



IHS Markit™

Automotive Software: Trends, Importance & Opportunities

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Who Is IHS Markit?

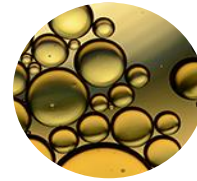
- ▶ Merger of IHS and Markit in July 2016
- ▶ Public company on NASDAQ: Symbol is INFO
- ▶ Market cap in \$16B range
- ▶ Over 12,500+ employees; Revenue \$3.4B+
- ▶ Industries IHS Markit serves:



Financial Markets



Energy



Chemical



Automotive



Aerospace,
Defense & Security



Product Design

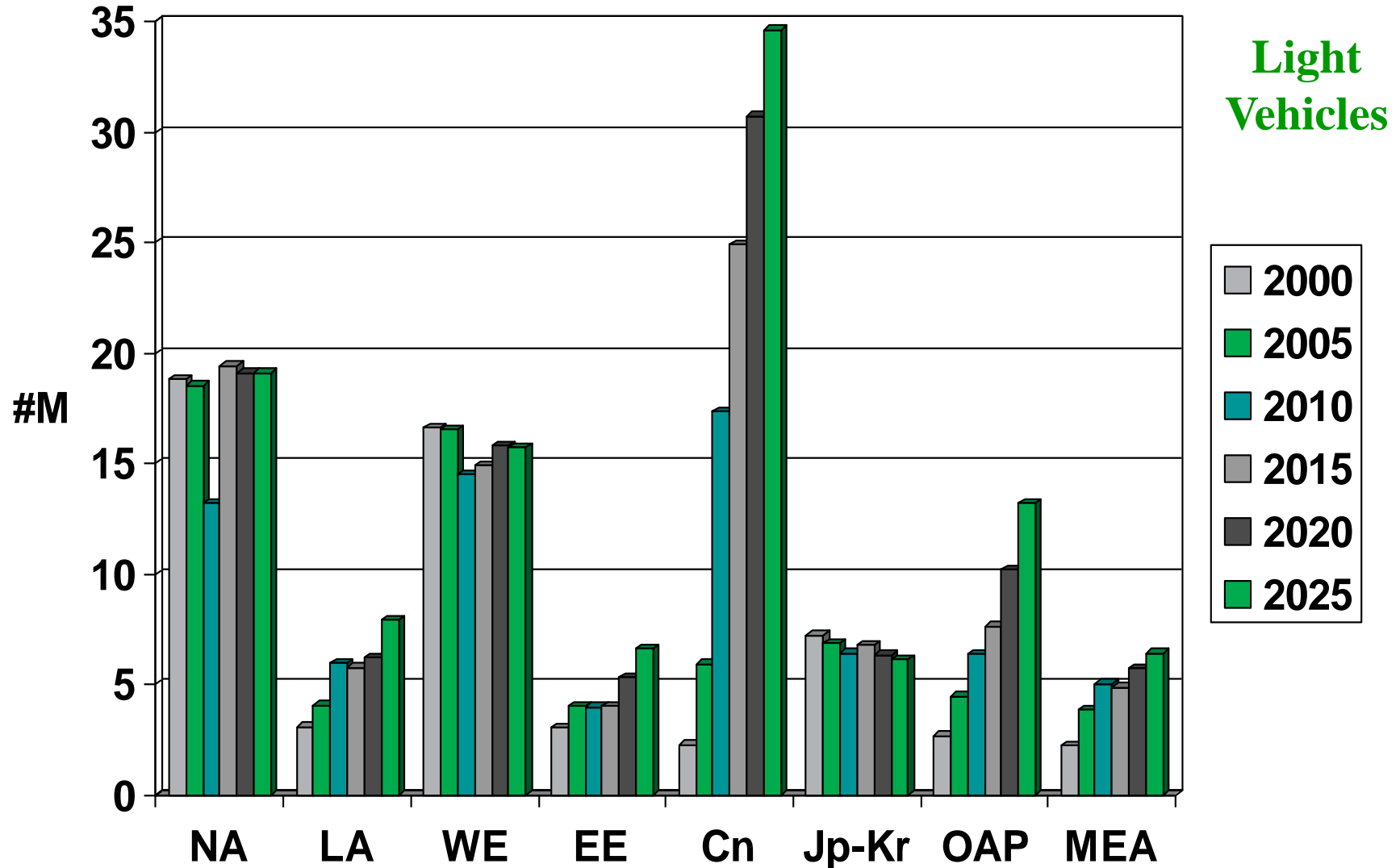


Technology, Media
& Telecom



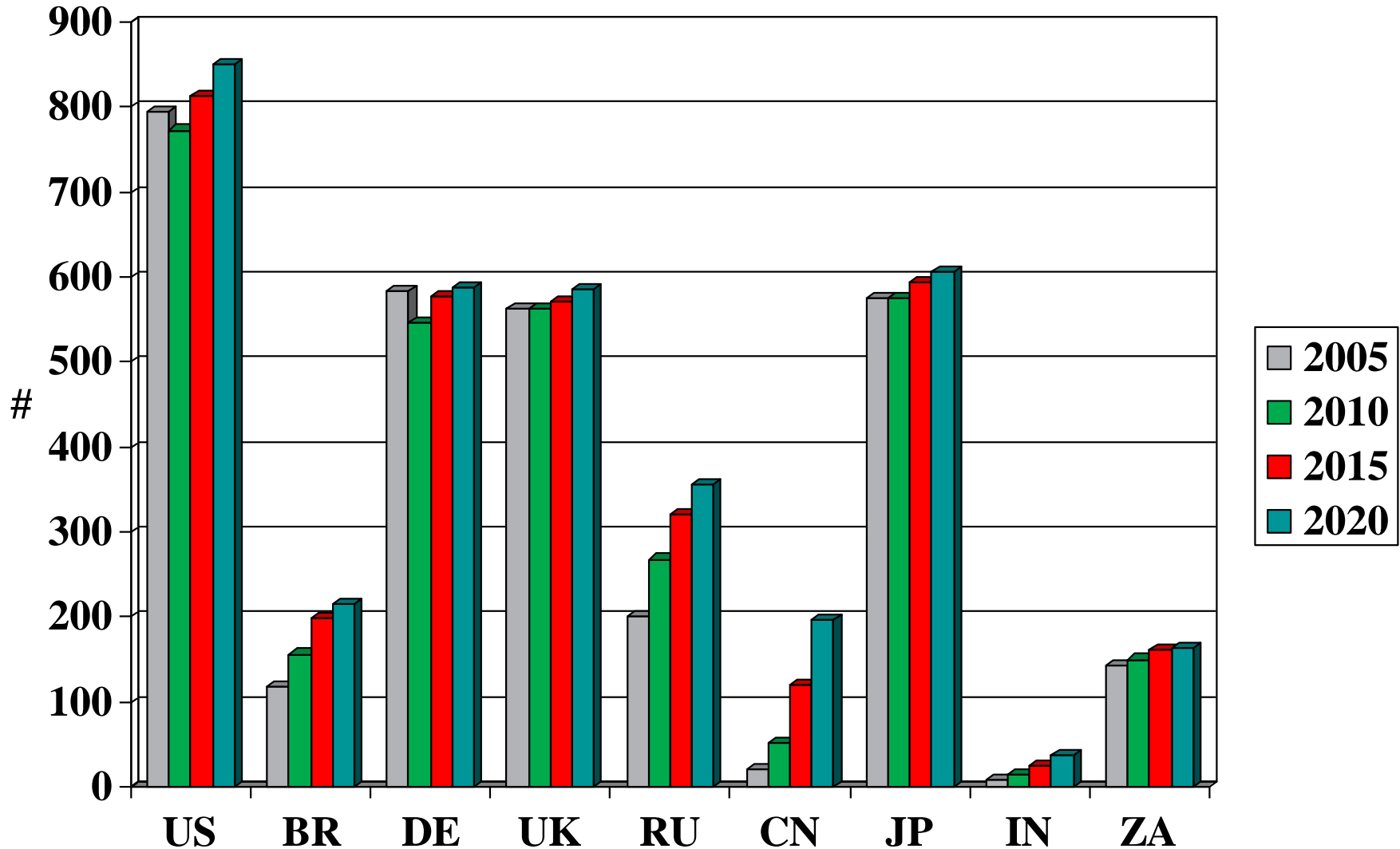
Maritime & Trade

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

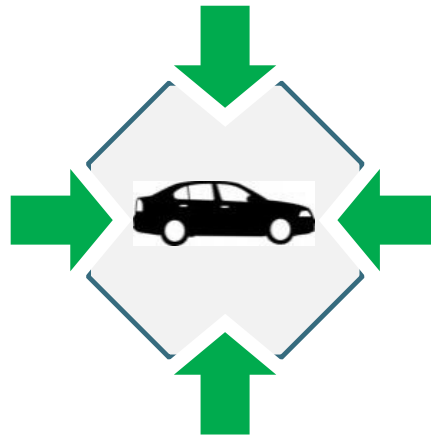
Implications for the Global Automotive Industry

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



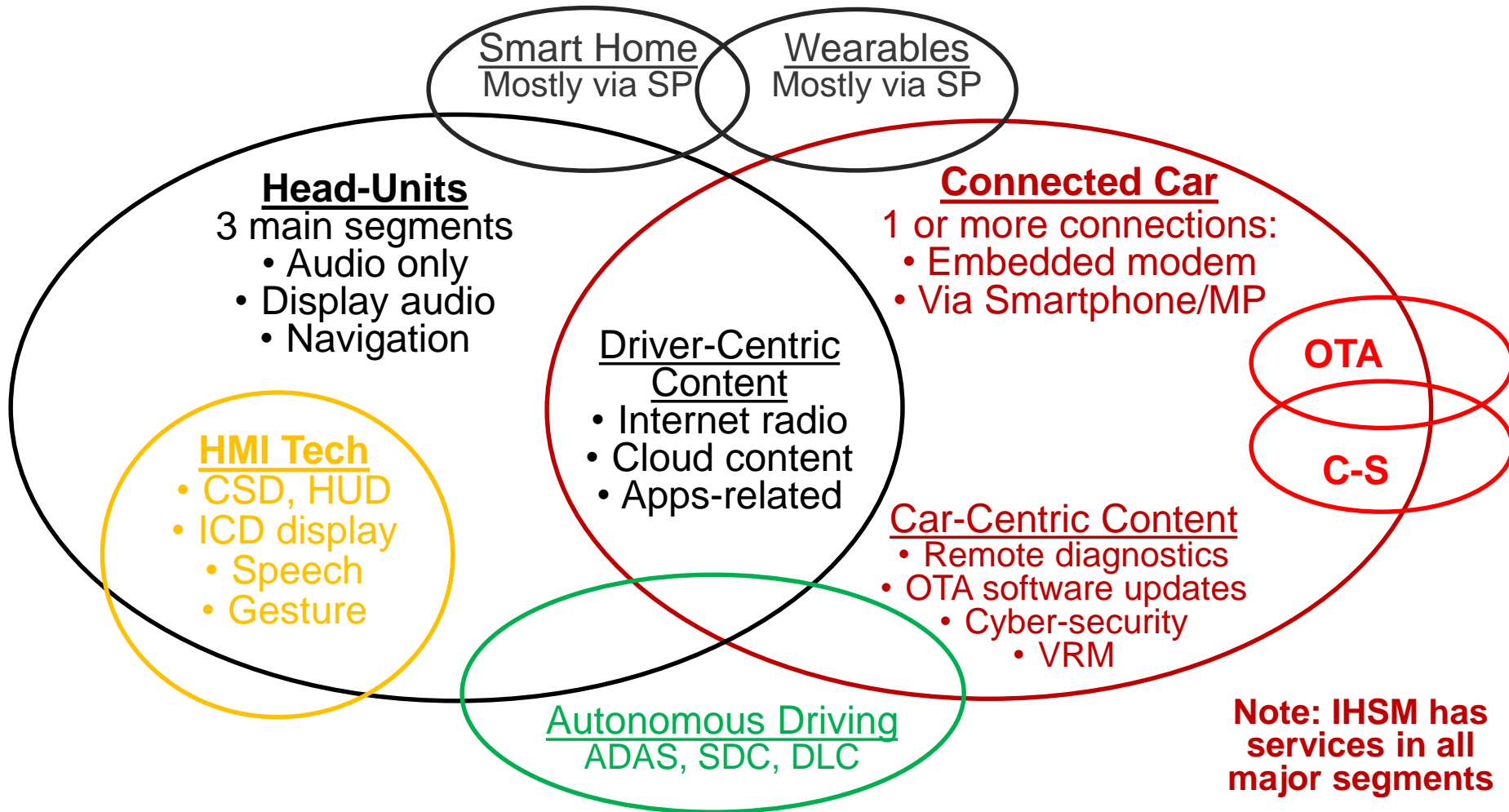
Connected cars:
New products & competitors
New content & cloud services
Opportunities for newcomers

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

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

OTA=Over-the-Air

Software Life Cycle Example: Infotainment

Software Create Phase		
<u>SW Design</u> • 30% of total • \$9M	<u>SW Coding</u> • 30% of total • \$9M	<u>SW Testing</u> • 40% of total • \$12M
Infotainment system development cost=\$30M Around 3 year development time Assume production volume of 200K units		

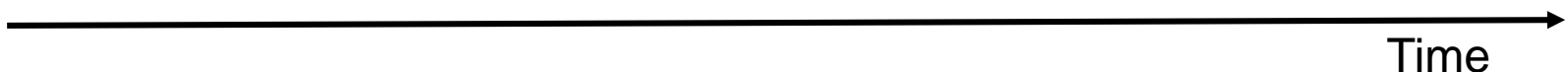
Production

- 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

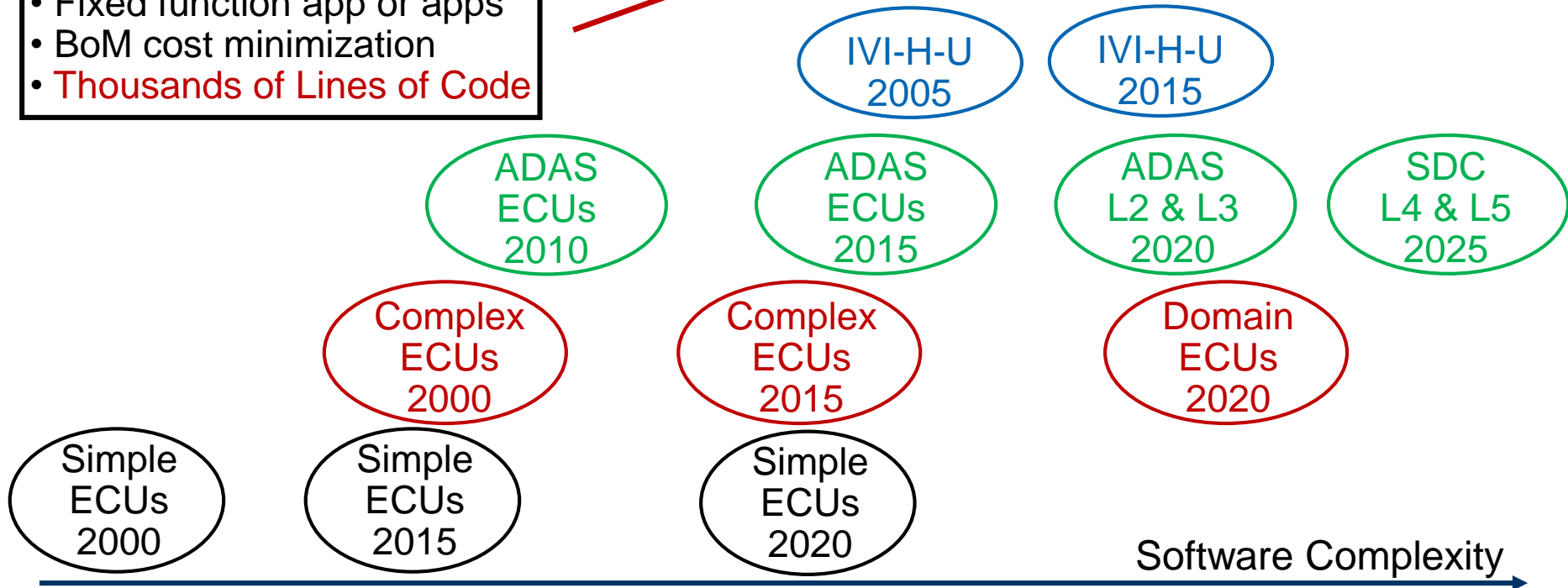
“Embedded Controllers”

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

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%
Total disengagements	124	100%

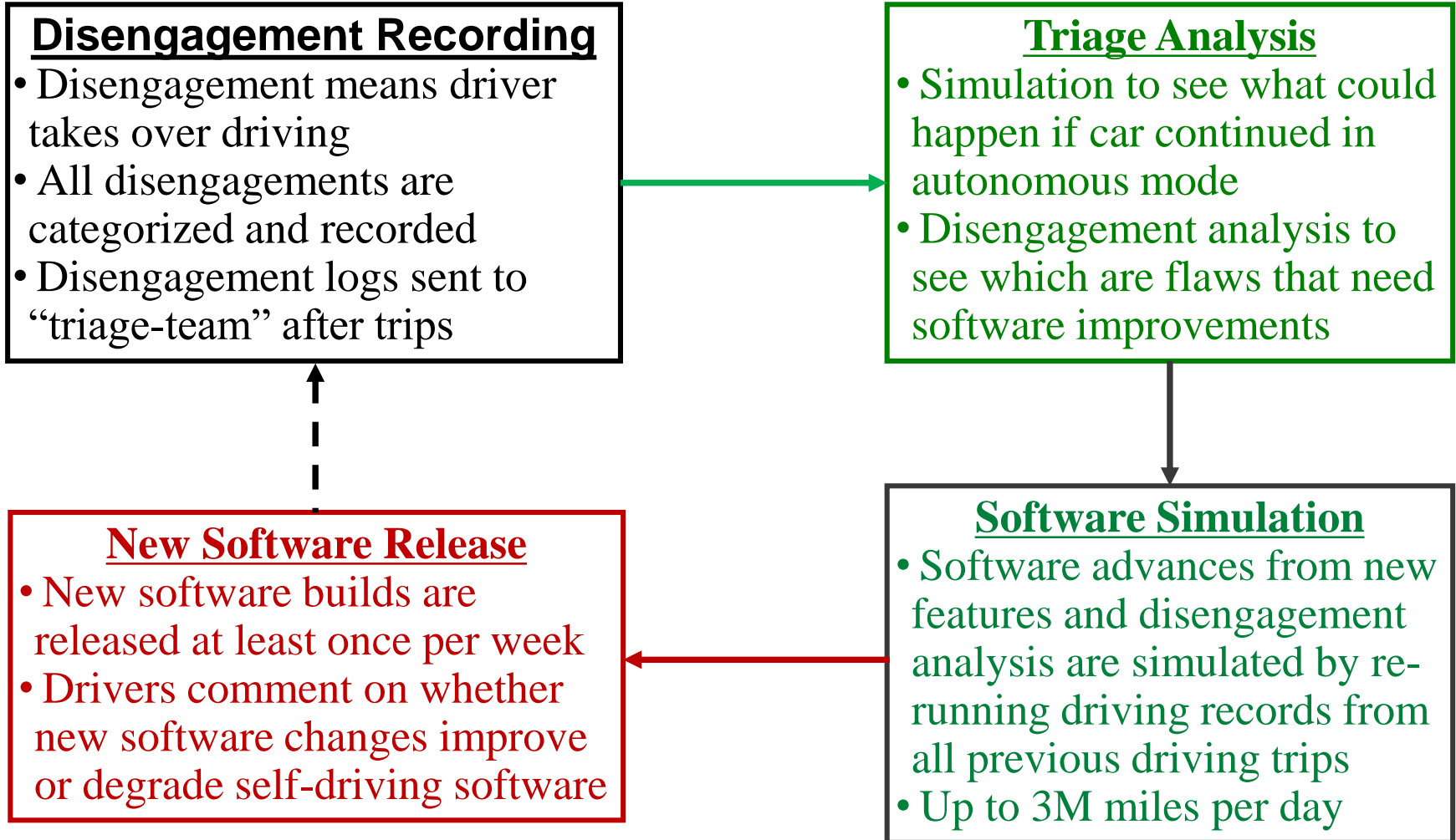
Source: Waymo via CA DMV

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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

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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Software Opportunity Perspectives

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

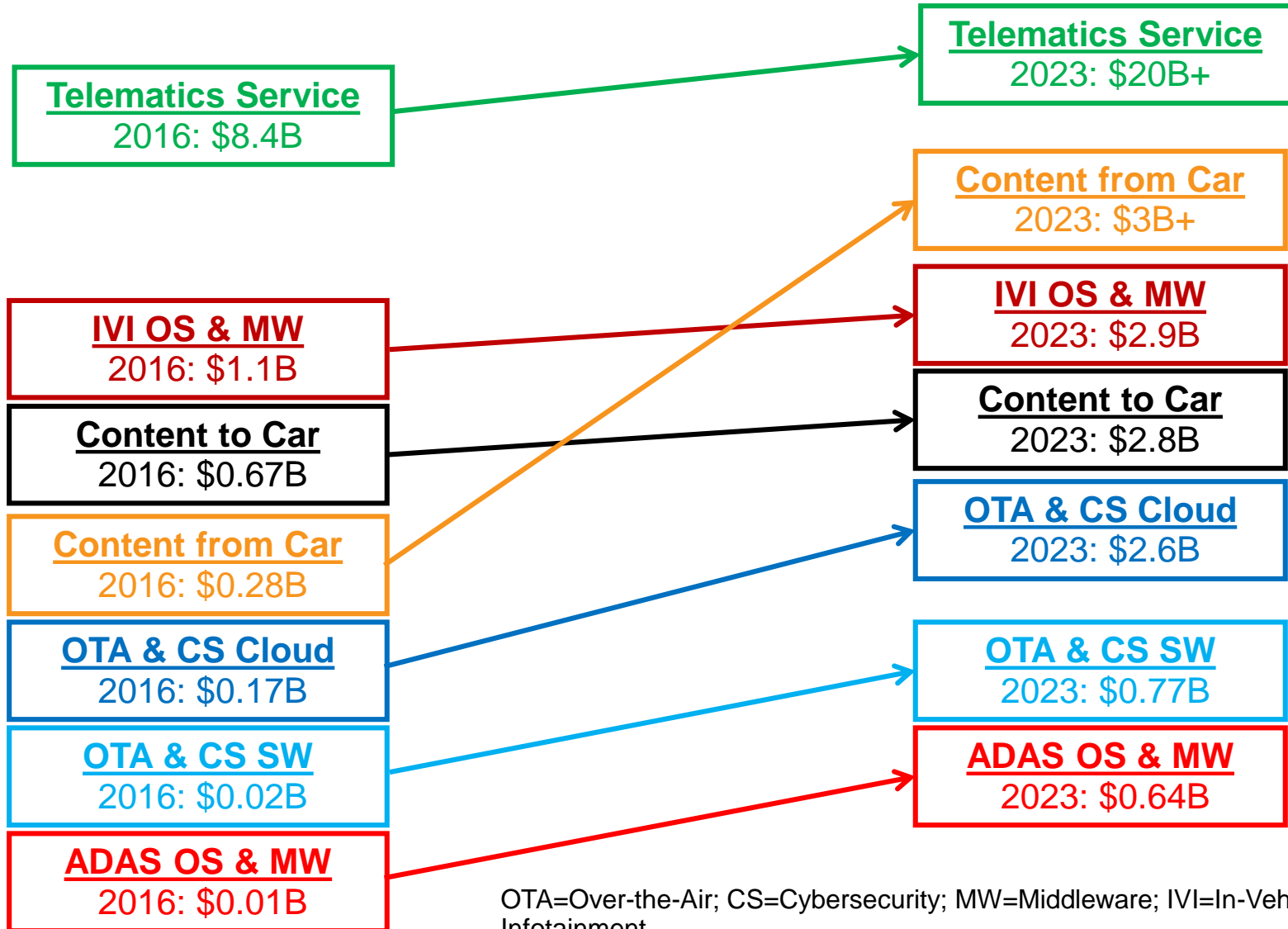
SaaS=Software-as-a-Service; OTA=Over-the-Air, SW=Software

Software Suppliers' Opportunities

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

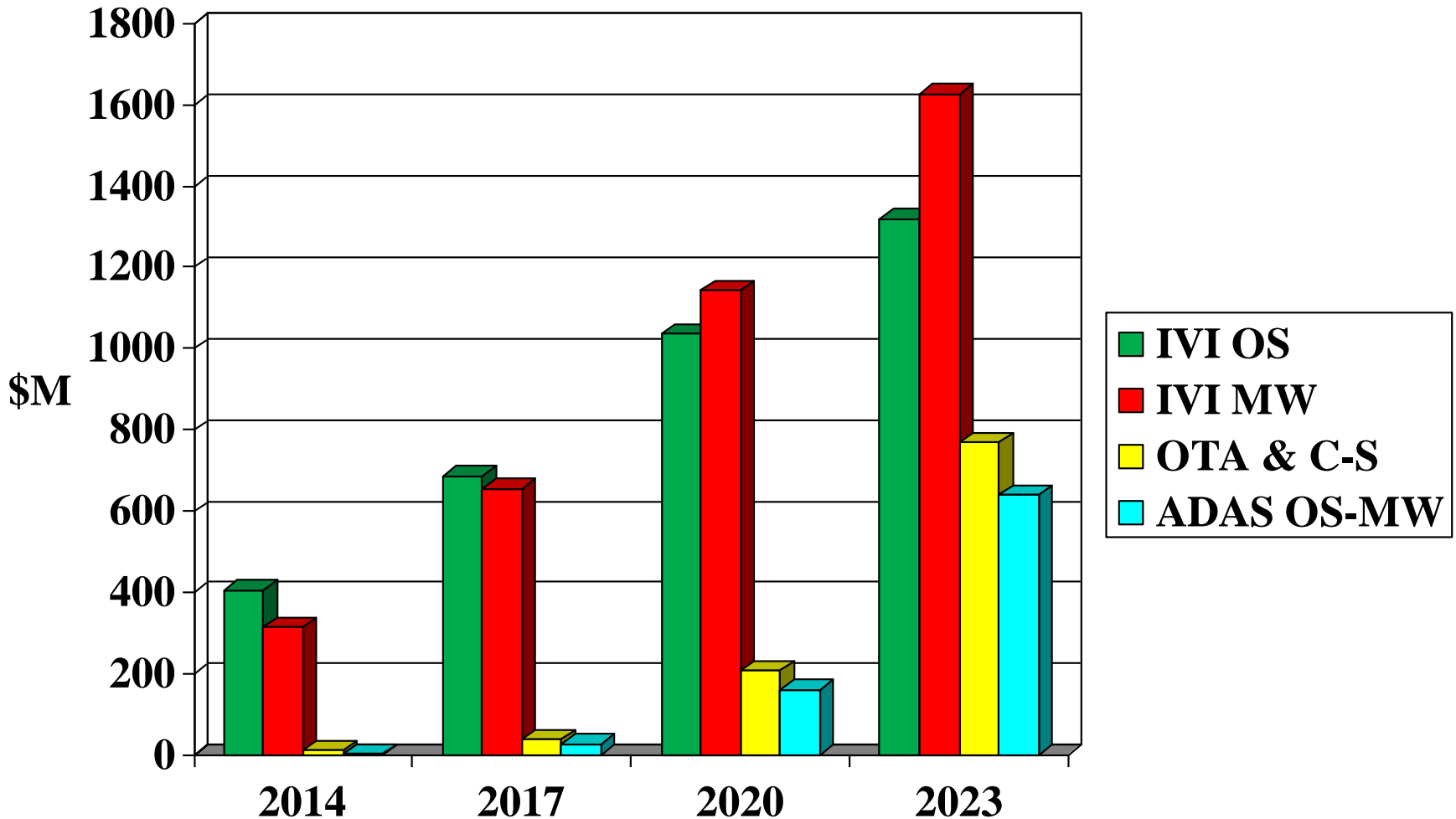
SaaS=Software-as-a-Service; OTA=Over-the-Air; SW=Software

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

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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:

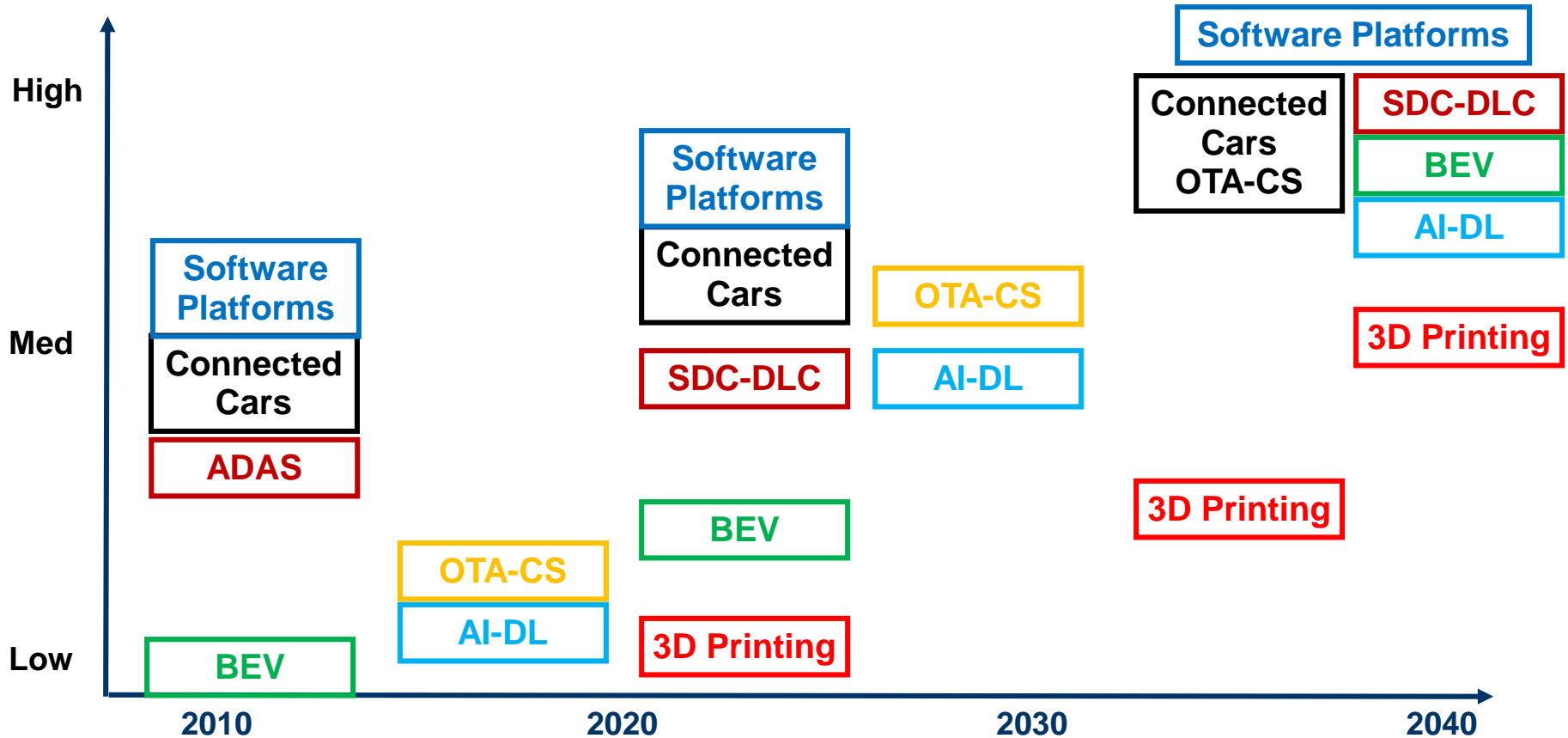
- Platform: Ecosystem & more business
- SW royalty: steady business model
- SW-cloud-service: better business model

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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DANKE

MERCI

GRAZIE

GRACIAS

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