IHS AUTOMOTIVE

Presentation

Connected Cars: Perspectives to 2025

IHS Automotive Technology

ihs.com

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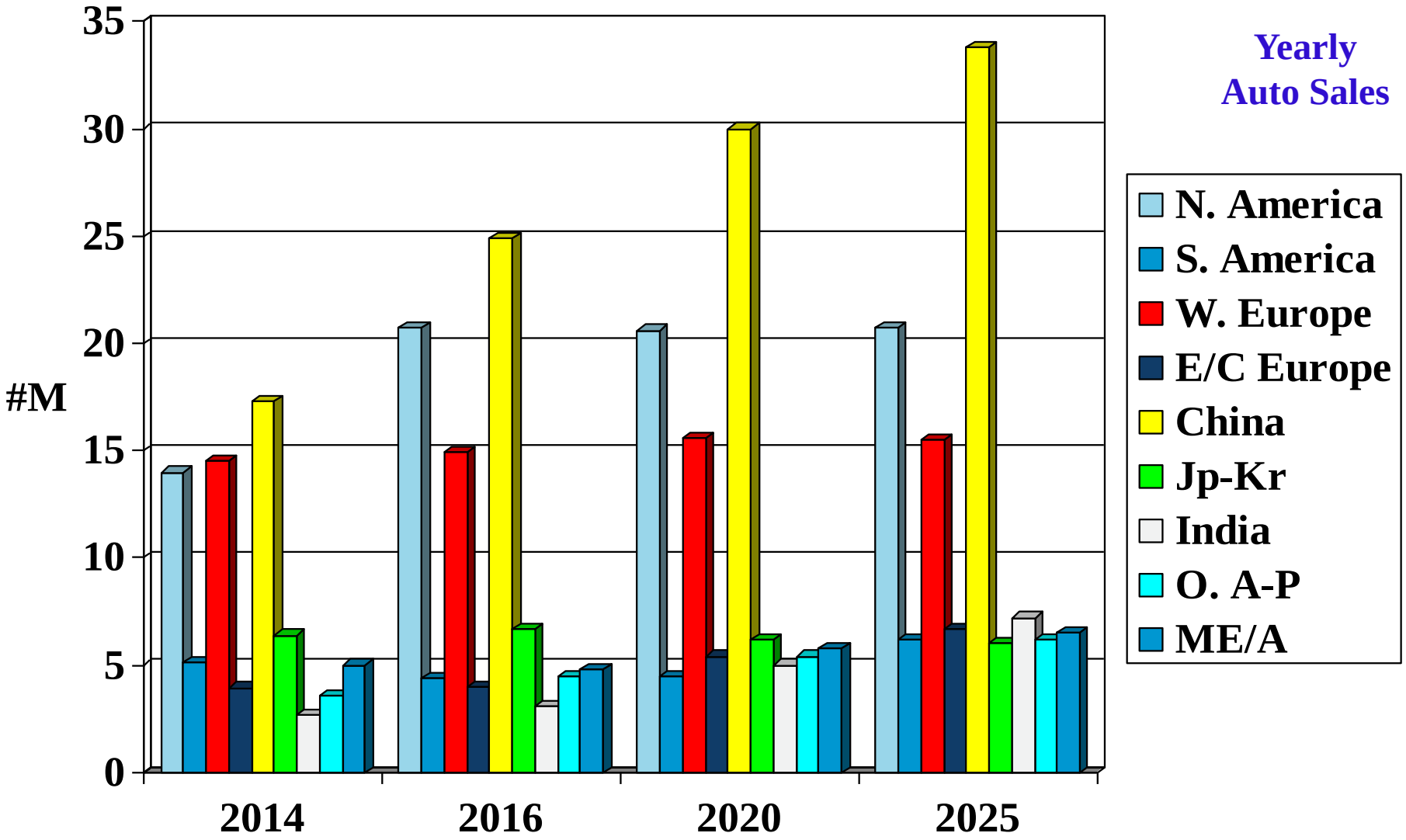
driven by POLK

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

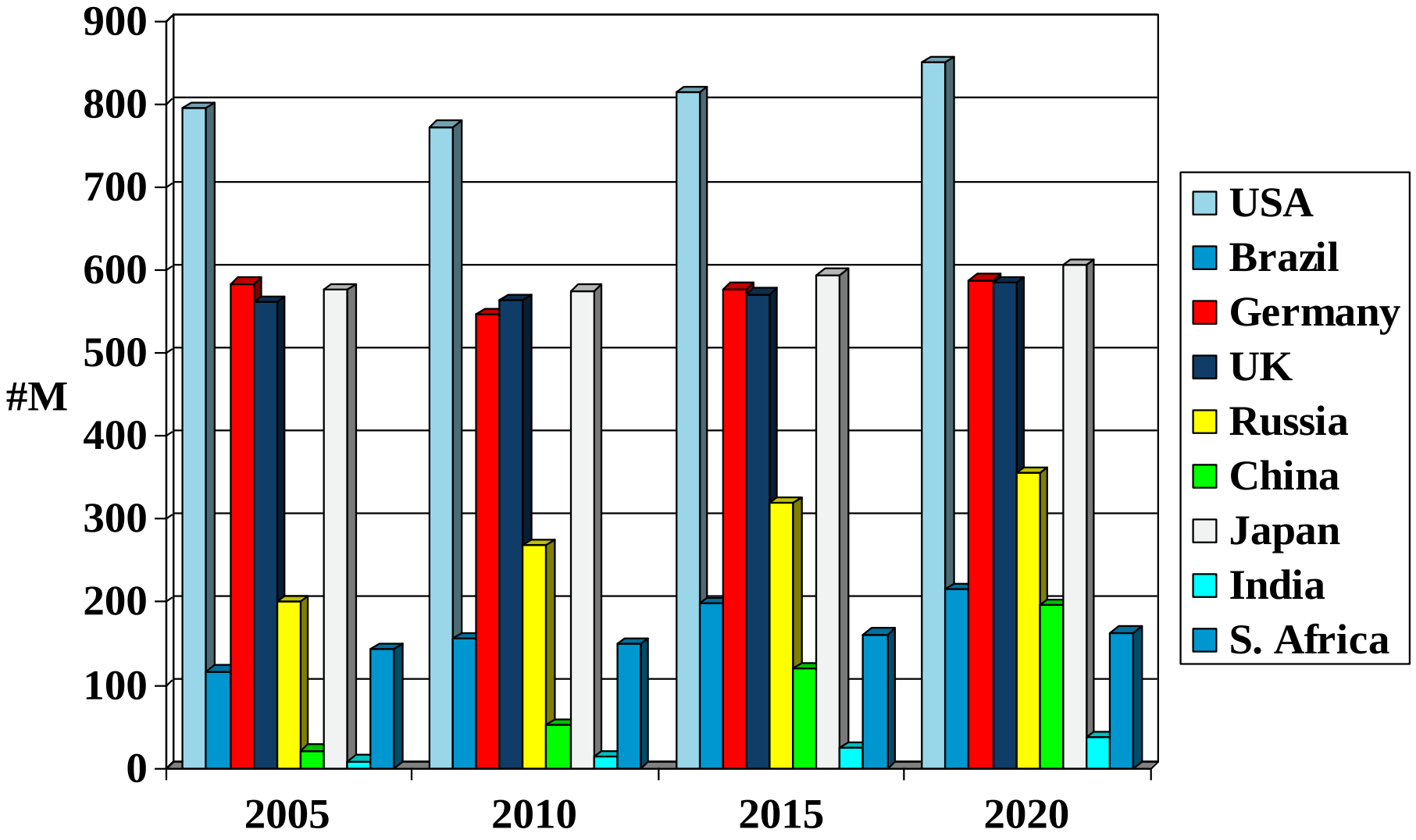
Auto Sales by Region



IHS March 2016 light vehicle forecast

SOURCE: IHS Automotive

Motorization: Autos In-Use per 1,000 People



SOURCE: IHS Automotive

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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!

SOURCE: IHS Automotive

Auto Industry and Software Impact

Every company has a structure similar to phases shown below:

Create	Make	Market	Product Use
• Product idea	• Factory control	• Product marketing	• Payment systems
• Technology R&D	• Parts management	• Product sales	• Customer support
• Product design	• Supplier mgmt.	• Distribution channels	• Warranty & repair
• Product testing	• Inventory mgmt.	• Delivery logistics	• Repeat customers

Software and apps impact all phases of most product

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

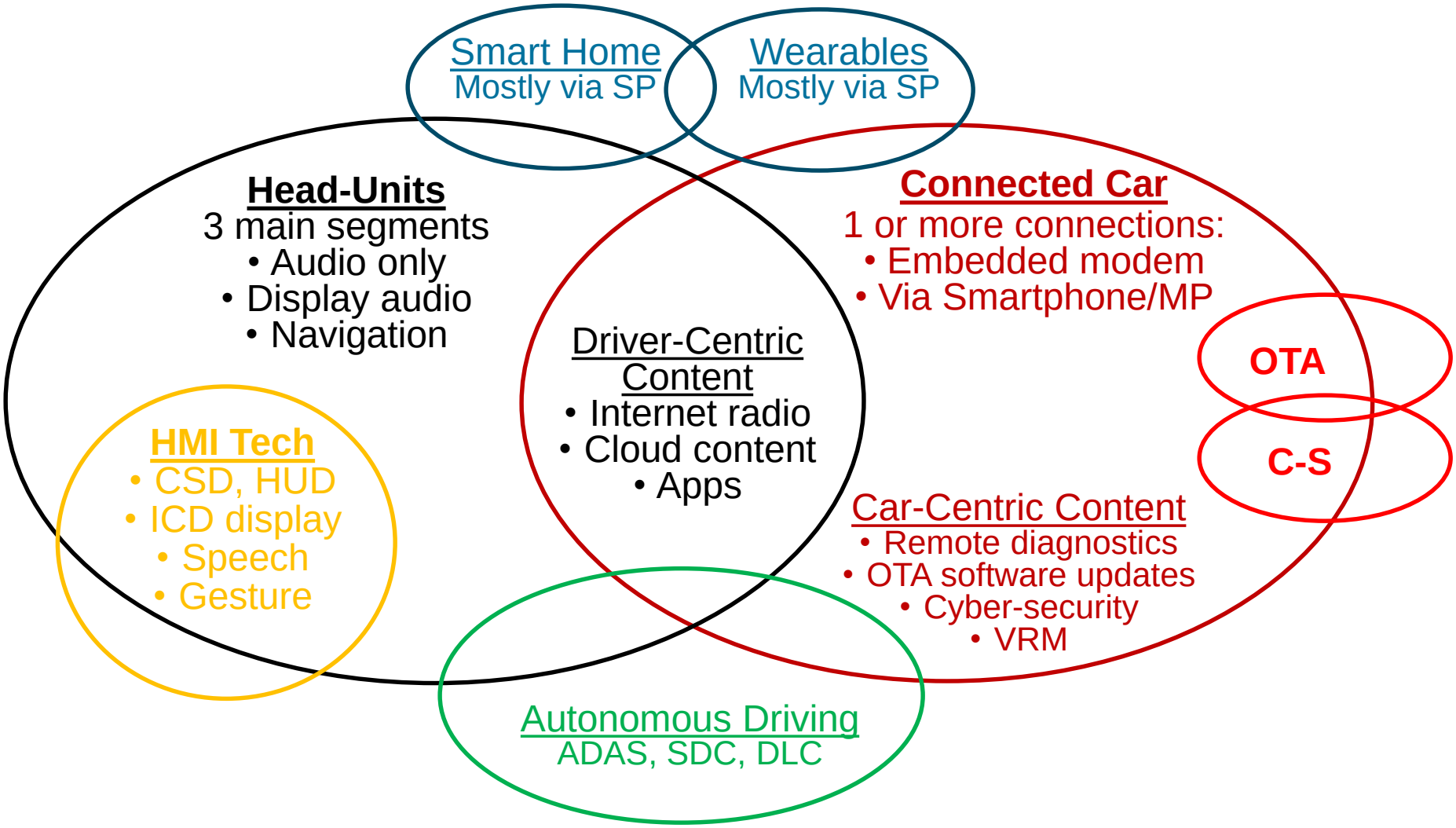
Take-away: Lower software development cost is key:

- **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

SOURCE: IHS Automotive

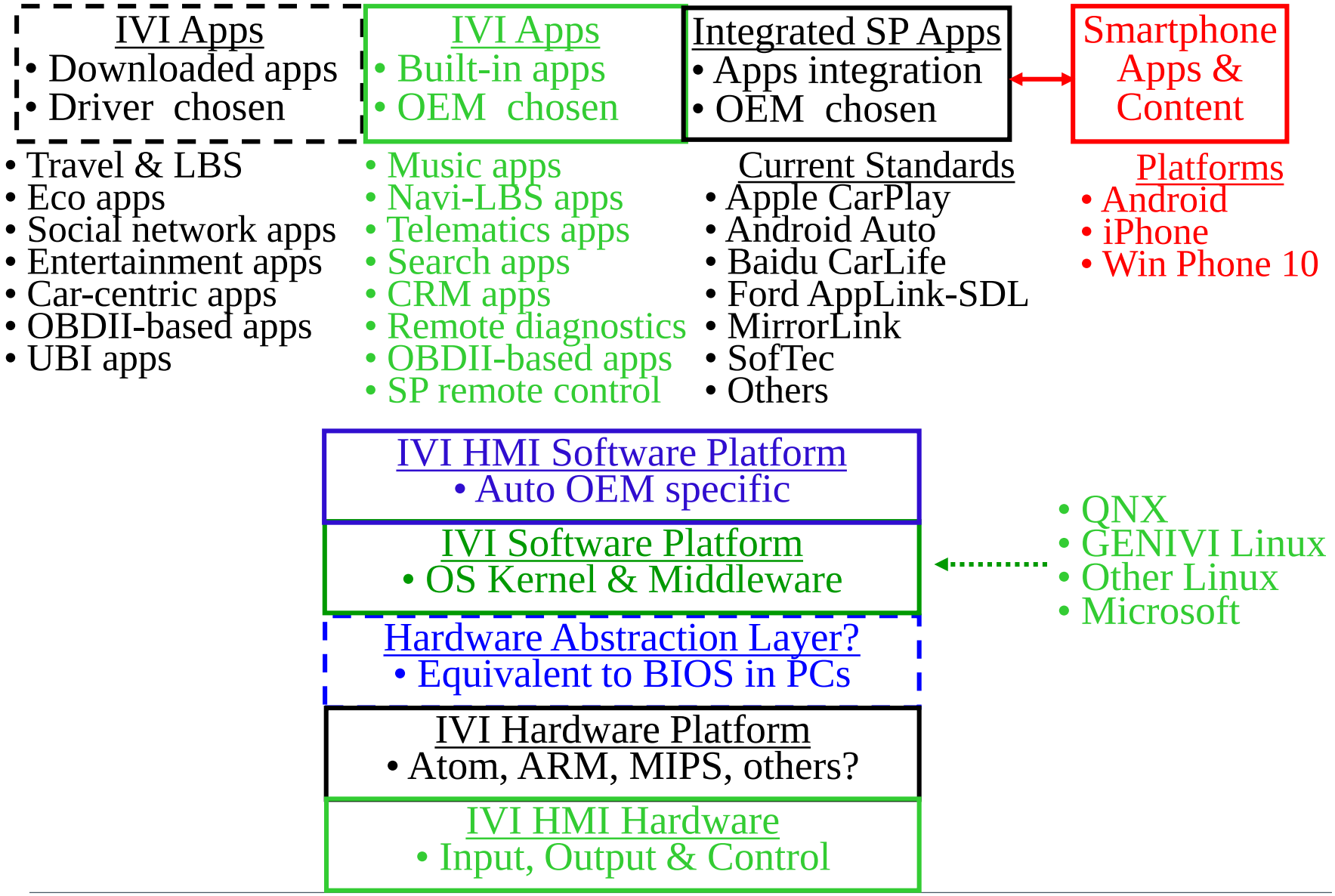
Infotainment: Connected Car vs. Head-Unit



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

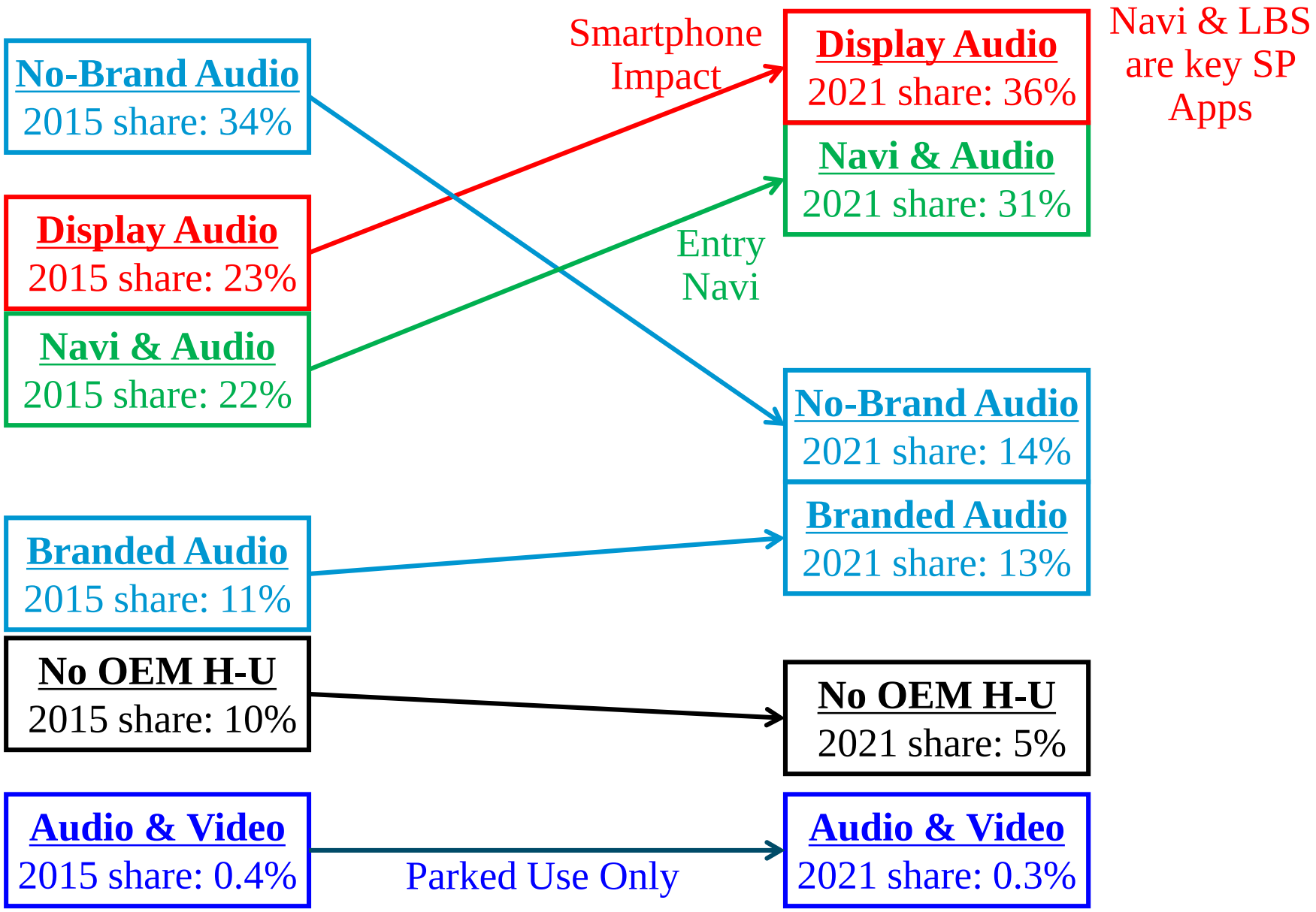
SOURCE: IHS Automotive

Infotainment Apps: Big Picture



SOURCE: IHS Automotive

Head-Unit System Trends



SOURCE: IHS Automotive
Infotainment Portal

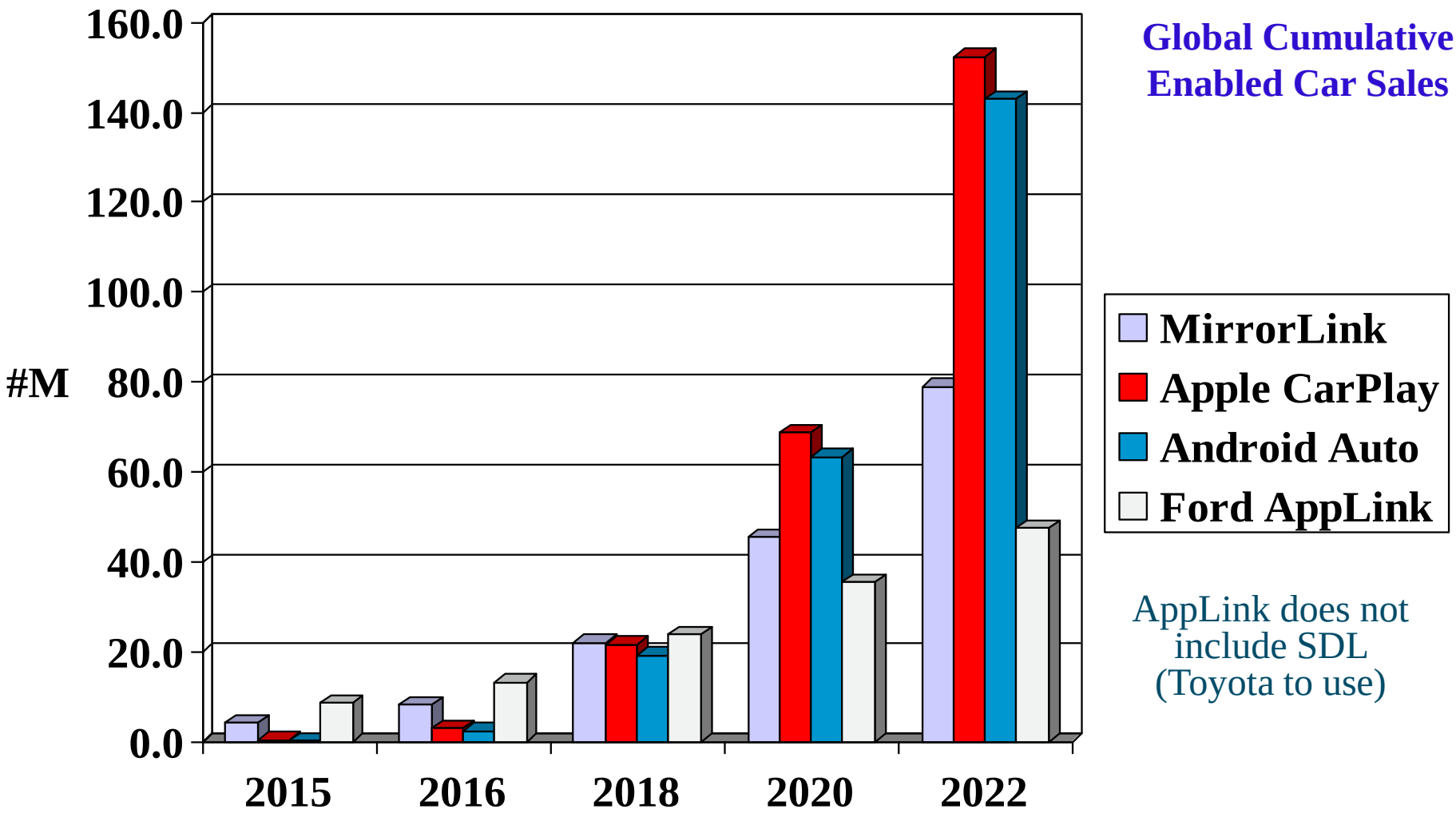
Smartphone Apps Integration: Status

	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

SOURCE: IHS Automotive
Software Apps & Service Portal

Smartphone Apps Integration: Enabled Autos



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

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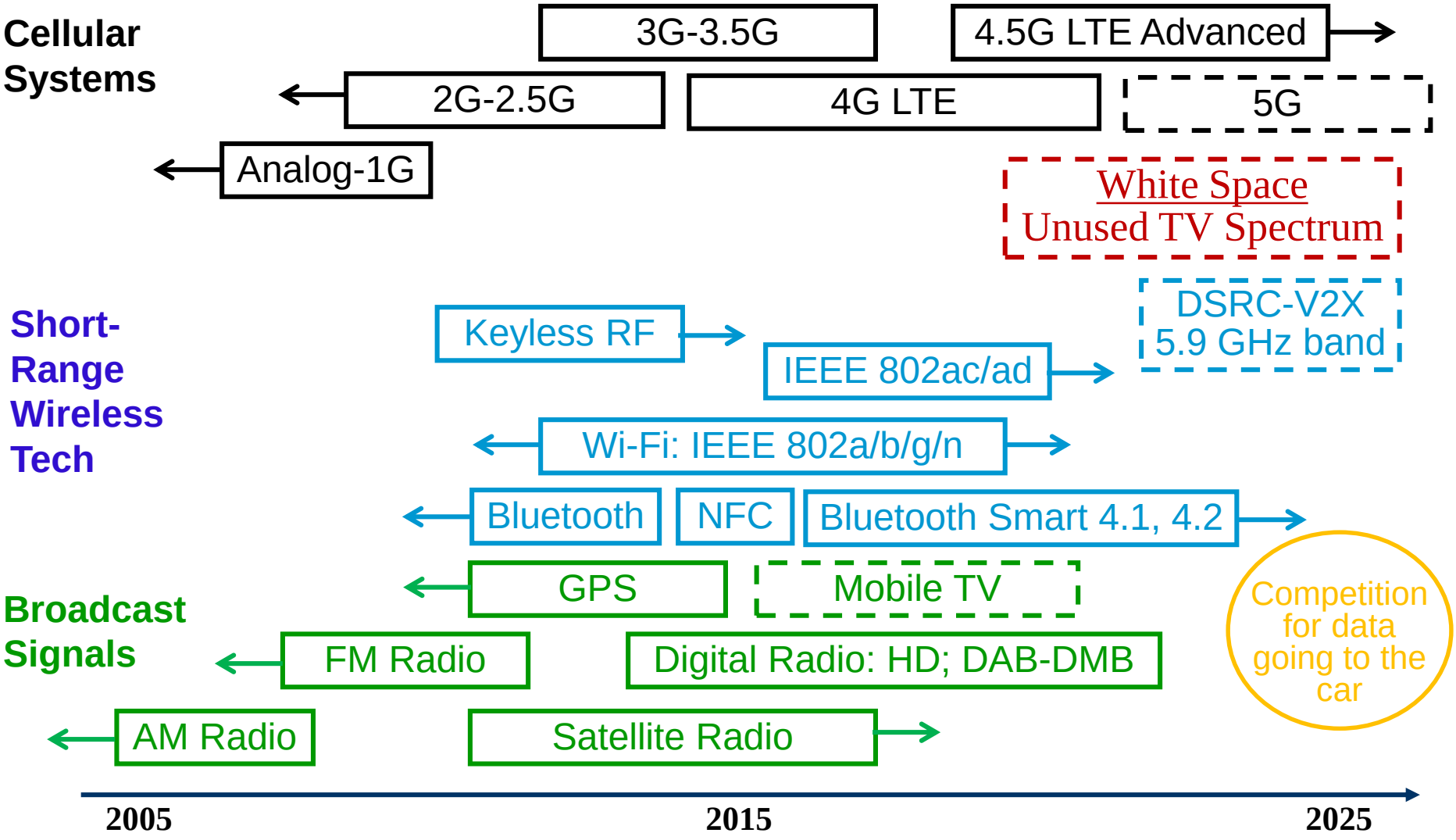
Connected Car Technologies Overview



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

SOURCE: IHS Automotive

Connected Car Trends: U.S. & EU

	U.S. Trends	EU Trends
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: MirroLink? 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

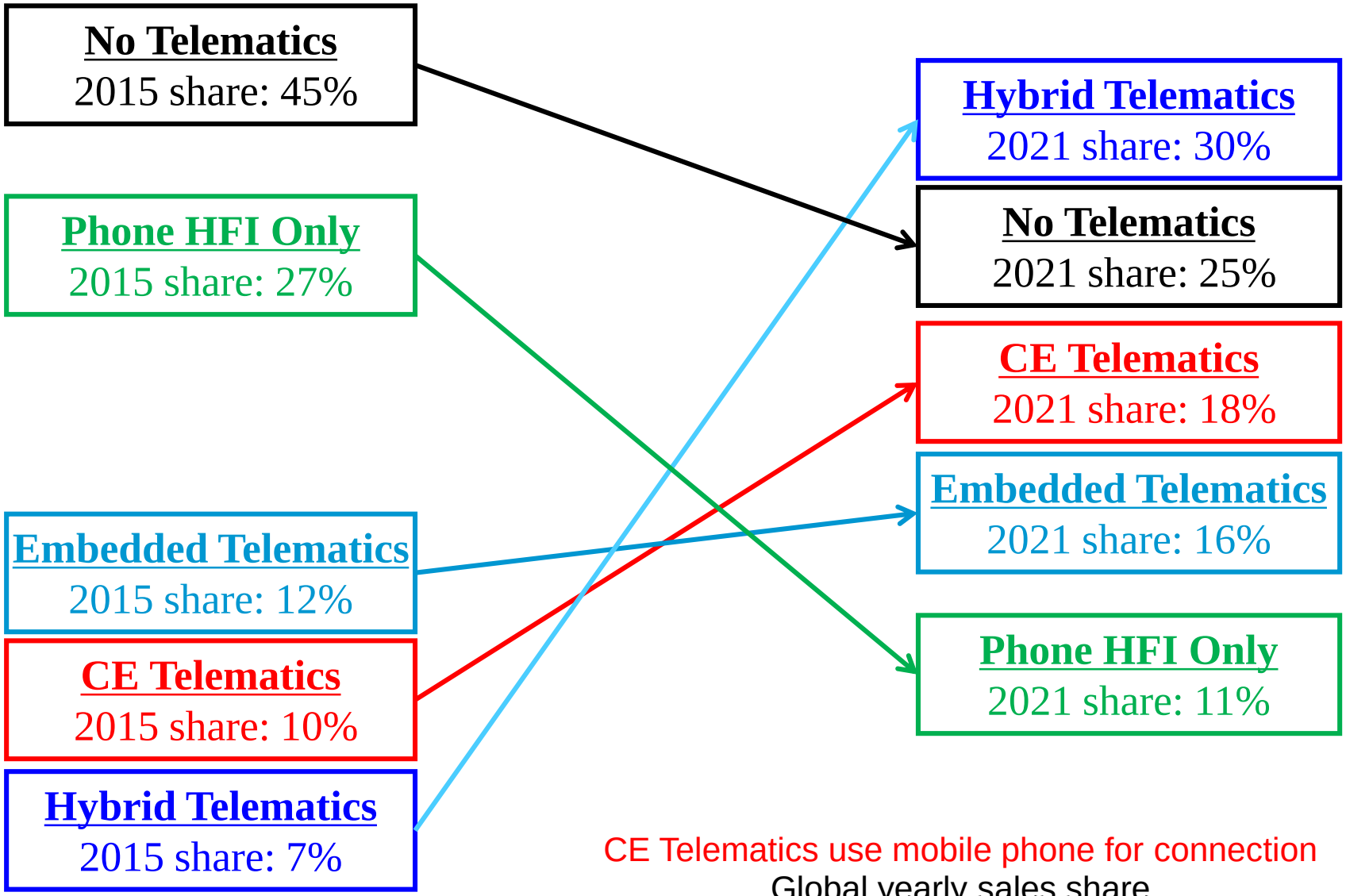
SOURCE: IHS Automotive
Software Apps & Service Portal

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

	U.S. Trends	AP Trends
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

SOURCE: IHS Automotive
Software Apps & Service Portal

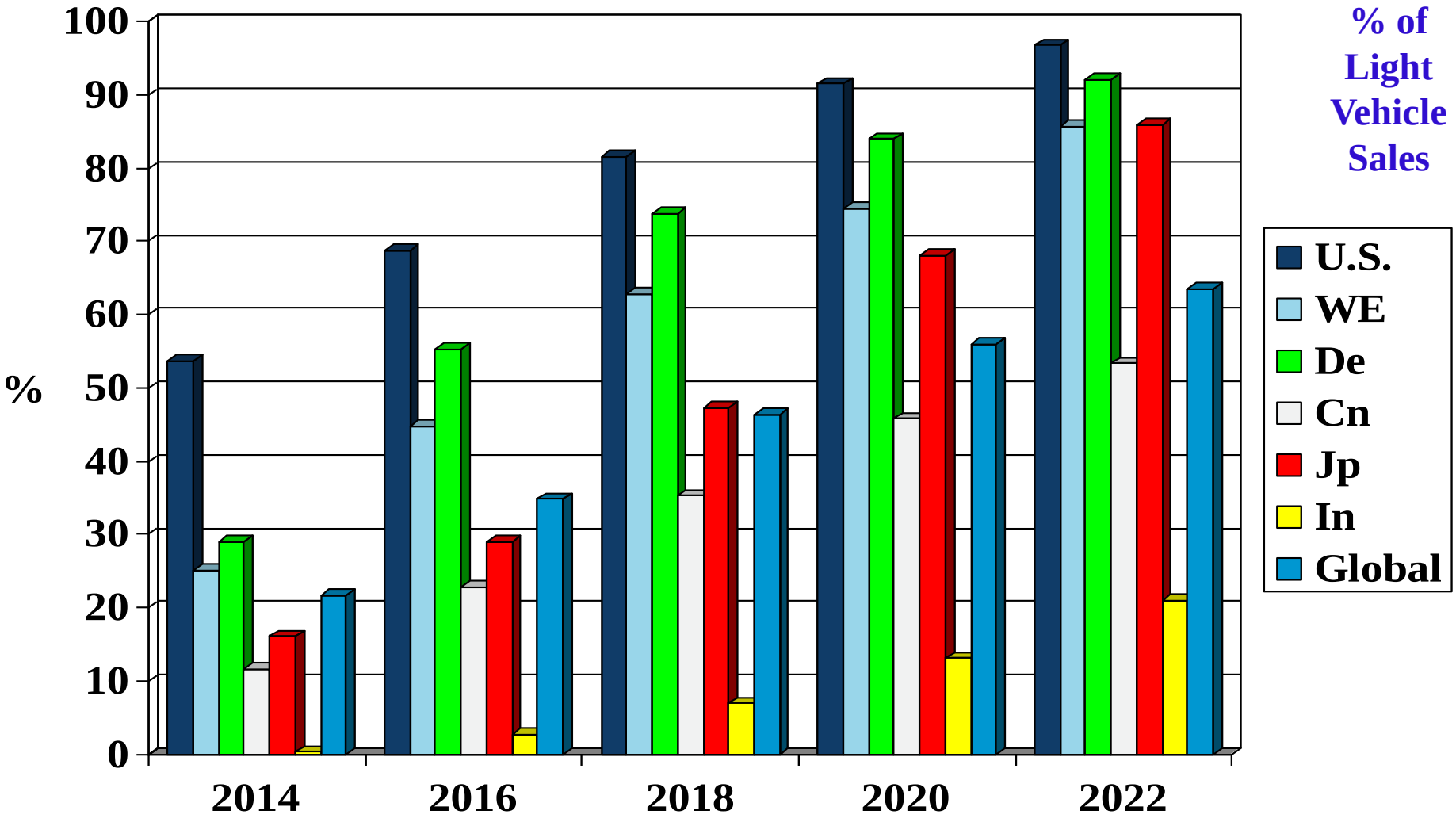
Connected Car Trends



CE Telematics use mobile phone for connection
Global yearly sales share

SOURCE: IHS Automotive
Infotainment Portal

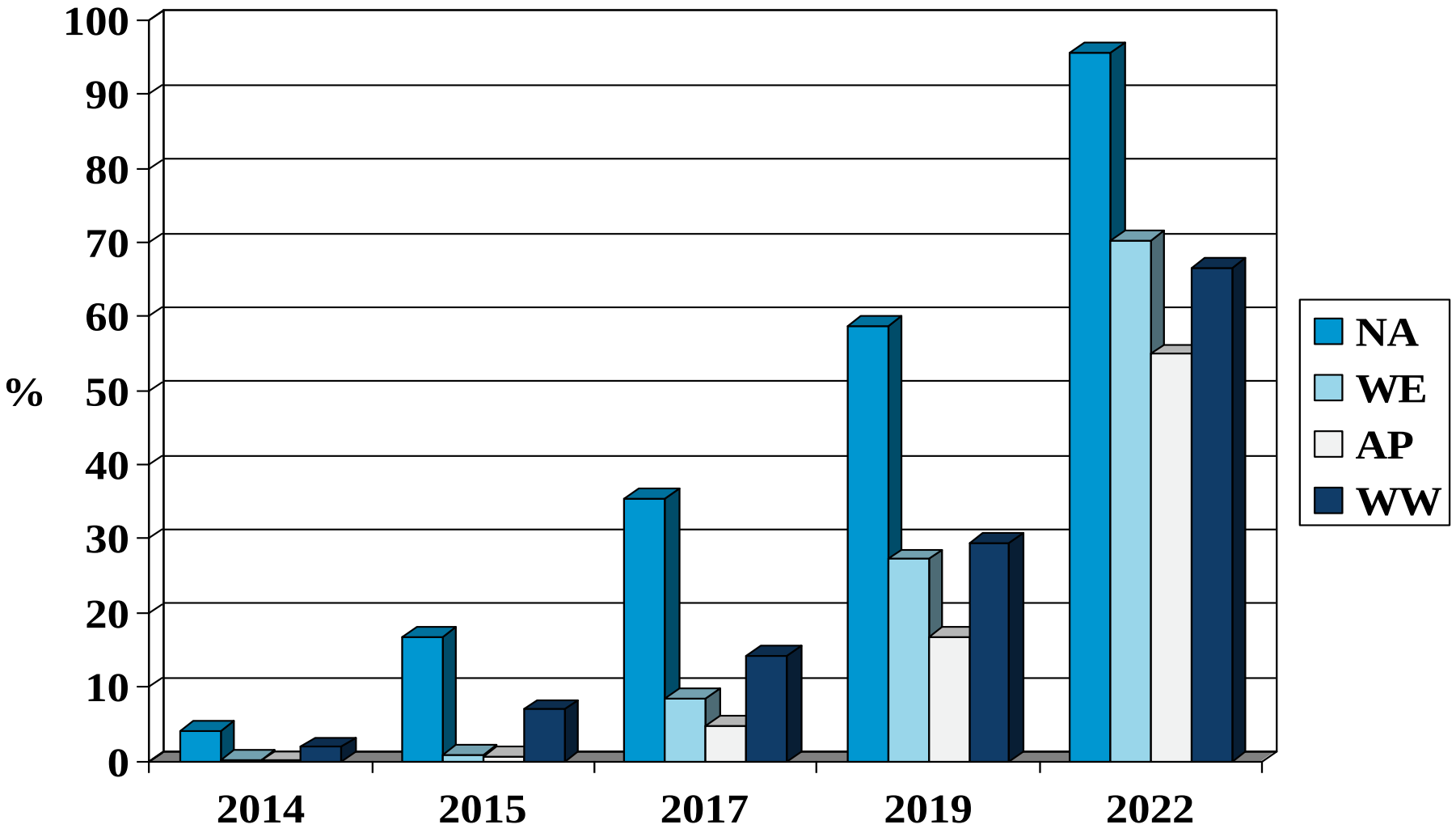
Connected Car Attach Rate



Includes connected car services via embedded modem, Smartphone & both

SOURCE: IHS Automotive
Infotainment Portal

LTE Share: Embedded Telematics Sales



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

SOURCE: IHS Automotive

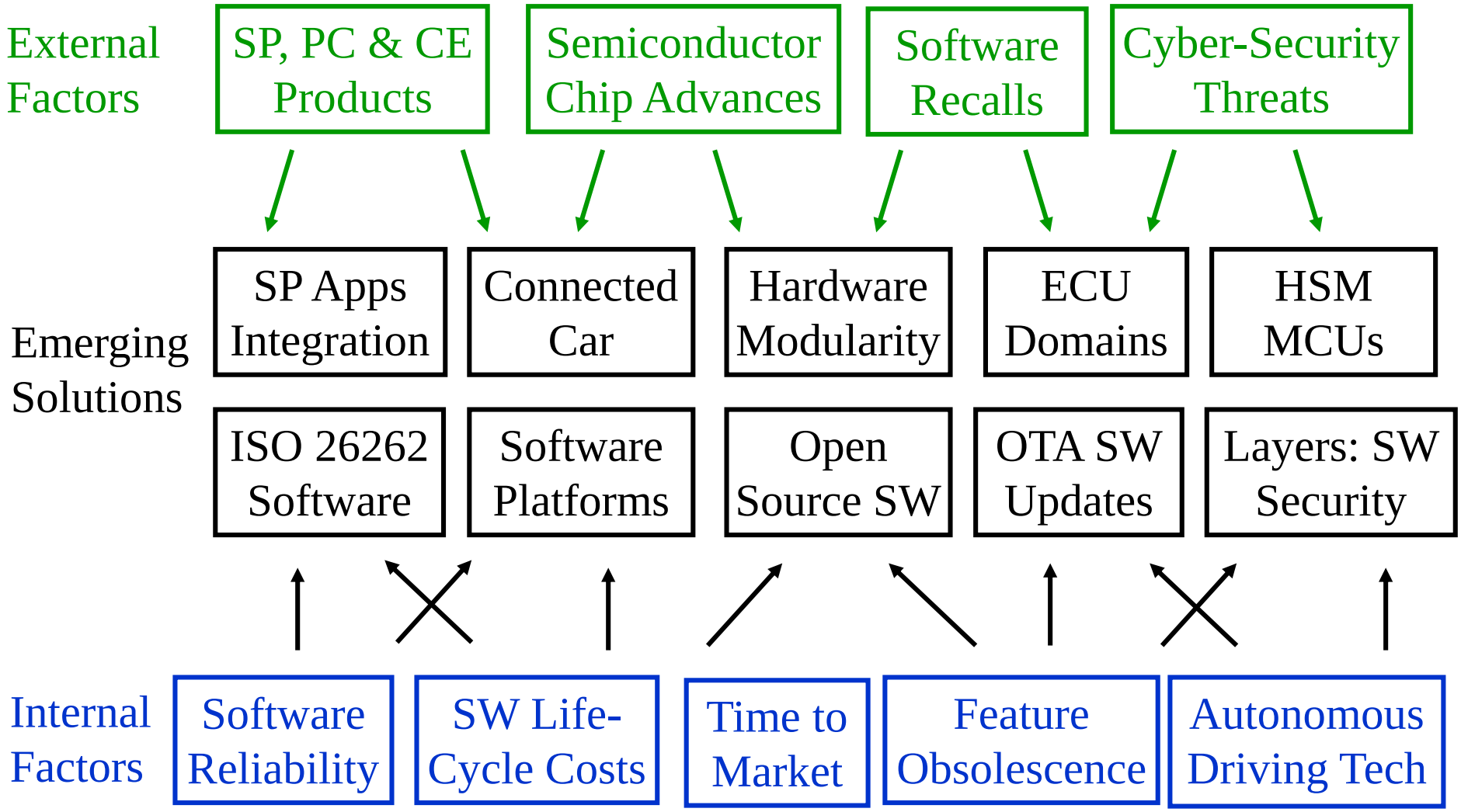
Who Benefits from Connected Cars?

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

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

SOURCE: IHS Automotive

Automotive Software Mega-Trends



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

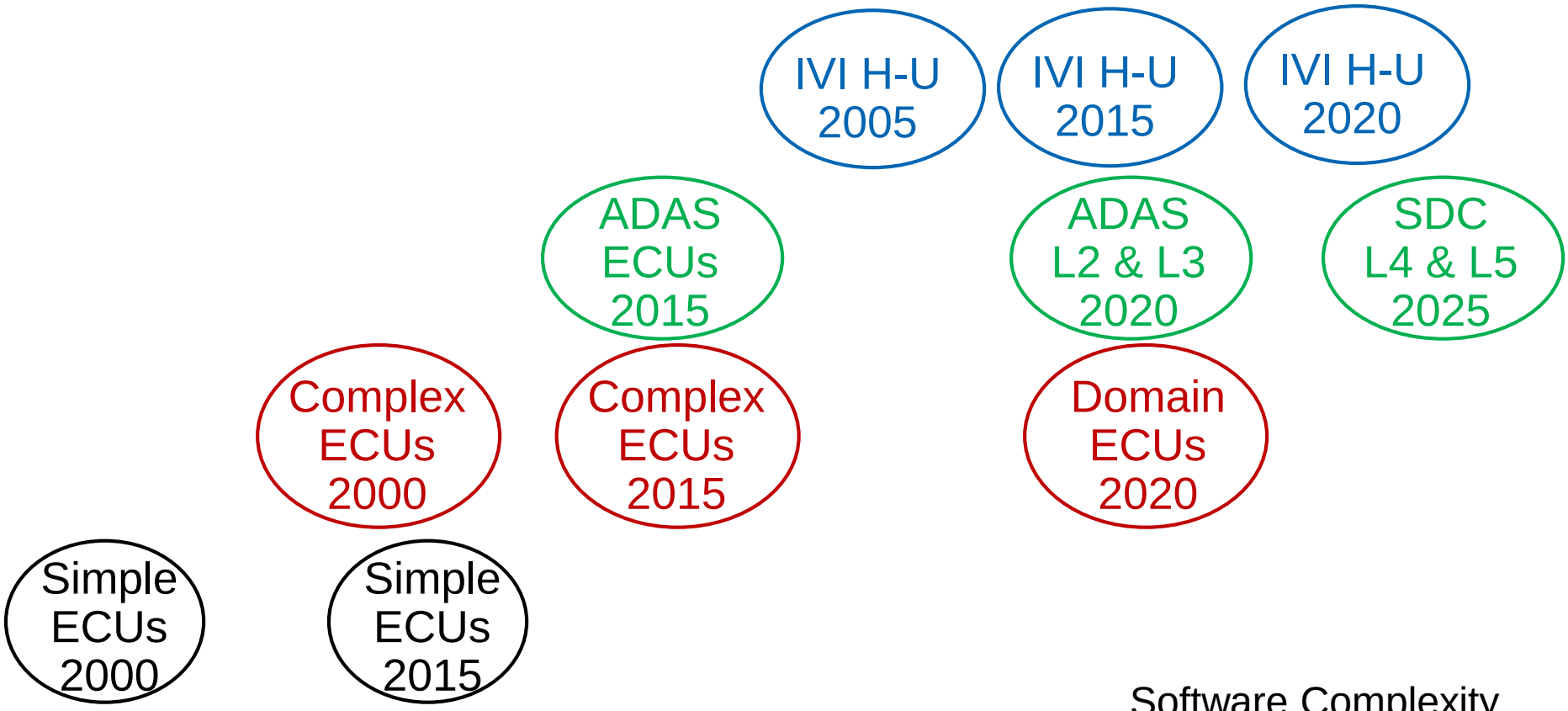
SOURCE: IHS Automotive
Software Apps & Service Portal

Auto Software Complexity Path

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

10X-100X Complexity

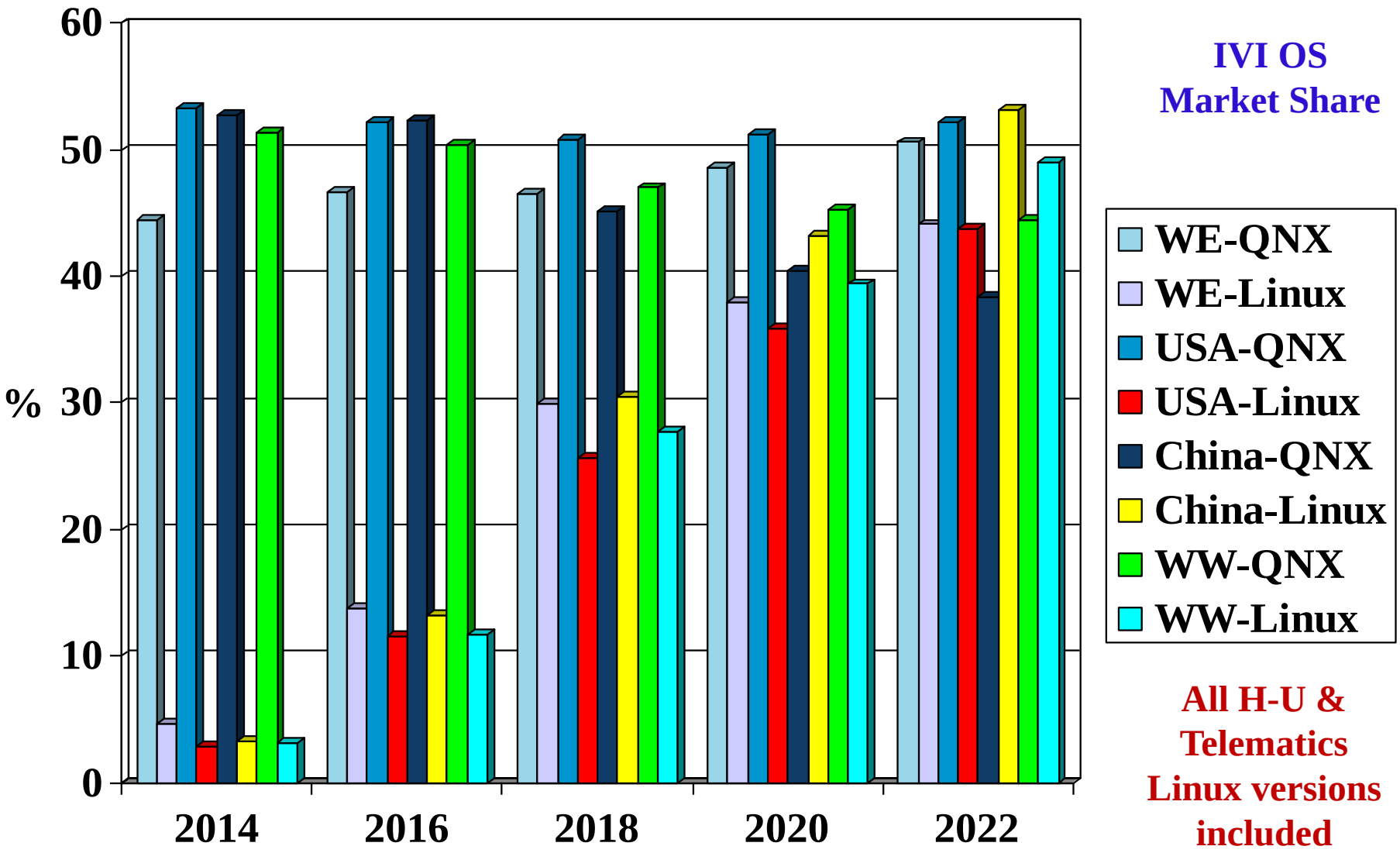
"Apps Computers"
- Complex operating system
- Computer middleware
- Industry-specific middleware
- Multiple changeable apps
- LoC* counted in millions



LoC=Lines of Code; SDC=Self-Driving Car

SOURCE: IHS Automotive

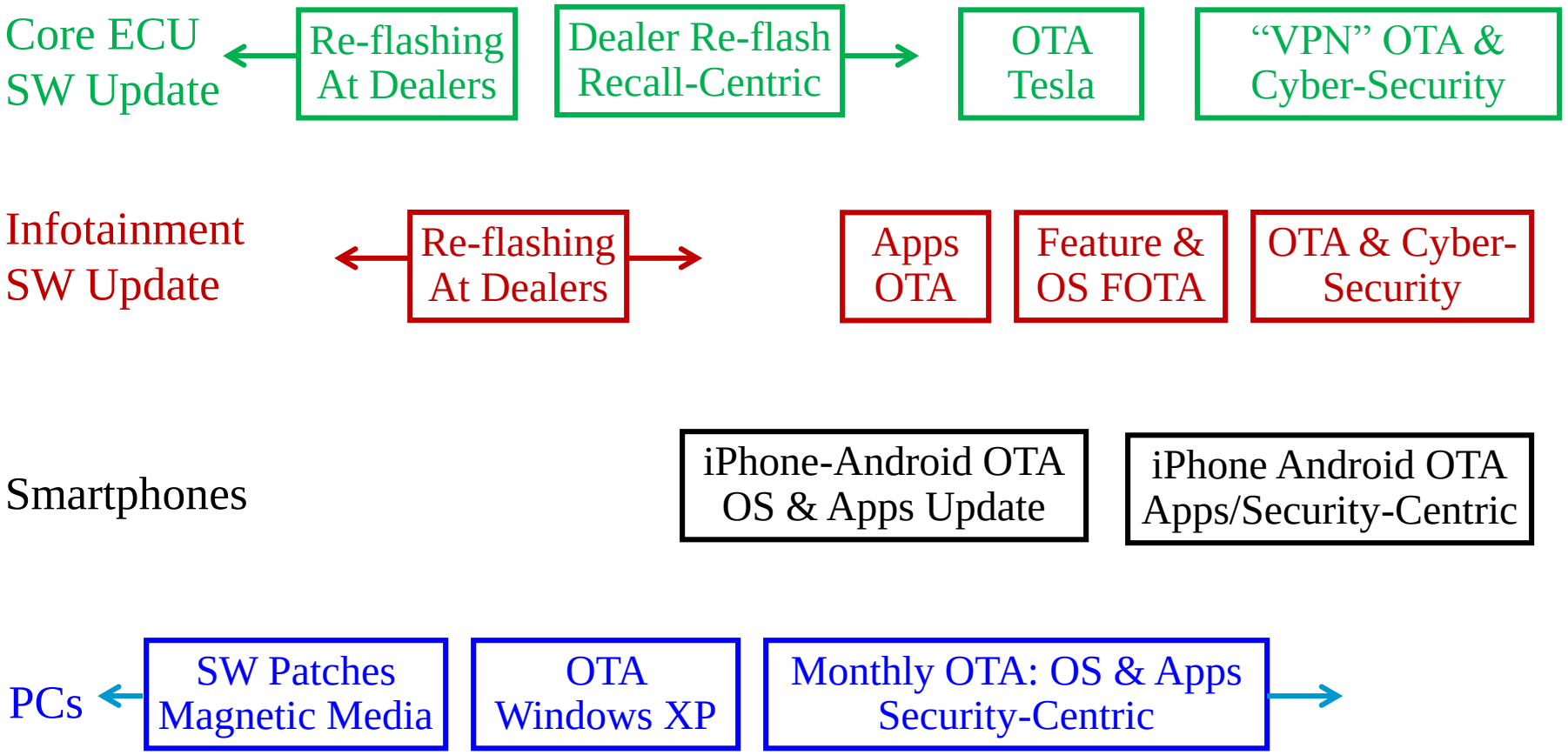
Infotainment OS Trends



WE=Western Europe; WW=Worldwide

SOURCE: IHS Automotive

OTA Software Update Evolution



OTA=Over The Air

SOURCE: IHS Automotive
Software Apps & Service Portal

OTA Software Update Advantages

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

SOURCE: IHS Automotive
Software Apps & Service Portal

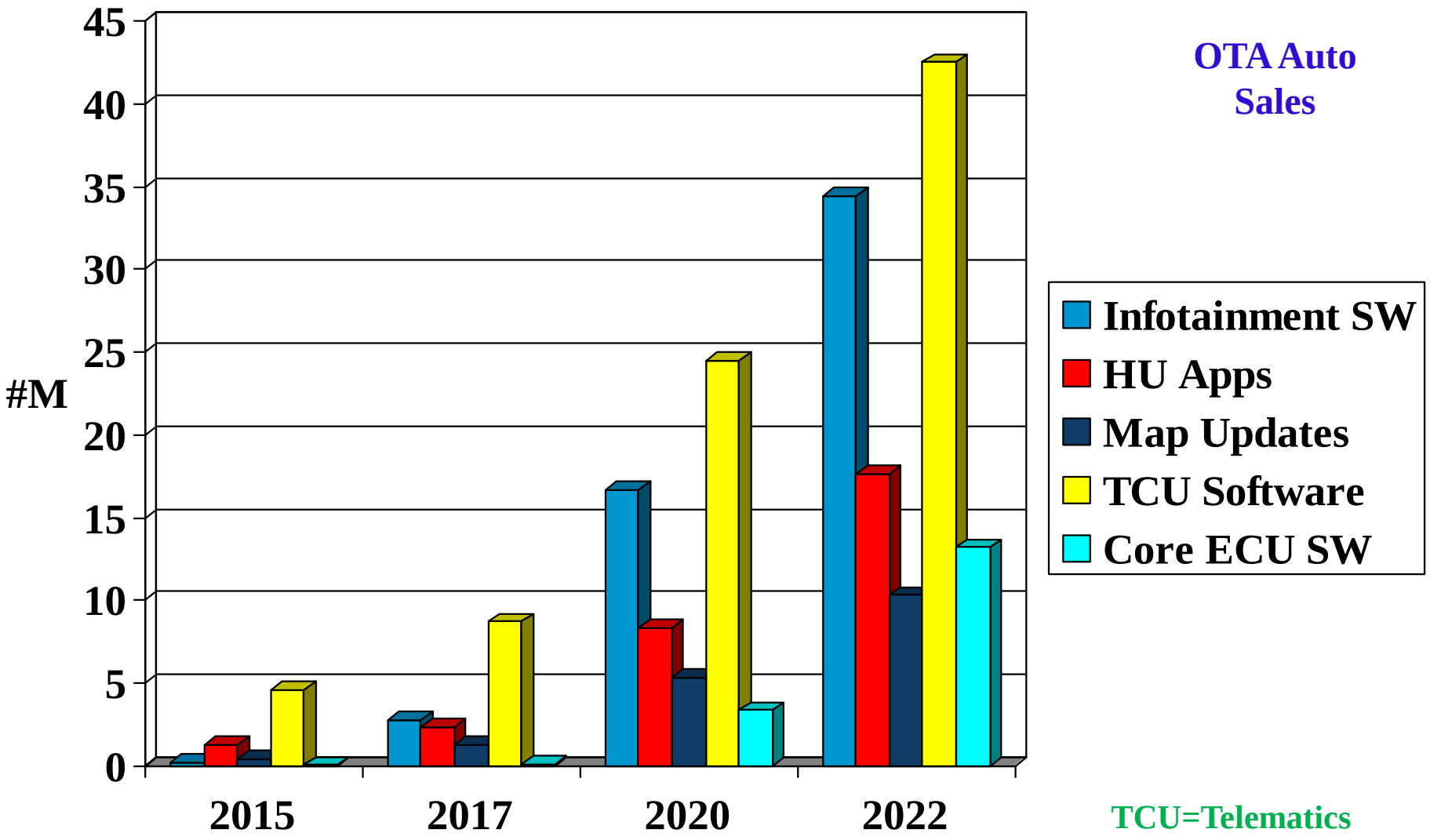
OTA Software Update Segments

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

*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!

SOURCE: IHS Automotive
Software Apps & Service Portal

Over-the-Air Software Update Forecast



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

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

SOURCE: IHS Automotive
Infotainment Portal

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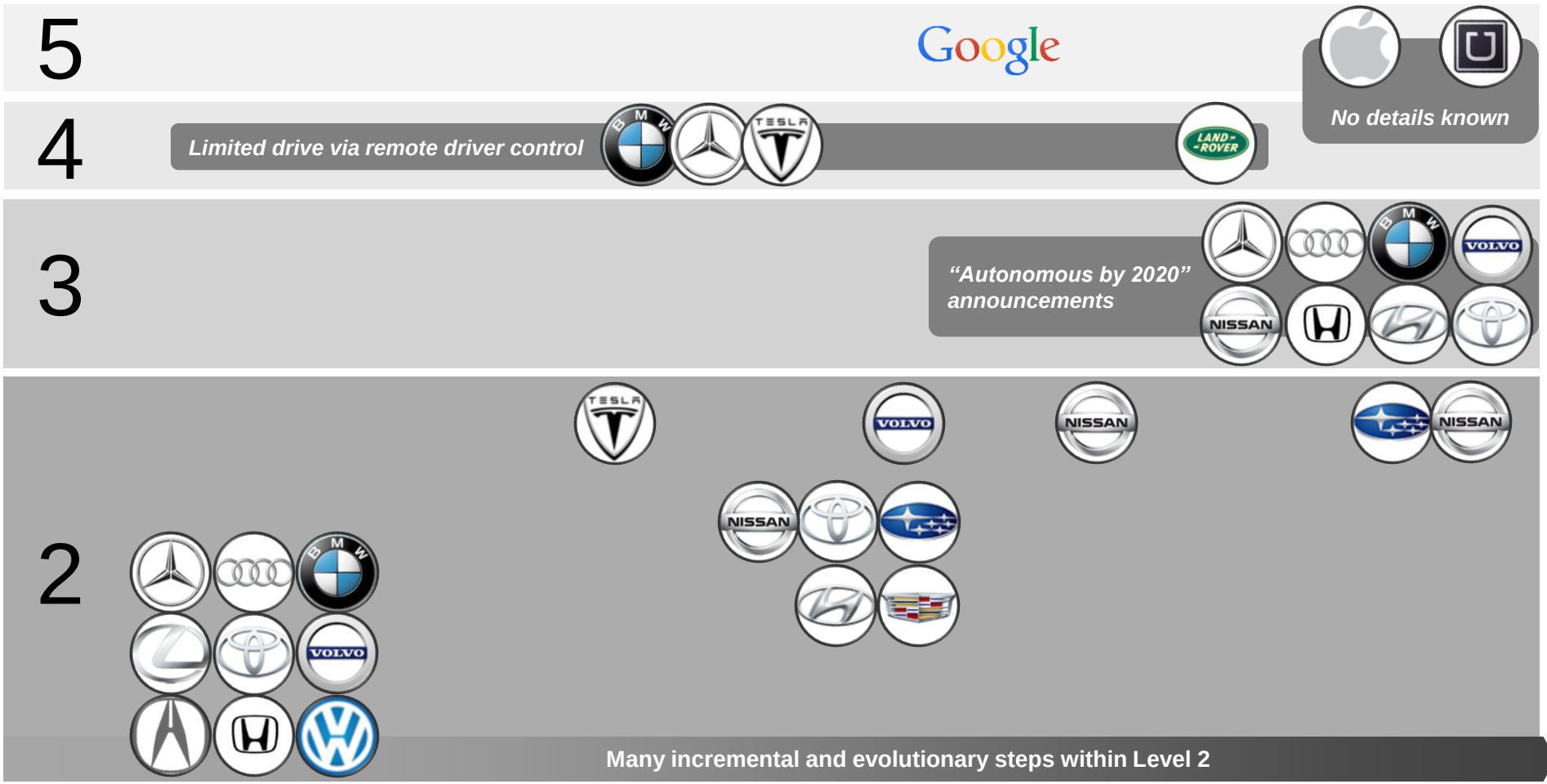
Current State of the Art & Announced Plans



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

SOURCE: IHS Automotive

2 Autonomous Driving Strategies

Focus:	Level 4 Vehicles	Level 5 Vehicles
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

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

SOURCE: IHS Automotive

Google SDC-DLC Software

	Key Information	Comments
Estimated Status	▶Better than nearly all drivers—at least in fair weather driving ▶Fewer emergencies ▶Know common driver weaknesses	▶Faster reaction time, never tired, never distracted, superior object tracking capabilities ▶From 1.5M miles in SDC mode
Next Focus	▶Finding and learning the once in a million events	▶Google has active projects to identify such events
Key Problems	▶Other drivers' negative reaction ▶Other cars run into SDC-DLCs ▶Computer ethics?	▶SDC-DLC follow all laws! ▶SDC driving style too different ▶Different views on its impact
Next Steps	▶Cooperative driving situations ▶Lower crashes by other drivers ▶Bad weather testing & learning	▶4-way stops is first step ▶SDC external info? What else? ▶Solutions in due time

Key Question:

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

SOURCE: IHS Automotive
Autonomous Driving Portal

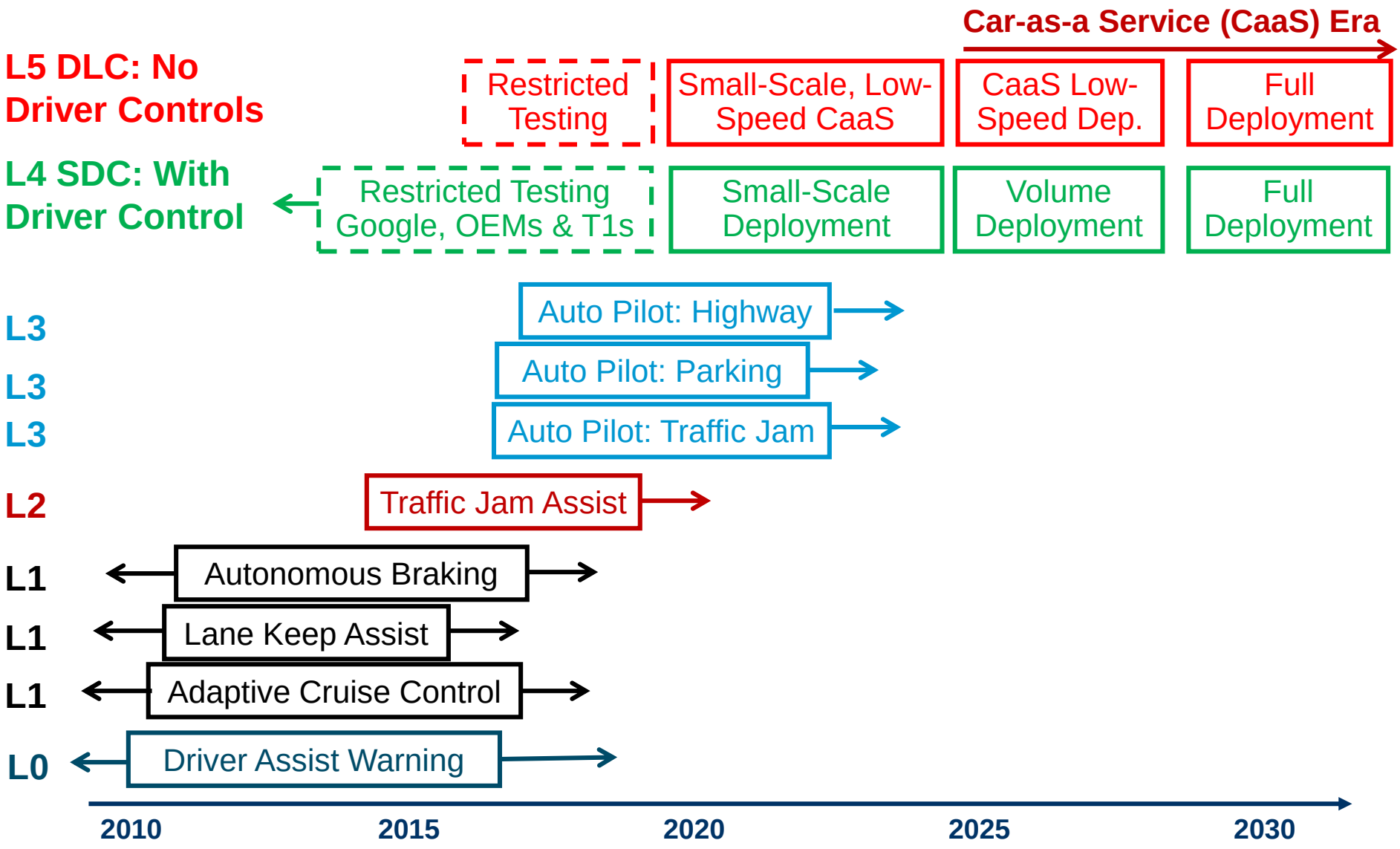
Mobility Implications

	Key Information	Other Information
Car Sharing	▸ Smartphone apps centric ▸ DLC lowers operating cost ▸ DLC fleets for car-sharing	▸ Convenience & availability ▸ No driver costs ▸ Likely first SDC deployment
Car Ownership	▸ Fewer cars/household when SDCs are fully available ▸ Higher miles per car year	▸ USA currently: 2.1 cars/HH ▸ USA projected: 1.2 w/SDCs* ▸ Quicker replacement rate
Car-as-a-Service Potential	▸ Worldwide population ▸ People with driver license ▸ People w/o driver license ▸ Urban population ▸ Seniors (65+ years old) ▸ Youth (Under 18 years old)	▸ 2015: 7.32B → 2035: 8.74B ▸ 2015: 1.13B → 2035: 1.9B ▸ 2015: 6.2B → 2035: 6.8B ▸ 2015: 4.1B → 2035: 5.7B ▸ 2015: 604M → 2035: 1.12B ▸ 2015: 2.26B → 2035: 2.36B
Mass Transit	▸ SDC for last mile service ▸ SDV for new mass transit ▸ SDV as mass transit	▸ To fill mass transit gaps ▸ Less cost than mass transit ▸ Current system competition

* UMTRI study, February 2015

SOURCE: IHS Automotive
Autonomous Driving Portal

Autonomous Driving Evolution



SOURCE: IHS Automotive *Autonomous Driving Portal*

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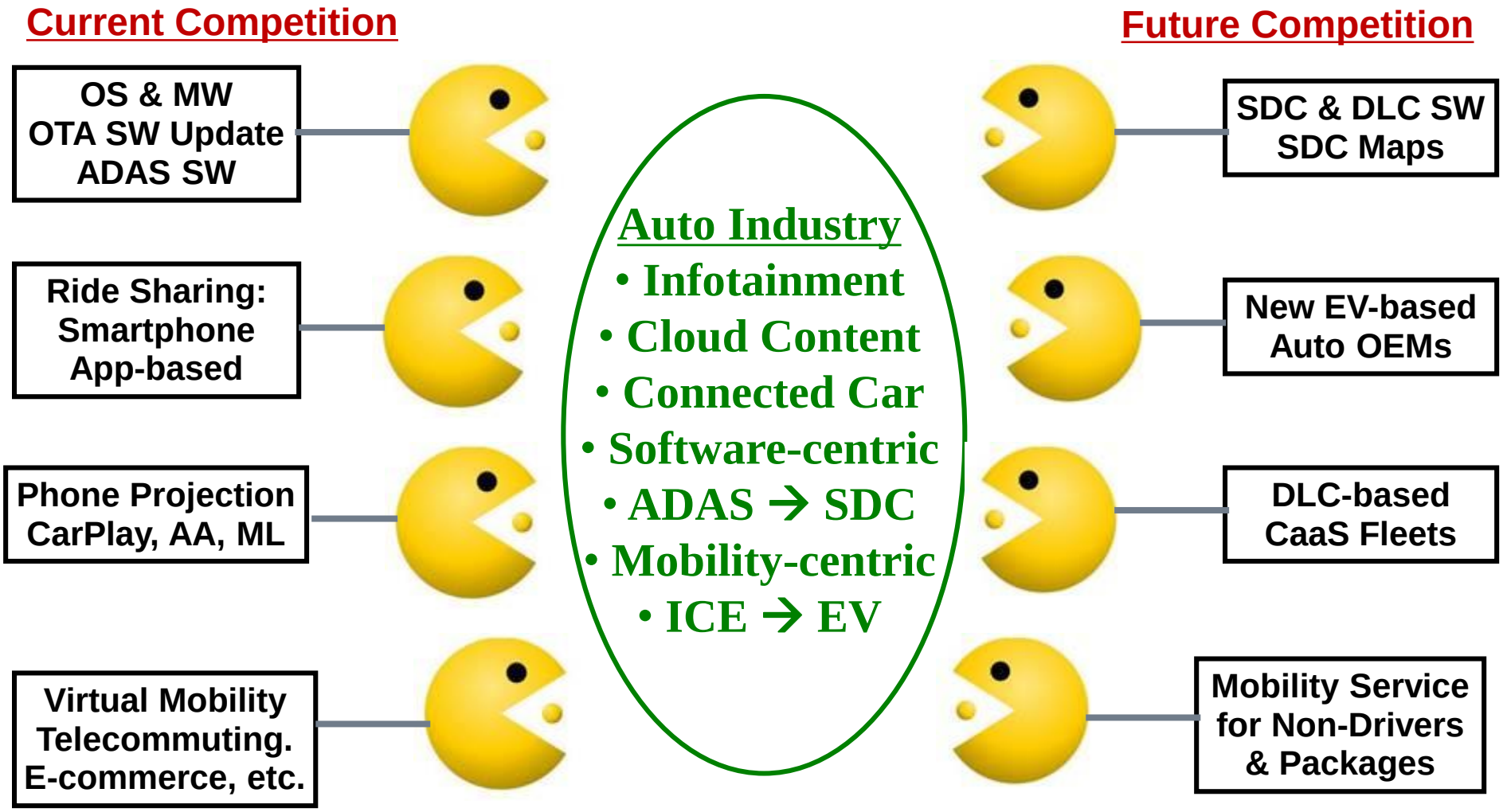
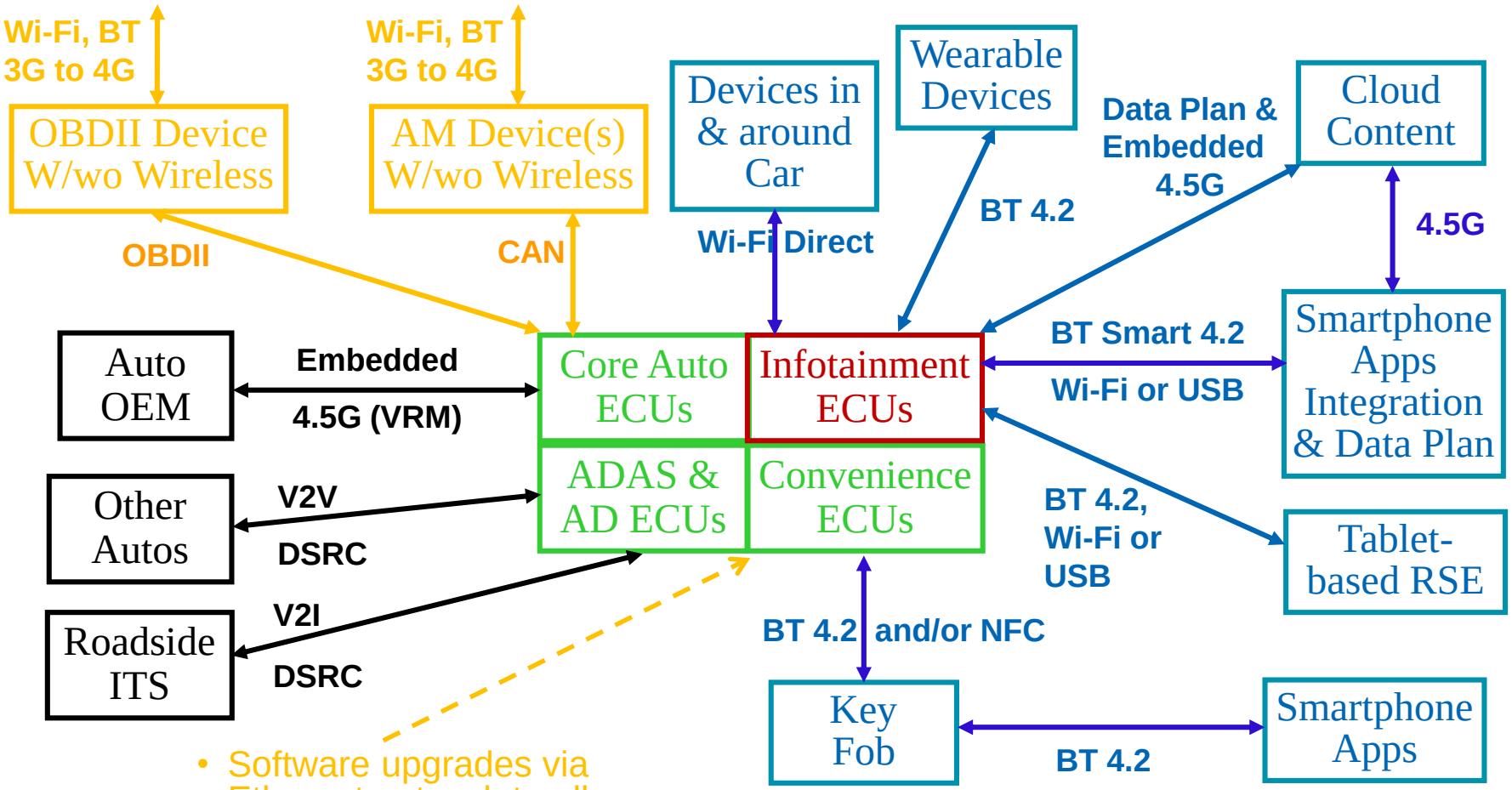
New Auto Industry Competition



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+

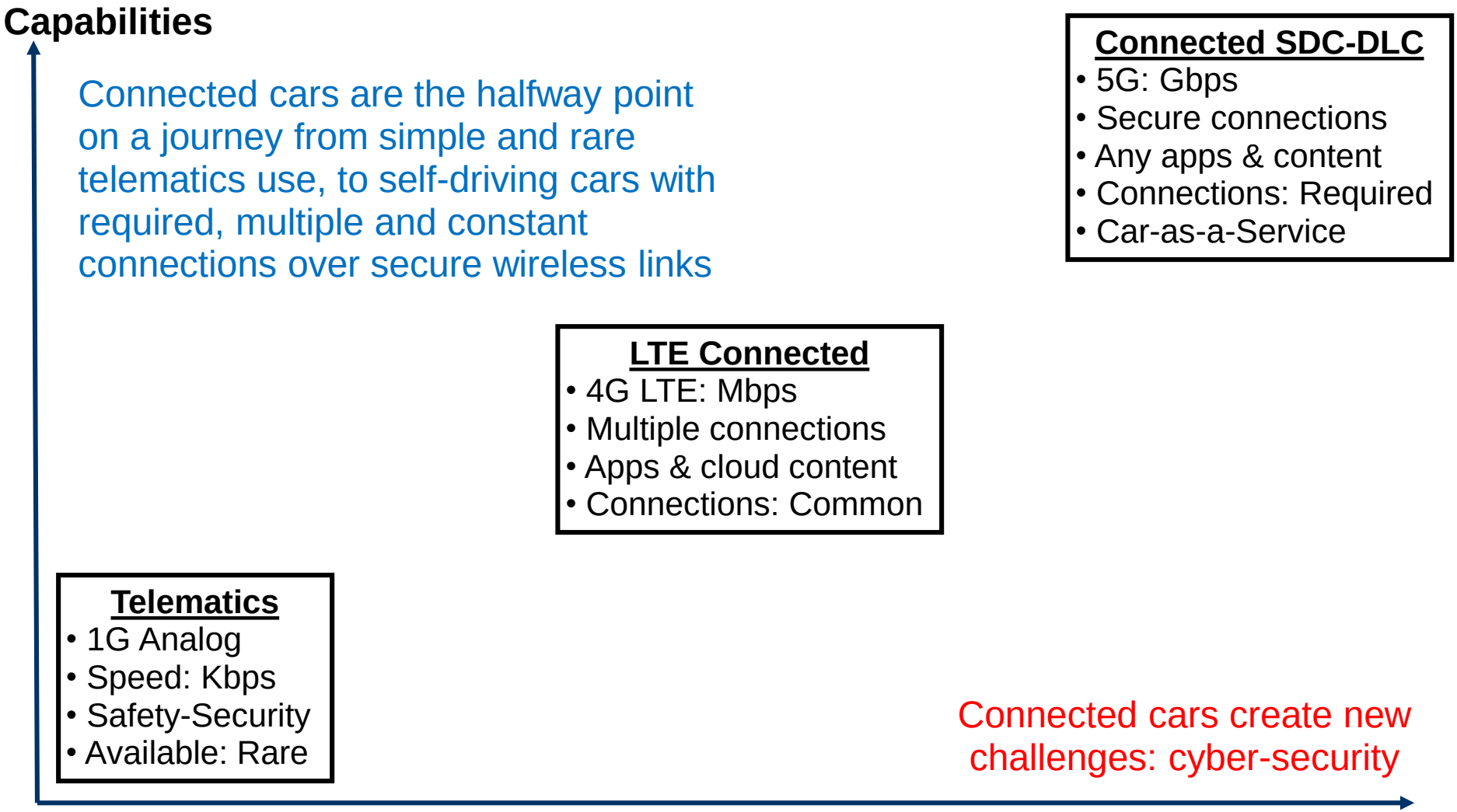


RSE=Rear Seat Entertainment

Embedded links: from shared to separate

SOURCE: IHS Automotive

Connected Car Revolution



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!

Connected Car
Remote SW Upgrades
Software security

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

Tesla is first SW-defined car

AUTOSAR
Remote Diagnostics
Software APIs

Digital Car Era
Platform architecture
Re-usable software

ECUs

Analog-Digital Car Era
Digital control system growth

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

SOURCE: IHS Automotive

Questions?

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