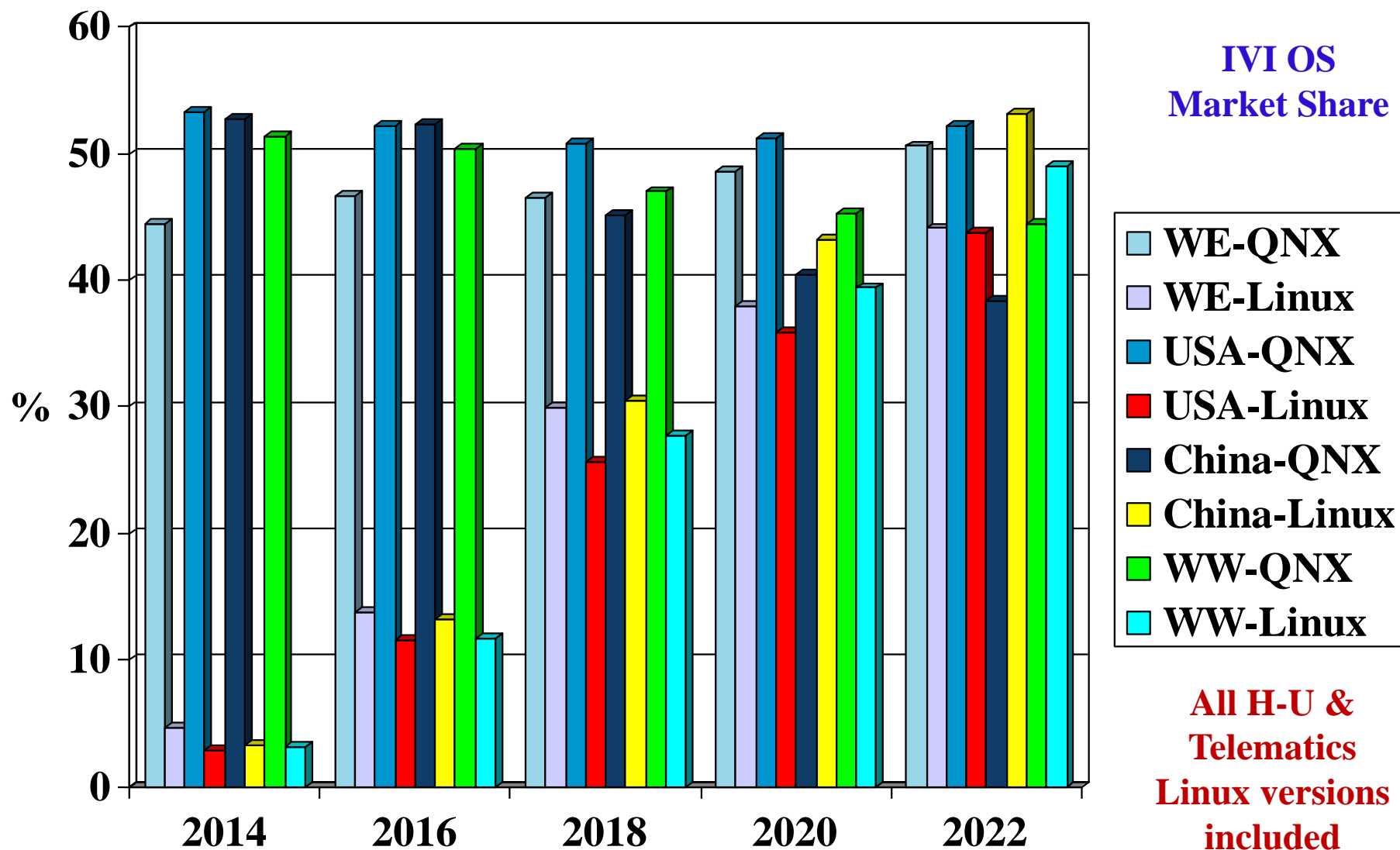


## “Apps Computers”

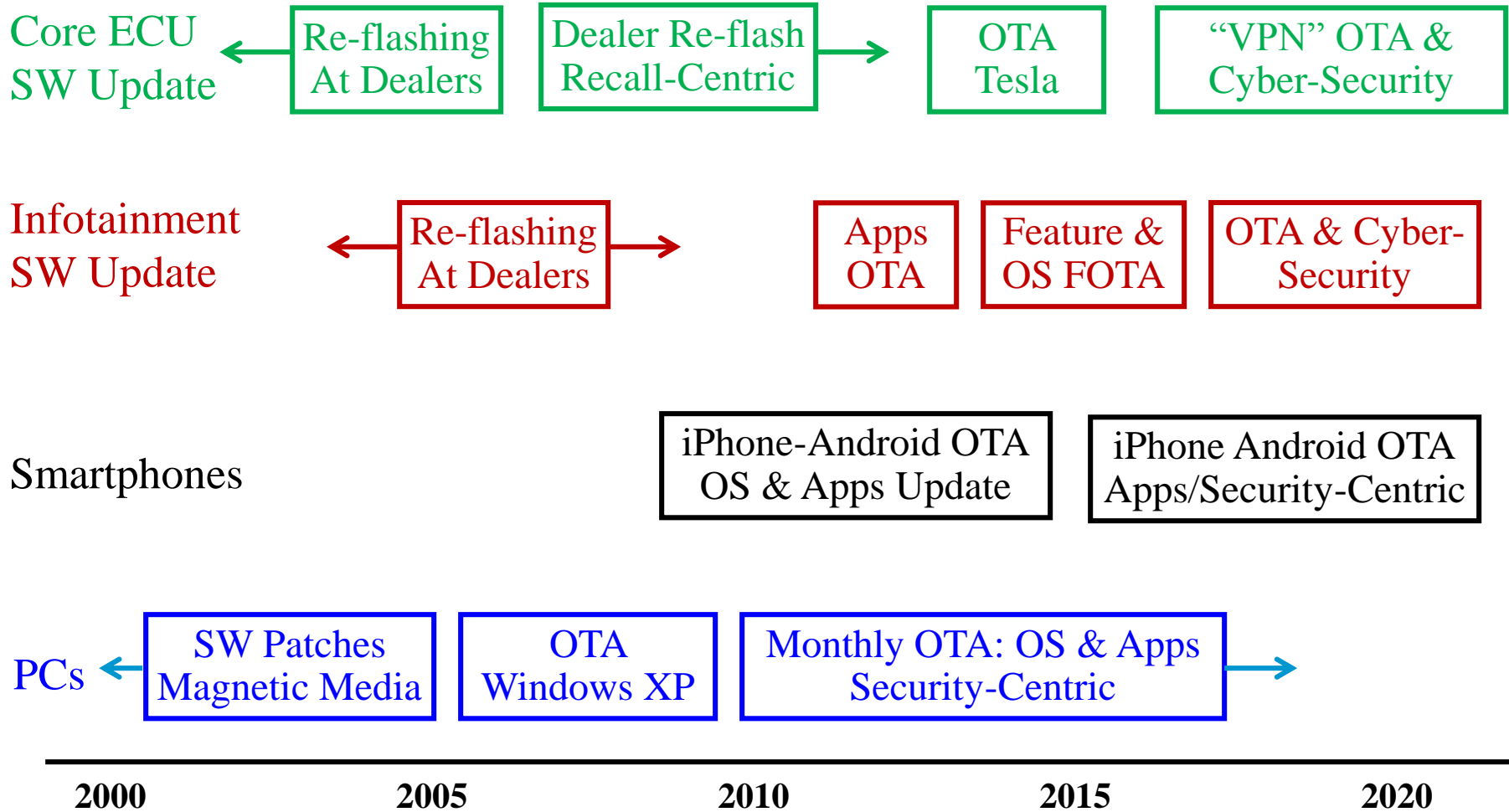
- Complex operating system
- Computer middleware
- Industry-specific middleware
- Multiple changeable apps
- LoC\* counted in **millions**



# Infotainment OS Trends



# OTA Software Update Evolution



OTA=Over The Air



# OTA Software Update Advantages

	Key Information	Other Information
Cost Savings	<ul style="list-style-type: none"> <li>▶ Dealer cost is \$70-100 per software update event</li> <li>▶ Lower notification costs</li> </ul>	<ul style="list-style-type: none"> <li>▶ OTA could save 50%</li> <li>▶ IT investment delays ROI</li> <li>▶ Electronic notification</li> </ul>
Time Savings	<ul style="list-style-type: none"> <li>▶ Quicker preparation time</li> <li>▶ Less notification time</li> </ul>	<ul style="list-style-type: none"> <li>▶ No dealer appointment</li> <li>▶ No mailing expected</li> </ul>
Recall Completion	<ul style="list-style-type: none"> <li>▶ 70% dealer recall completion</li> <li>▶ OTA should do much better</li> </ul>	<ul style="list-style-type: none"> <li>▶ Many unsafe cars on road</li> <li>▶ OTA completion? 90%+</li> </ul>
Future Business	<ul style="list-style-type: none"> <li>▶ Value of functional updates</li> <li>▶ A portion will pay for this</li> </ul>	<ul style="list-style-type: none"> <li>▶ Mostly aftermarket now</li> <li>▶ Future OEM revenue stream</li> </ul>

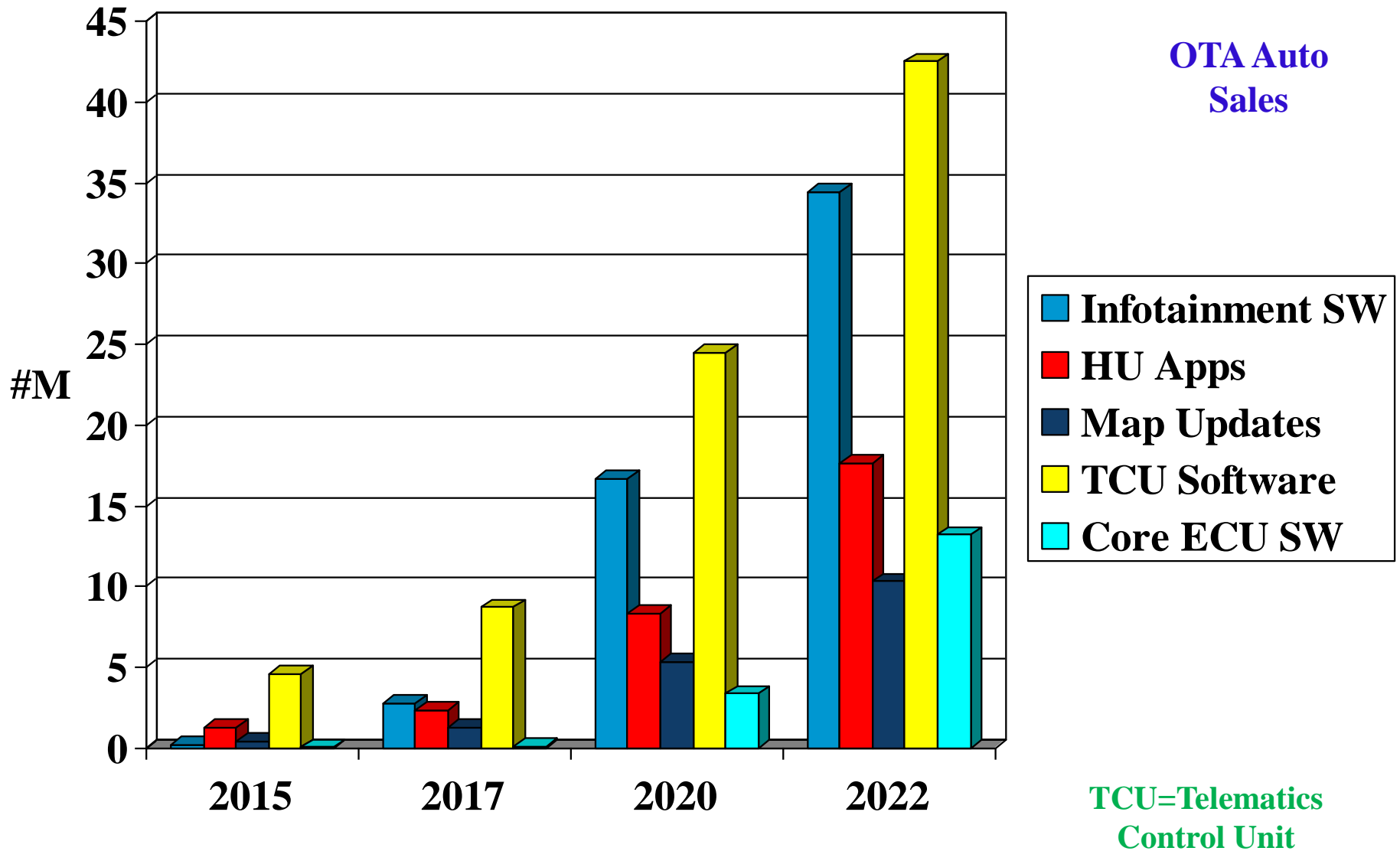
# OTA Software Update Segments



	What Is Updated	OEM Deployment
Infotainment Apps	<ul style="list-style-type: none"><li>▶ Head-unit apps</li><li>▶ Telematics apps</li></ul>	<ul style="list-style-type: none"><li>▶ Toyota, Chrysler</li><li>▶ Chrysler brands, Infiniti</li></ul>
Infotainment Software	<ul style="list-style-type: none"><li>▶ Telematics software</li><li>▶ Head-unit software</li><li>▶ Including operating system</li></ul>	<ul style="list-style-type: none"><li>▶ BMW, GM, M-B, Ford</li><li>▶ Mercedes-Benz</li><li>▶ Emerging now</li></ul>
Core Auto ECUs	<ul style="list-style-type: none"><li>▶ Powertrain ECU software</li><li>▶ Chassis ECU software</li><li>▶ Convenience ECU software</li></ul>	<ul style="list-style-type: none"><li>▶ Public: Tesla* since 2012</li><li>▶ Emerging: 2017+</li><li>▶ Required: 2020+</li></ul>
Navigation Map	<ul style="list-style-type: none"><li>▶ Map software</li><li>▶ POI database</li><li>▶ Autonomous Driving Map</li></ul>	<ul style="list-style-type: none"><li>▶ Japan OEMs in Japan; BMW, Audi, Tesla &amp; others</li><li>▶ Future AD Map required</li></ul>

\*Tesla added hardware for L2-L3 autonomy in model D in November 2014, but software & apps were downloaded in October 2015  
Adds new level of future proofing!

# Over-the-Air Software Update Forecast



# 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

## 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**

## Complacency Stage

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

2010

2015

2020

2025

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# Current State of the Art & Announced Plans

5

Google



No details known

4

Limited drive via remote driver control



3

"Autonomous by 2020" announcements



2



Many incremental and evolutionary steps within Level 2

2014

2015

2016

2017

2018

2019

2020

**NHTSA**  
LEVEL OF  
AUTOMATION  
(L5 = IHS)

# 2 Autonomous Driving Strategies

Focus:	Level 4 Vehicles	Level 5 Vehicles
Autonomy Levels	<ul style="list-style-type: none"><li>▶ Self-driving car mode</li><li>▶ Human driving mode</li></ul>	<ul style="list-style-type: none"><li>▶ Driverless car mode only</li><li>▶ No driving controls</li></ul>
Business Models	<ul style="list-style-type: none"><li>▶ Traditional car ownership</li><li>▶ Car-as-a-Product (CaaP)</li></ul>	<ul style="list-style-type: none"><li>▶ Car-as-a-Service (CaaS)</li><li>▶ Some car ownership</li></ul>
Proponents	<ul style="list-style-type: none"><li>▶ Mercedes-Benz</li><li>▶ Other luxury brands</li><li>▶ Volume OEMs</li></ul>	<ul style="list-style-type: none"><li>▶ Google, Uber, Lyft, Didi, Ola</li><li>▶ Fleet operators (taxi etc.)</li><li>▶ Some OEMs (Ford, GM)</li></ul>
Advantages	<ul style="list-style-type: none"><li>▶ Fewer accidents</li><li>▶ Time, space &amp; privacy*</li><li>▶ Evolution from ADAS</li></ul>	<ul style="list-style-type: none"><li>▶ Fewer accidents</li><li>▶ Mobility to anyone</li><li>▶ Mobility to anything</li></ul>
Implications	<ul style="list-style-type: none"><li>▶ Driver license for HDC</li><li>▶ Some degree of CaaS?</li></ul>	<ul style="list-style-type: none"><li>▶ No driver license needed</li><li>▶ CaaS for nearly all people</li></ul>
Summary	<ul style="list-style-type: none"><li>▶ Cars to make drivers better</li></ul>	<ul style="list-style-type: none"><li>▶ Cars are better than drivers</li></ul>

\* Mercedes-Benz SDC positioning

# Google SDC & DLC Success



	Key Information	Comments
Highway Testing-L4	<ul style="list-style-type: none"> <li>▶ L4 Cars since 2009</li> <li>▶ L4: Now driving assertively</li> </ul>	<ul style="list-style-type: none"> <li>▶ Driven 880K+ miles</li> <li>▶ Inch forward at 4-way stops</li> </ul>
L4 City Testing	<ul style="list-style-type: none"> <li>▶ L4: Mostly in Mt. View, CA</li> <li>▶ L4: Started in Austin, TX</li> </ul>	<ul style="list-style-type: none"> <li>▶ Driven 620K+ miles</li> <li>▶ July 2015 (12 cars in Dec)</li> </ul>
L5 Pod Testing	<ul style="list-style-type: none"> <li>▶ Initially restricted area tests</li> <li>▶ June start in Mt. View (L4 mode)</li> </ul>	<ul style="list-style-type: none"> <li>▶ In Google's restricted areas</li> <li>▶ Sep 2015 start in Austin, TX</li> </ul>
Restricted Testing	<ul style="list-style-type: none"> <li>▶ NASA Moffett Field (1,000 acres)</li> <li>▶ Castle AF Base, Merced, CA</li> </ul>	<ul style="list-style-type: none"> <li>▶ 60 year lease: Google projects</li> <li>▶ L4 &amp; L5 tests on 100 acres</li> </ul>
Vehicles (Mar 31, 2016)	<ul style="list-style-type: none"> <li>▶ 23 Lexus RX450h SUVs</li> <li>▶ 33 Pod cars (L5 or L4 mode)</li> <li>▶ Total self-driving miles: 1.5M</li> <li>▶ SDC simulation &amp; modeling</li> </ul>	<ul style="list-style-type: none"> <li>▶ Mt. View-15; Austin-7; Kirkland-1</li> <li>▶ Mt. View-24; Austin-7; Kirkland-2</li> <li>▶ Self-driving miles/week: 12-15K</li> <li>▶ 3M miles/day; test new SW</li> </ul>
Next Steps	<ul style="list-style-type: none"> <li>▶ Seattle-area &amp; Detroit-area tests</li> <li>▶ Cooperative driving situations</li> <li>▶ Lower crashes by other drivers</li> </ul>	<ul style="list-style-type: none"> <li>▶ Rain, snow &amp; bad weather</li> <li>▶ 4-way stops is first step</li> <li>▶ SDC external info? What else?</li> </ul>



# 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 1.5M miles in SDC mode</li></ul>
Next Focus	<ul style="list-style-type: none"><li>▶ Finding and learning the once in a million events</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' negative 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>
Next Steps	<ul style="list-style-type: none"><li>▶ Cooperative driving situations</li><li>▶ Lower crashes by other drivers</li><li>▶ Bad weather testing &amp; learning</li></ul>	<ul style="list-style-type: none"><li>▶ 4-way stops is first step</li><li>▶ SDC external info? What else?</li><li>▶ Solutions in due time</li></ul>

## Key Question:

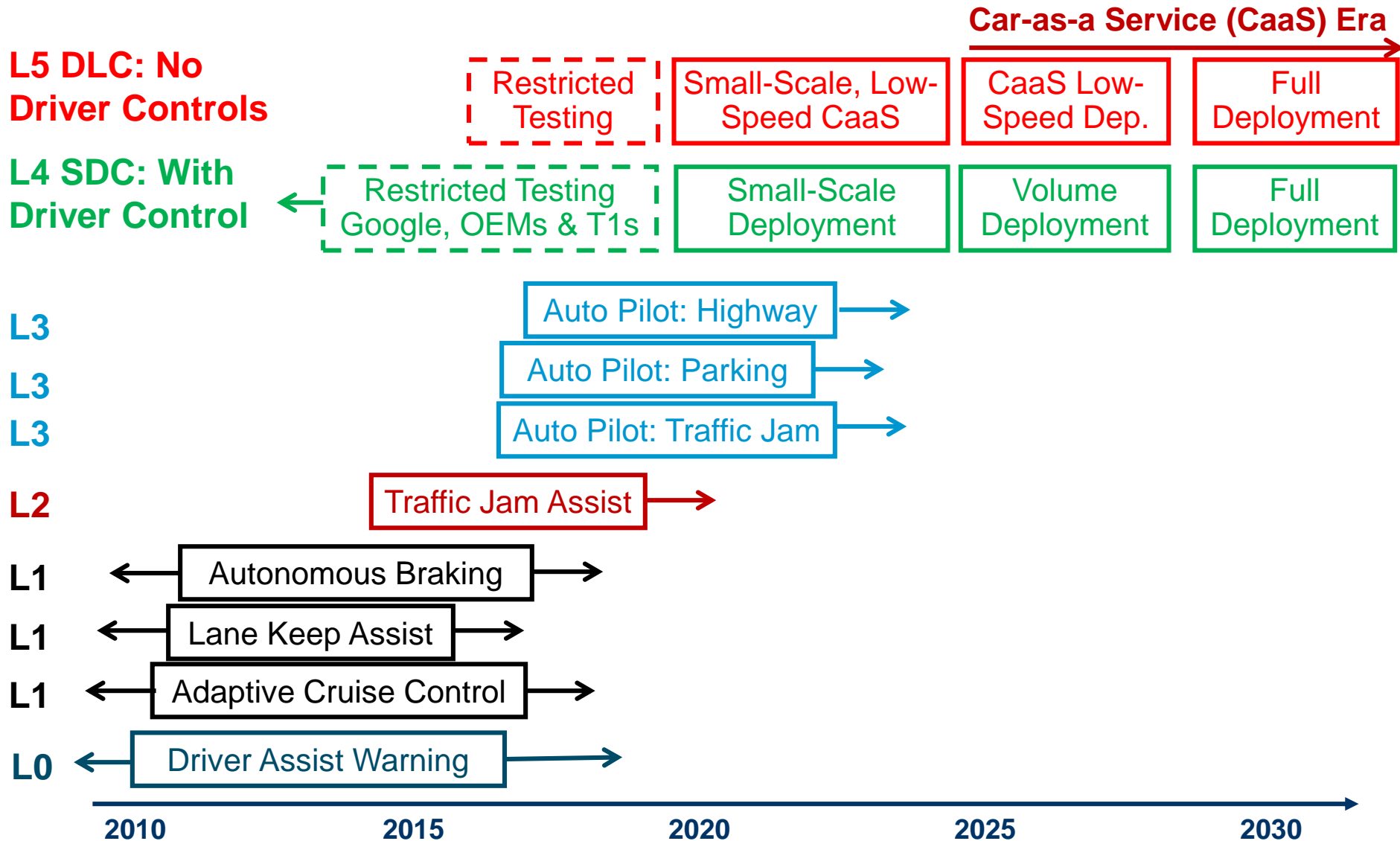
How much better than the best drivers will DLC software need to be for deployment?

# Mobility Implications



	Key Information	Other Information
Car Sharing	<ul style="list-style-type: none"> <li>▶ Smartphone apps centric</li> <li>▶ DLC lowers operating cost</li> <li>▶ DLC fleets for car-sharing</li> </ul>	<ul style="list-style-type: none"> <li>▶ Convenience &amp; availability</li> <li>▶ No driver costs</li> <li>▶ Likely first SDC deployment</li> </ul>
Car Ownership	<ul style="list-style-type: none"> <li>▶ Fewer cars/household when SDCs are fully available</li> <li>▶ Higher miles per car year</li> </ul>	<ul style="list-style-type: none"> <li>▶ USA currently: 2.1 cars/HH</li> <li>▶ USA projected: 1.2 w/SDCs*</li> <li>▶ Quicker replacement rate</li> </ul>
Car-as-a-Service Potential	<ul style="list-style-type: none"> <li>▶ Worldwide population</li> <li>▶ People with driver license</li> <li>▶ People w/o driver license</li> <li>▶ Urban population</li> <li>▶ Seniors (65+ years old)</li> <li>▶ Youth (Under 18 years old)</li> </ul>	<ul style="list-style-type: none"> <li>▶ 2015: 7.32B → 2035: 8.74B</li> <li>▶ 2015: 1.13B → 2035: 1.9B</li> <li>▶ 2015: 6.2B → 2035: 6.8B</li> <li>▶ 2015: 4.1B → 2035: 5.7B</li> <li>▶ 2015: 604M → 2035: 1.12B</li> <li>▶ 2015: 2.26B → 2035: 2.36B</li> </ul>
Mass Transit	<ul style="list-style-type: none"> <li>▶ SDC for last mile service</li> <li>▶ SDV for new mass transit</li> <li>▶ SDV as mass transit</li> </ul>	<ul style="list-style-type: none"> <li>▶ To fill mass transit gaps</li> <li>▶ Less cost than mass transit</li> <li>▶ Current system competition</li> </ul>

# Autonomous Driving Evolution



# 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.



**Auto Industry**

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

## Future Competition

SDC & DLC SW  
SDC Maps



New EV-based  
Auto OEMs



DLC-based  
CaaS Fleets

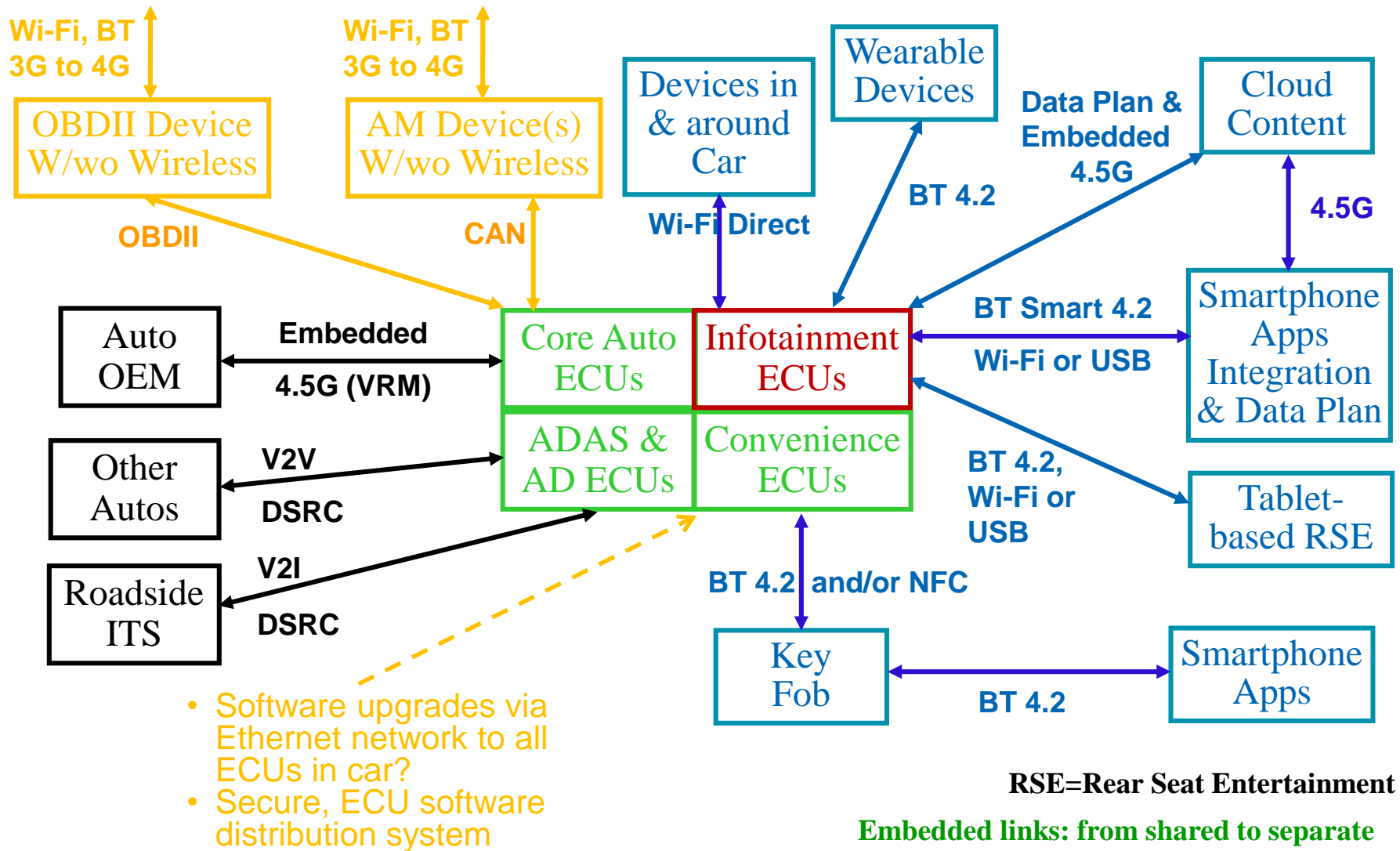


Mobility Service  
for Non-Drivers  
& Packages



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

# Connected Car by 2020+



# Connected Car Revolution



## Capabilities

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

### Connected SDC-DLC

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

### LTE Connected

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

### Telematics

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

Connected cars create new challenges: cyber-security

2000

2015

2030

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

# Software-Defined Car Evolution



**The car is the most complex product in volume production!**

Connected Car  
Remote SW Upgrades  
Software security

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

**Tesla is first SW-defined car**

Digital Car Era  
Platform architecture  
Re-usable software

AUTOSAR  
Remote Diagnostics  
Software APIs

Analog-Digital Car Era  
Digital control system growth

ECUs

Analog Car Era  
Analog control systems

## Next 20 Year HW Improvements

- MCU performance: 400 times
- Memory chip: 32,000 times

1995

2005

2015

2025

2035



# Questions?

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