Technology Overview

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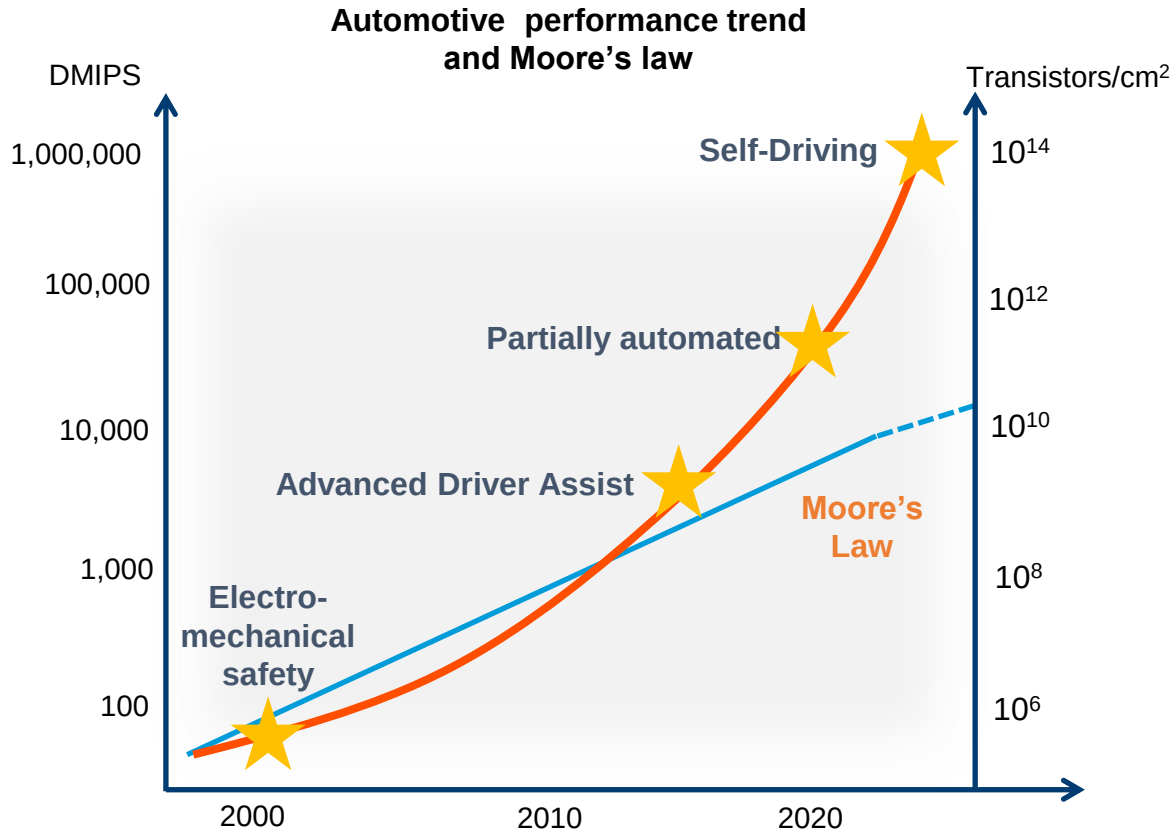
Innovation for the Real World

Automotive computing: “**More than Moore’s Law**”



Automotive computing requirements are Outpacing Moore’s Law



new car has 100M lines of code

* Charts provided by Intel

ADAS and AD processing requirements are skyrocketing

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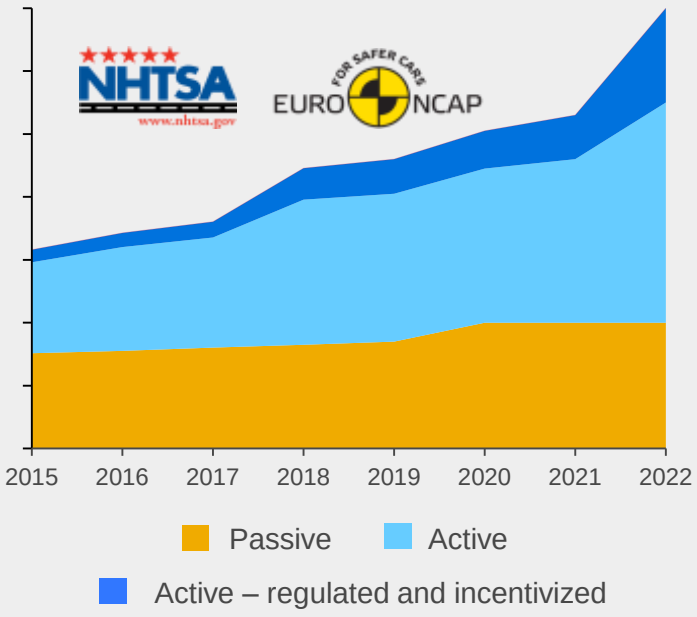
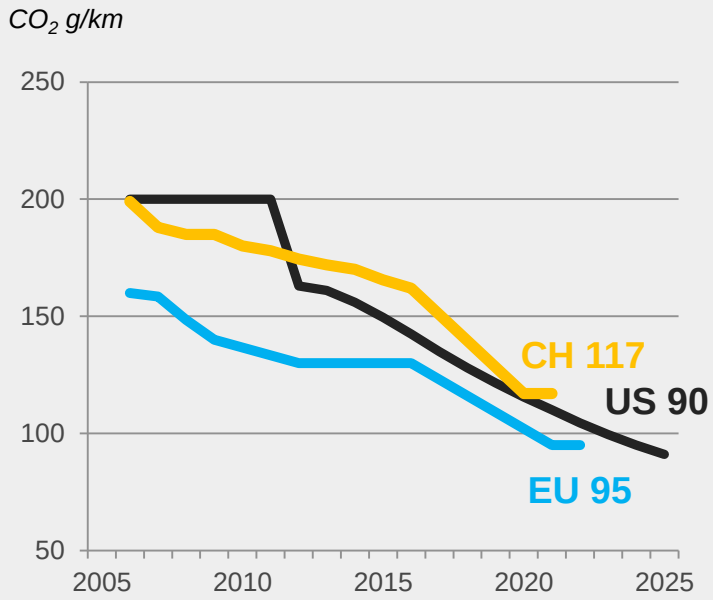
Accelerating macro trends create new challenges

Regulated Active Safety growing with increased consumer awareness	Best-value electrification required to meet step function change in regulation	IoT driving connected car to new levels & creating new challenges

More **safe**



More **green**



More **connected**



Connectivity

- Validating 5.9GHz standard for Dedicated Short-Range Radio Communication (DSRC)

Cybersecurity

- Auto Information Sharing and Analysis Center (ISAC) developing process to share & fix vulnerabilities

Big Data

- OEMs enabled to collect but not personalize information

Providing integrated intelligent solutions for our customers

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Building blocks of Intelligent Driving

Optimized Vehicle Architecture

Multi-Domain Controller
High speed electrical architecture
Engine management system

Manage complexity & performance

Connected Infotainment

Integrated Cockpit Controller
BYOD
Cloud computing

Features & functionality



Active Safety Sensor Fusion

Suite of sensors

Redundancy & reliability

Enabling Automated Driving

Massive amounts of Software

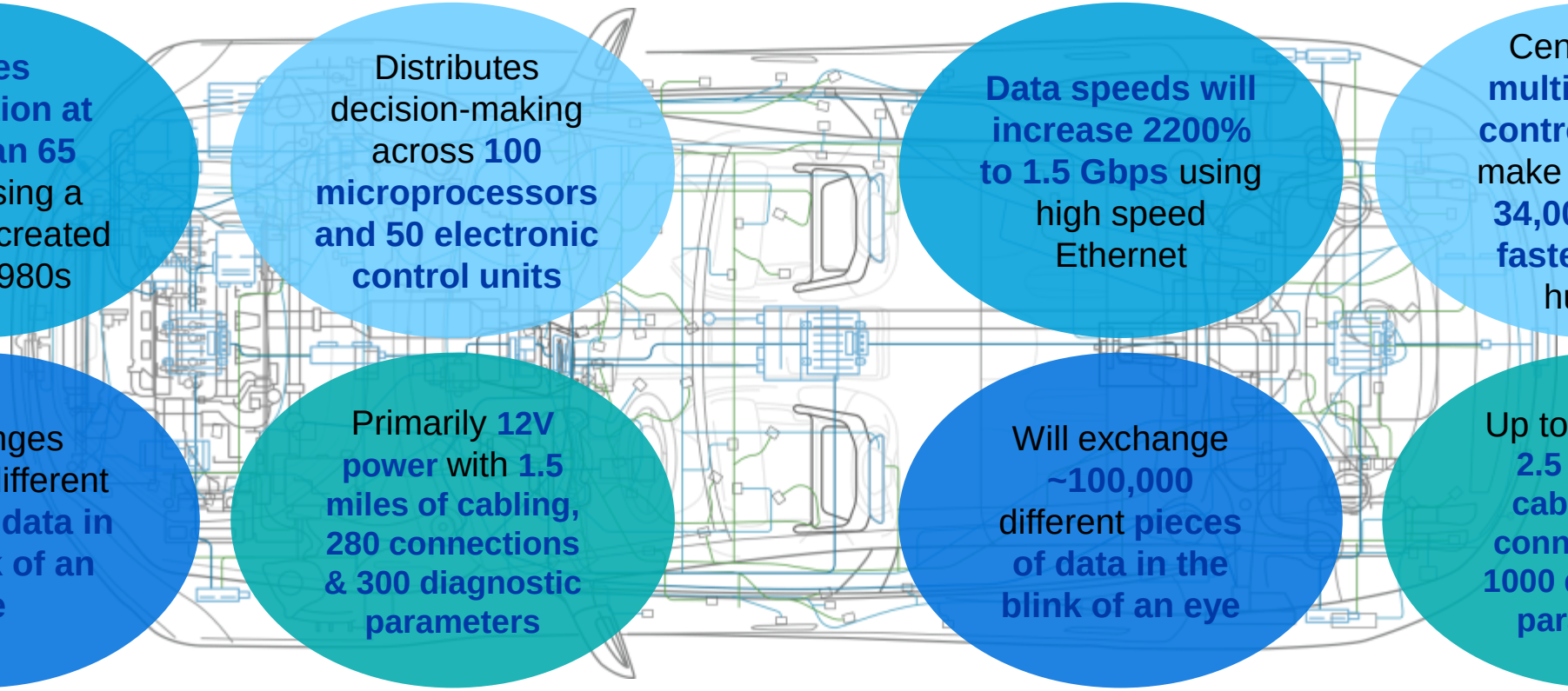
Coded by Delphi and partners

Automated algorithms, learning as you drive

Delphi responding to opportunities with end-to-end solutions

Future solutions enabled by industry-leading architectures

2015 → **2020+**



Moves information at less than 65 Mbps using a language created in the 1980s

Distributes decision-making across **100 microprocessors and 50 electronic control units**

Data speeds will increase 2200% to 1.5 Gbps using high speed Ethernet

Centralized **multi-domain controllers** will make decisions **34,000 times faster** than a human

Exchanges **~15,000** different **pieces of data in the blink of an eye**

Primarily **12V power** with **1.5 miles of cabling, 280 connections & 300 diagnostic parameters**

Will exchange **~100,000** different **pieces of data in the blink of an eye**

Up to **600V** with **2.5 miles of cabling, 350 connections & 1000 diagnostic parameters**

High speed data enables tomorrow's technology today

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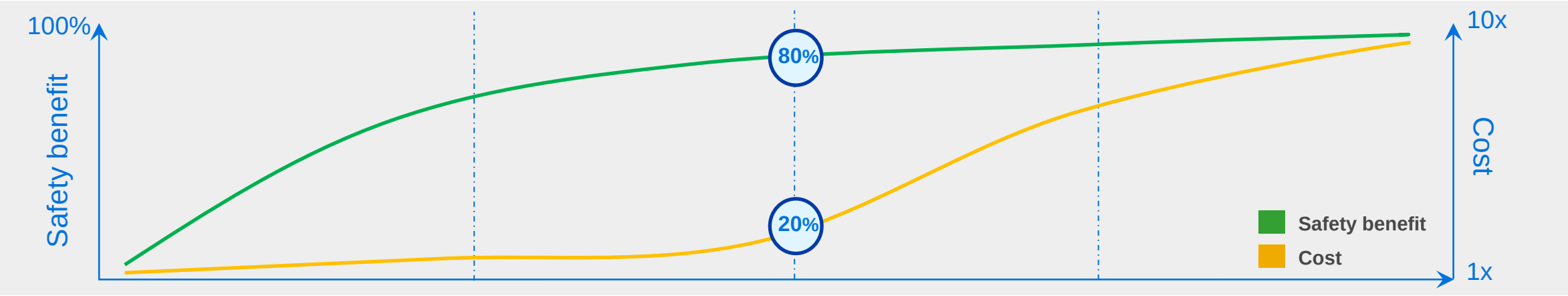
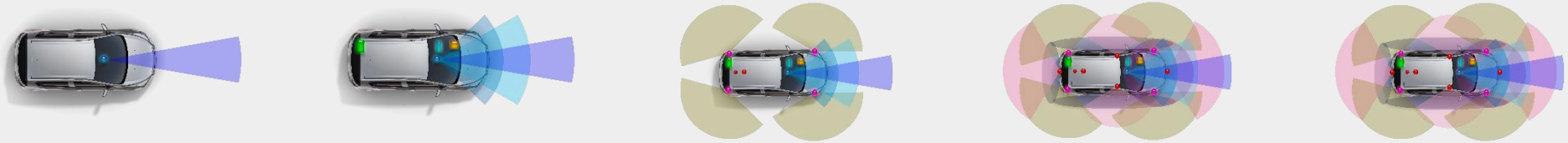
Active safety as the foundation of automated driving



Level 0 No automation	Level 1 Function-specific automation	Level 2 Combined function automation	Level 3 Limited self-driving automation	Level 4 High self-driving automation	Level 5 Full self-driving automation
Driver is in complete control of vehicle	Automation of one or more control functions	Automation of two or more control functions	Driver able to cede full control of all safety-critical functions under certain conditions	Driver able to cede full control of all safety-critical functions for an entire trip	No driver required



Level 2 automation delivers 80% of the benefit for 20% of the cost of full automation

Note: Levels of vehicle automation as defined by NHTSA

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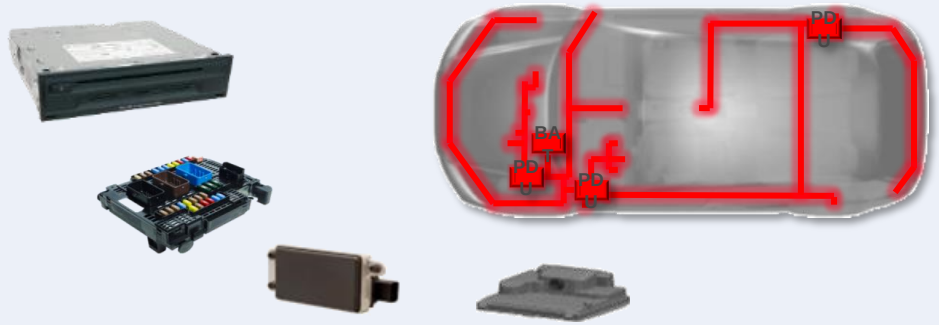
Evolution of computing platform architecture

Individual component controllers

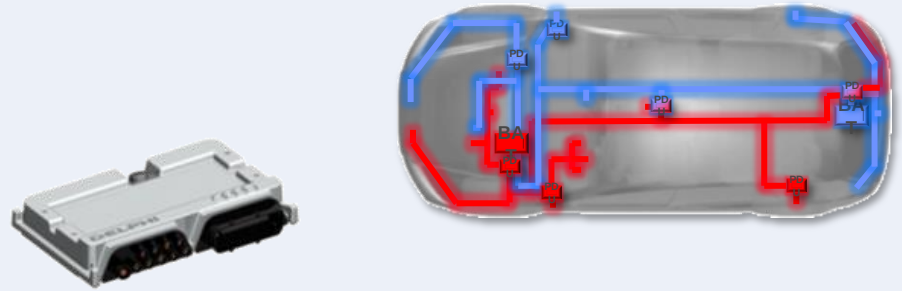
- Separate ECUs with individual custom microprocessors
- Primarily low and mid speed data busses with conventional power distribution network



- Autosar and one operating system per ECU
- Scalable by removing or adding processors
- Cybersecurity risks

Multi domain system controllers

- Integrated ECUs with multi-purpose processors
- High speed busses (ETH, LVDS) with fault tolerant power distribution network supporting redundancy



- Adaptive Autosar and multi-OS (Hypervisor)
- Scalable computing platform processing power
- Cybersecurity “built-in” with intrusion detection & OTA

High end performance processors with scalability and hardware abstraction

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Computing platform: Multi Domain Controller (MDC)

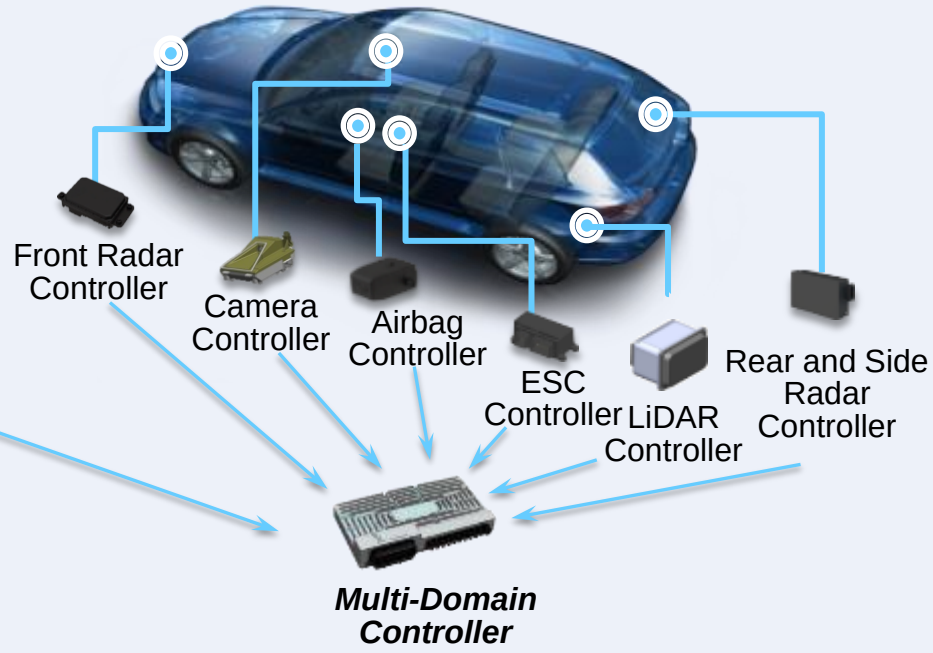
Active Safety Multi-Domain Controller (MDC)



- **Scalable software platform**
- **Reduced architecture complexity**
- **Faster communication/interconnection**
- **Multi-processor configurations**

Production launch in 2017

ADAS Centralized Sensor Fusion/Control



Enables future system SW optimization / upgradability

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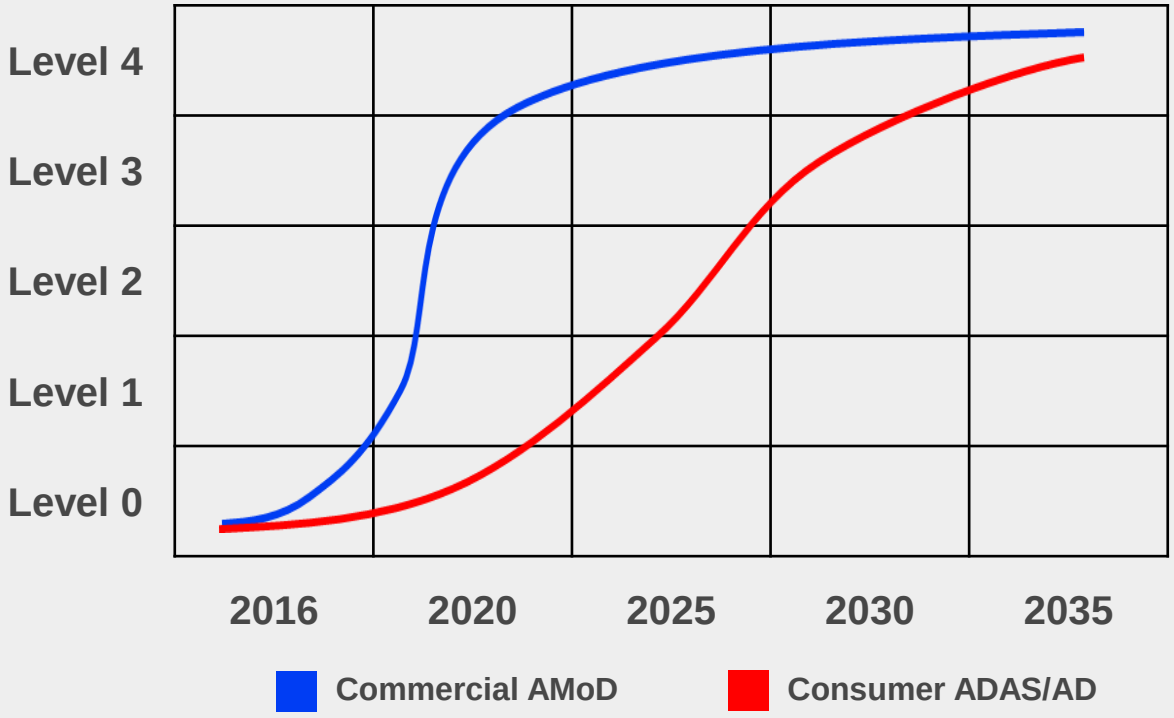
Automated Mobility on Demand (AMoD)

Key accelerators driving early adoption of commercial Automated Mobility solutions



Market driver

- Motivated by economics rather than just safety or convenience

Governance

- Simplified regulatory and legal environment at the local level vs. federal/state

Mobility profile

- Limited use cases in commercial applications in contrast with the consumer market

AMoD also creates opportunities for a more connected car

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Delphi and Mobileye CSLP level 4/5 platform

Mobileye's best-in-class vision (camera) systems and real-time mapping and vehicle location

Delphi's Ottomatika Automated Driving software, sensor suite, and computing platform

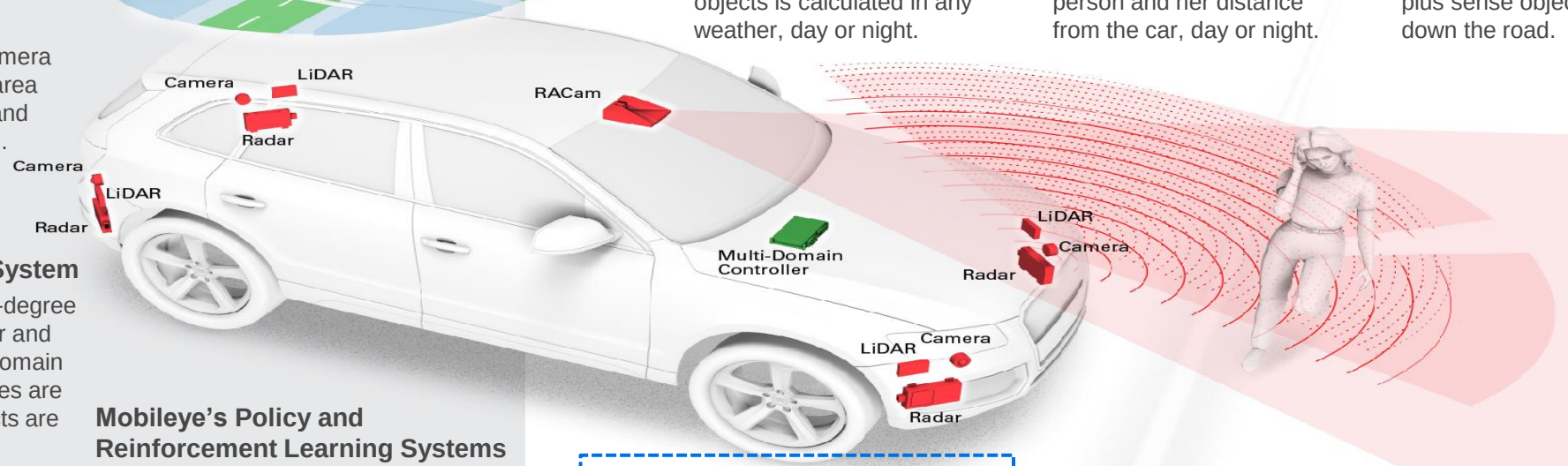
Mobileye's real-time mapping and vehicle location (REM™)

Performs detailed interpretations of camera images to map the area around the vehicle and plots a drivable path.



Delphi's Sensor Suite

- **Radars:** Radio waves sent out and bounce off objects, like this pedestrian. The speed and distance of these objects is calculated in any weather, day or night.
- **LiDAR:** Light pulses sent out and reflect off objects like this pedestrian. LiDAR identifies the object as a person and her distance from the car, day or night.
- **RACam:** Combines a mid-range radar and a forward-facing camera that can see and identify the pedestrian, plus sense objects further down the road.



Mobileye Vision System

Cameras take a 360-degree image around the car and send it to the Multi-Domain Controller. The images are processed and objects are identified.

Mobileye's Policy and Reinforcement Learning Systems

Helps negotiate with other human drivers and pedestrians in complex urban scenes.

Delphi's Multi-Domain Controller

Information from the sensing systems as well as mapping and navigation data is fused to make driving decisions such as when to stop or go.

Offering a fully autonomous solution to OEMs by 2019

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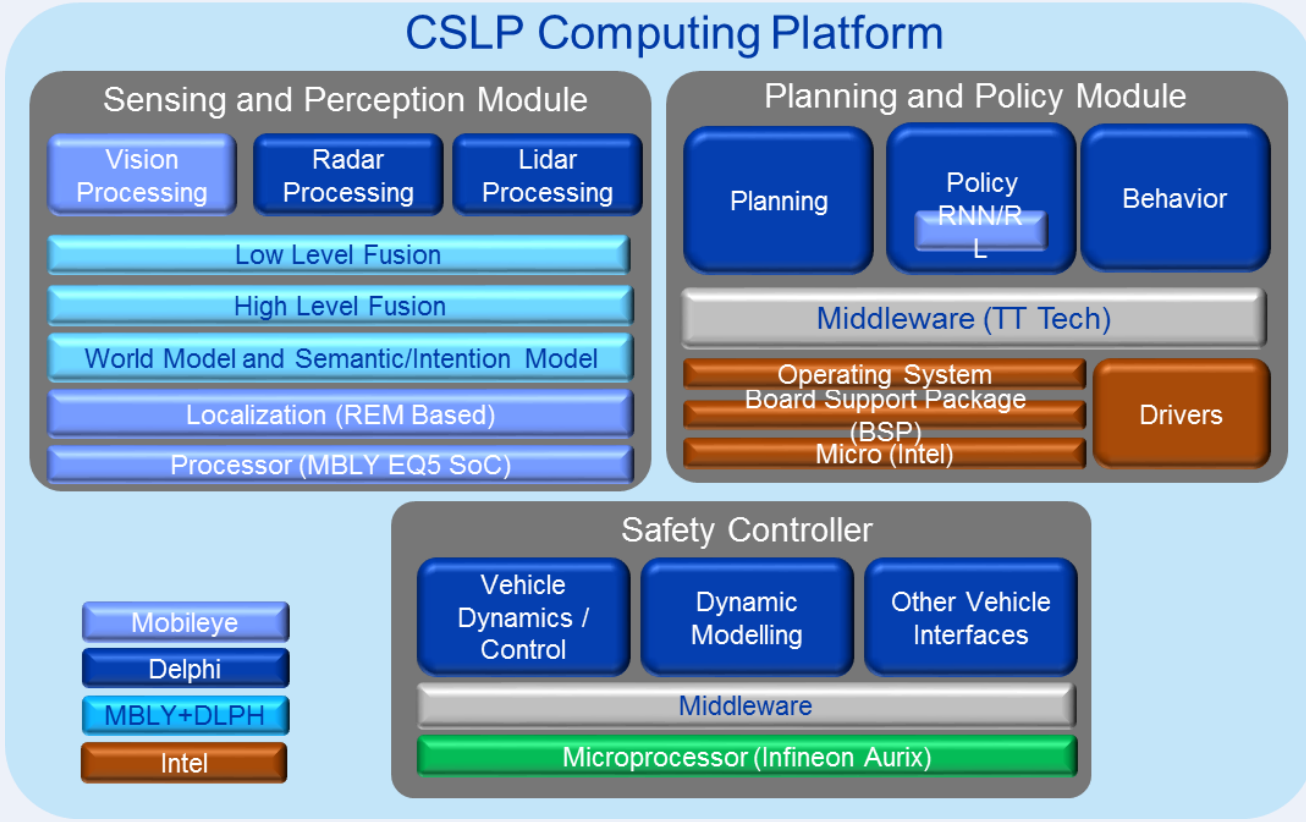
CSLP platform – leveraging partnerships

- **Mobileye:**
  - Vision Systems & Fusion
  - Reference Learning / AI
  - Localization using REM
- **Intel:**
  - Automated Driving SoC
  - OS and support Software
  - Connectivity
  - Data Centers / Management
- **Intel / Delphi / Partners**
  - Middleware and Tools
  - Functional Safety



Key partners create the CSLP Platform

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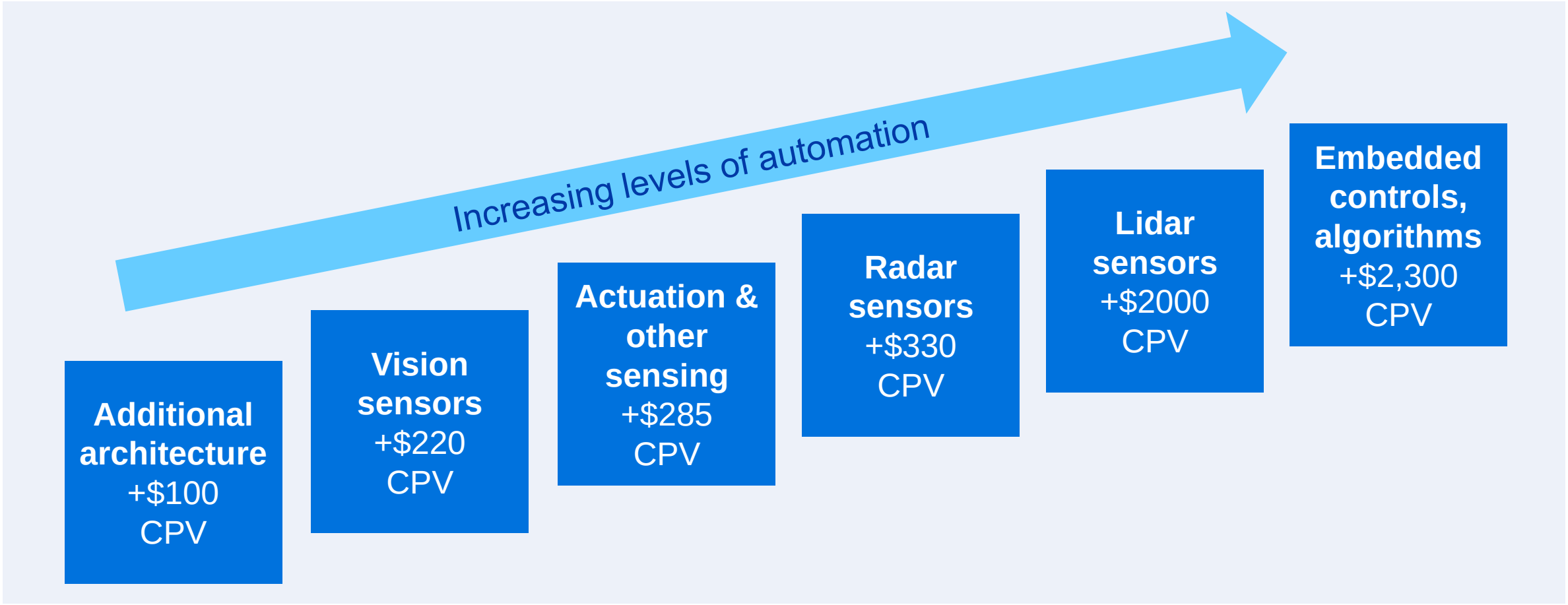
Increasing content per vehicle – Automated Driving



+$5,000 - $5,500 CPV when moving to a Level 4/5 vehicle in 2020

Note: assumes 2020 volumes; and four lidar sensors, five radar sensors and six vision sensors

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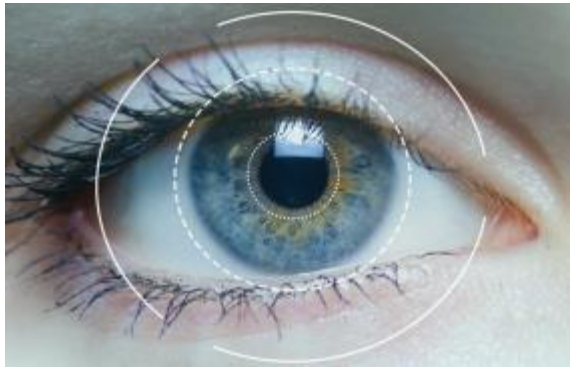
Redefining connected Infotainment: Integrated Cockpit

Creating a configurable, rich and “touch-free” user experience



Eye glance



Gesture control



Voice recognition



3D Displays



Customized Information in 3D: full-color, high-resolution, re-configurable

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Consumer demand is driving connected car capability

World-class connectivity helps address safe & green challenges



The IoT is disrupting traditional automotive

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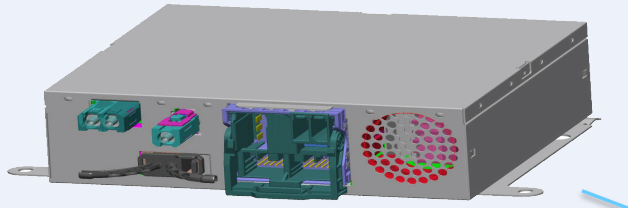
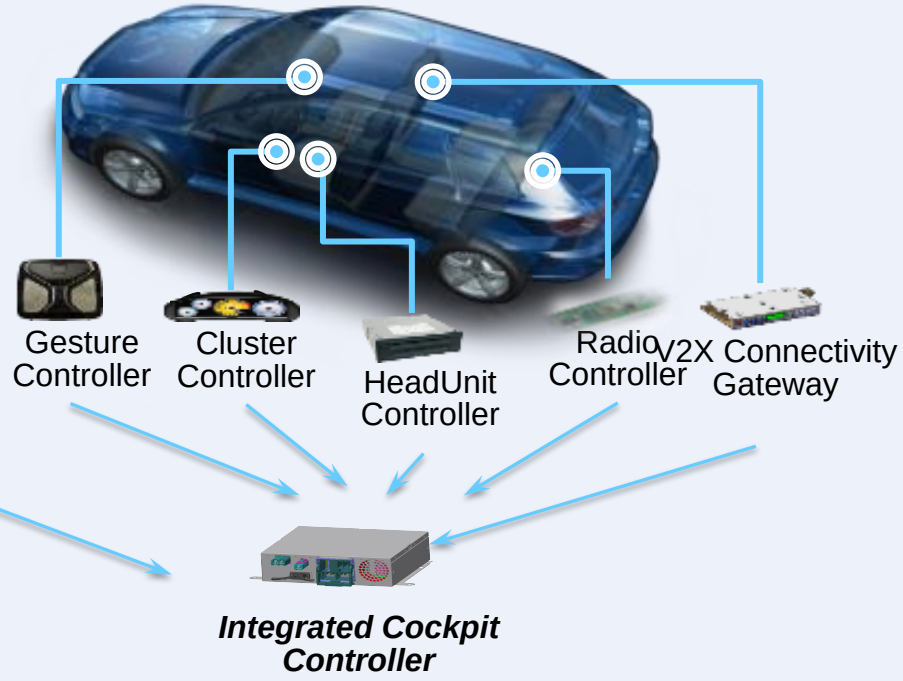
Computing platform: Integrated Cockpit Controller (ICC)

Integrated Cockpit Controller (ICC)



- **Scalable software platform**
- **Reduced architecture complexity**
- **Faster communication/interconnection**
- **Multi-processor configurations**

Infotainment & User Experience Centralized Control



Enables future system SW upgradability and a rich user experience

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IDI computing platform and software architecture



System Integration by Delphi

Vehicle Embedded Micro Server

Audio Video Processing

- Audio
- Tuner
- Router
- Middleware
- Operating System
- Board Support Package (BSP)
- Micro (e.g., TI Jacinto SoC)
- Drivers

Multi Domain SoC

Linux · GENIVI · QNX · ANDROID

- Health Monitoring & Services Layer
- Hypervisor
- Board Support Package (BSP)
- Micro (e.g., NVIDiA or Intel SoC)
- Drivers

Vehicle Interface & Security Controller

- Vehicle Control
- Autosar
- Other Vehicle Interfaces
- Middleware
- Microprocessor (e.g., M4, V850, K0R,…)

OME / Other
Delphi
3'rd Party
SoC Provider

Goal: Become the industry standard for IDI platforms

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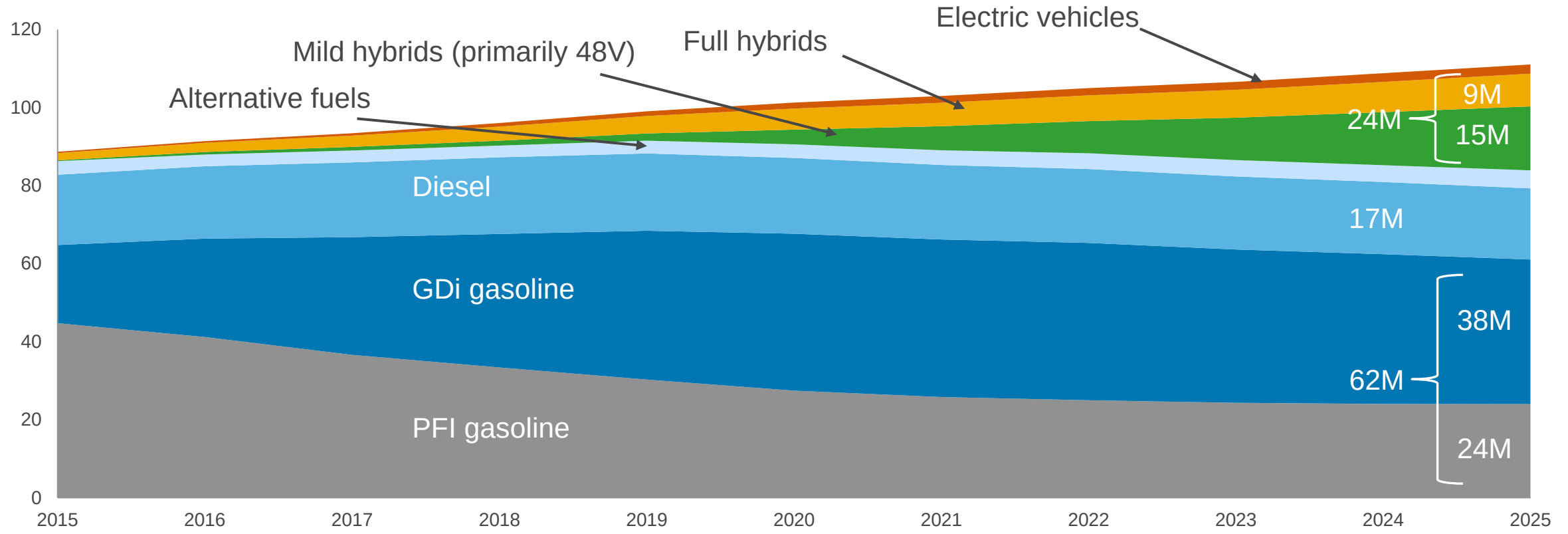
Electrification expected to grow…

Hybrids increase in the next 10 years: ~24M by 2025



>95% of all light-duty will have an internal combustion engine in 2025

Source: IHS October 2016

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Electrification provides more power & closes regulation gap

Stringent regulatory fleet targets cannot be achieved with engine systems alone

US	**Fuel economy:** 54.5 mpg – 2025	**EU**	**Emissions:** 95 CO_2 g/km – 2021	**China**	**Emissions:** 117 CO_2 g/km – 2020

Best-value electrification: 48V mild hybrid

An enjoyable ride

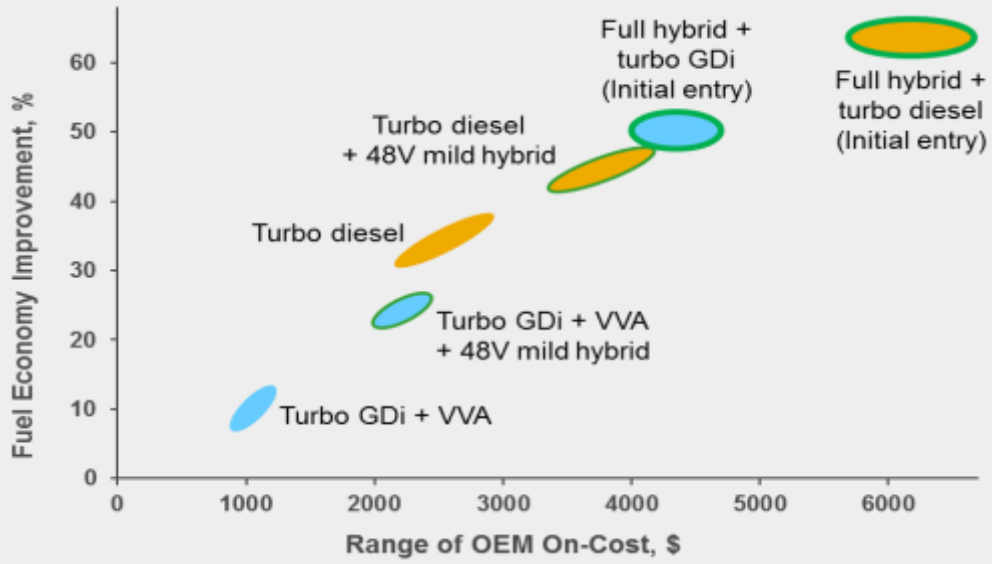
- Provides more power for features & functions
- Incorporates an e-charger for launch assist
- Enables premium safety, entertainment & convenience

A greener choice

- Electrification enables a downsized engine
- Maximizing the use of the e-motor
- Best value hybrid solution

Stringent regulations

Baseline: 4-cyl. turbo GDi with dual cam phasing



4x the voltage, 4x the power, think of the possibilities…

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Creating intelligent electrification with Delphi's 48V solution

48V electrification

Optimized electrical architecture is the foundation

The Delphi solution

Builds on electrical solution competency

- Includes electrical architecture, power electronics and management

Designs a custom vehicle architecture

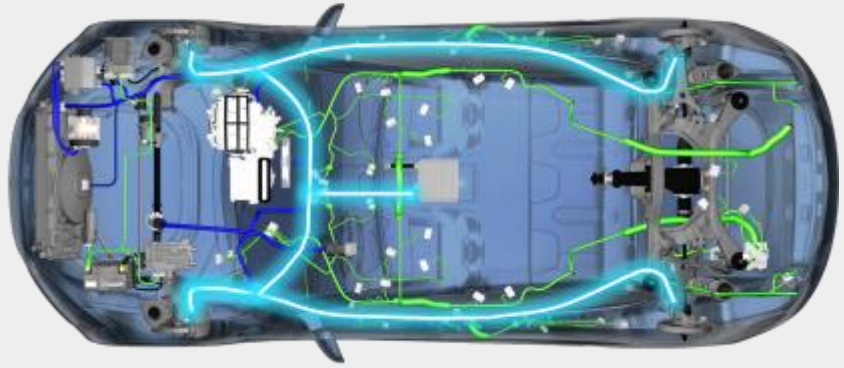
- Maximizes the use of power, moving high load components to 48V & incorporating all desired comfort, convenience & functional features

Incorporates Delphi's suite of products

Enabling intelligent electrification

Improved functionality, better performance, greater efficiency

Software, software, software…



Optimized electrification architecture

Fuel injection systems
Engine control
Valve Train & engine sensors
DC/DC converter
Connected Infotainment
Active Safety

Customized vehicle architectures for all applications

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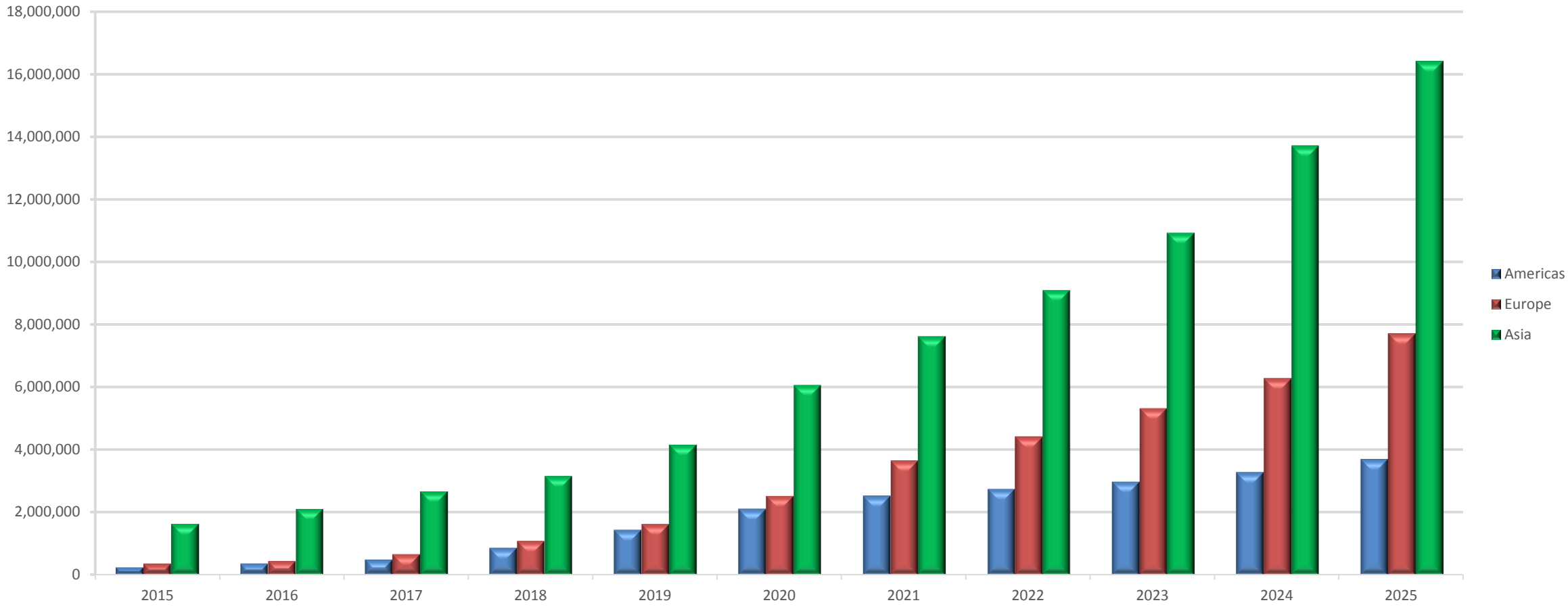
Electrification growth forecast by region



Significant growth in Asia and Europe

Source: IHS October 2016

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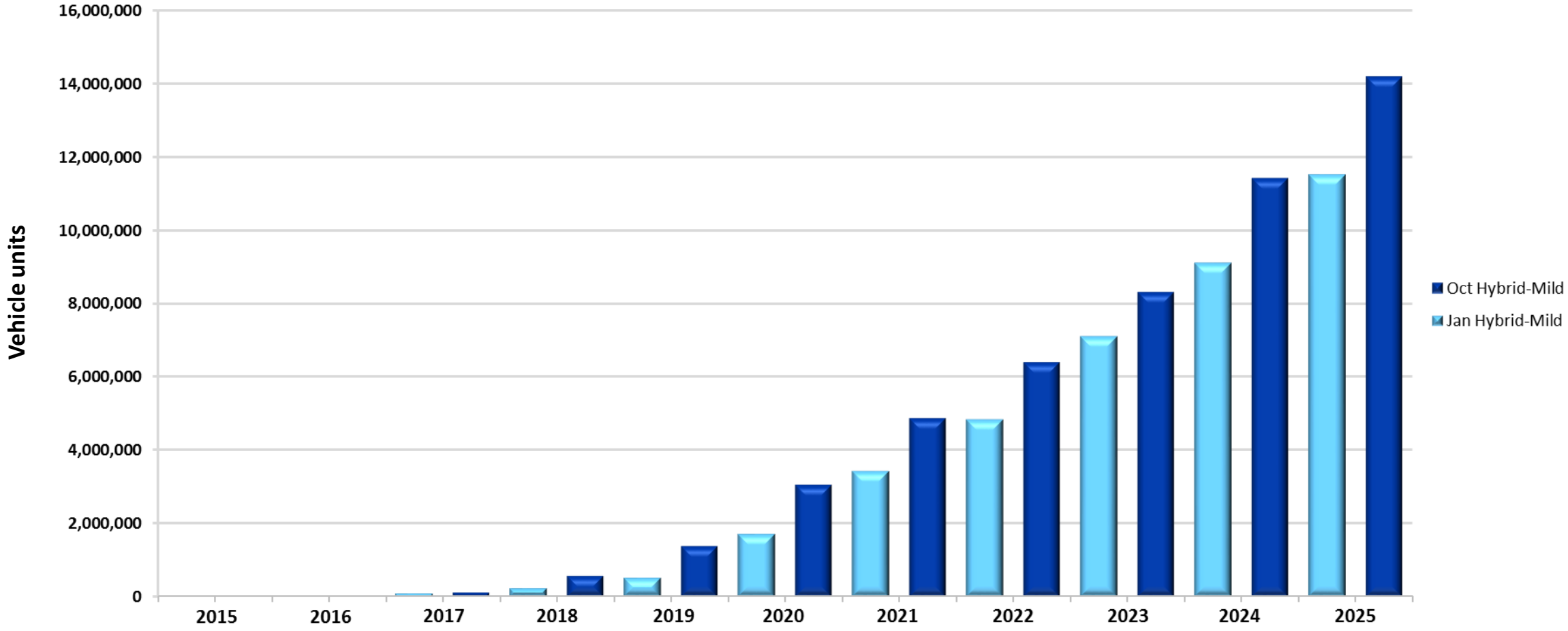
Mild hybrid production volumes
January & October 2016 IHS update



China & Europe markets dominate 48V mild hybrid projection: ~12M in 2025

Source: IHS January & October 2016

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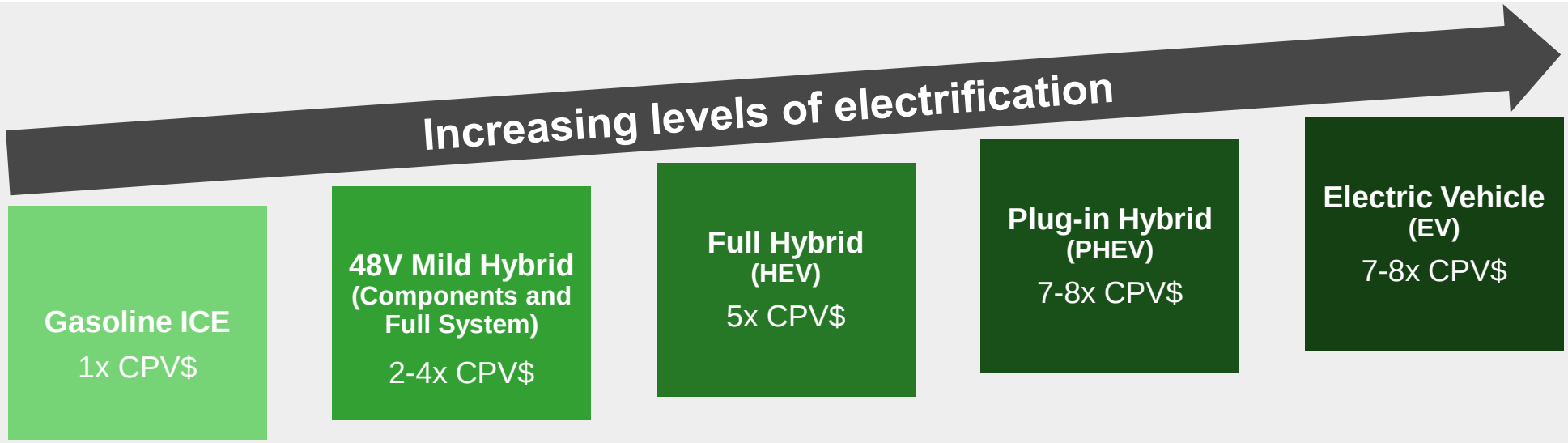
Electrification increases Delphi content per vehicle (CPV)

Powertrain Management	Electrical System	Battery Management
• Supervisory controller • Supervisory software • Inverter • Combined inverter/converter • 48V Driver module	• 48V fusing & distribution • High power & voltage connectors • High voltage shielded cable • DC/DC converter	• Charging inlets and cables • Internal battery connections • 12V battery monitor • Battery pack controller • On-board charger

E/EA
Powertrain



Comprehensive portfolio enables vehicle electrification

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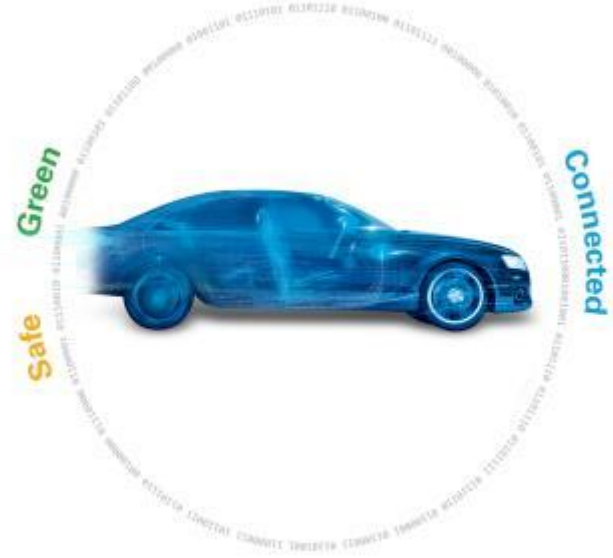
Macro trends and disruptors create new growth opportunities

Market challenge	Delphi portfolio expansion	Delphi solution
• A safer ride • Increasing regulation	Active Safety → Automated Driving	
• Power for functions • More stringent regulations	Engine systems → 48V hybrid electrification	
• Demand for IoT • Leveraging BYOD	Onboard navigation → Connected car	



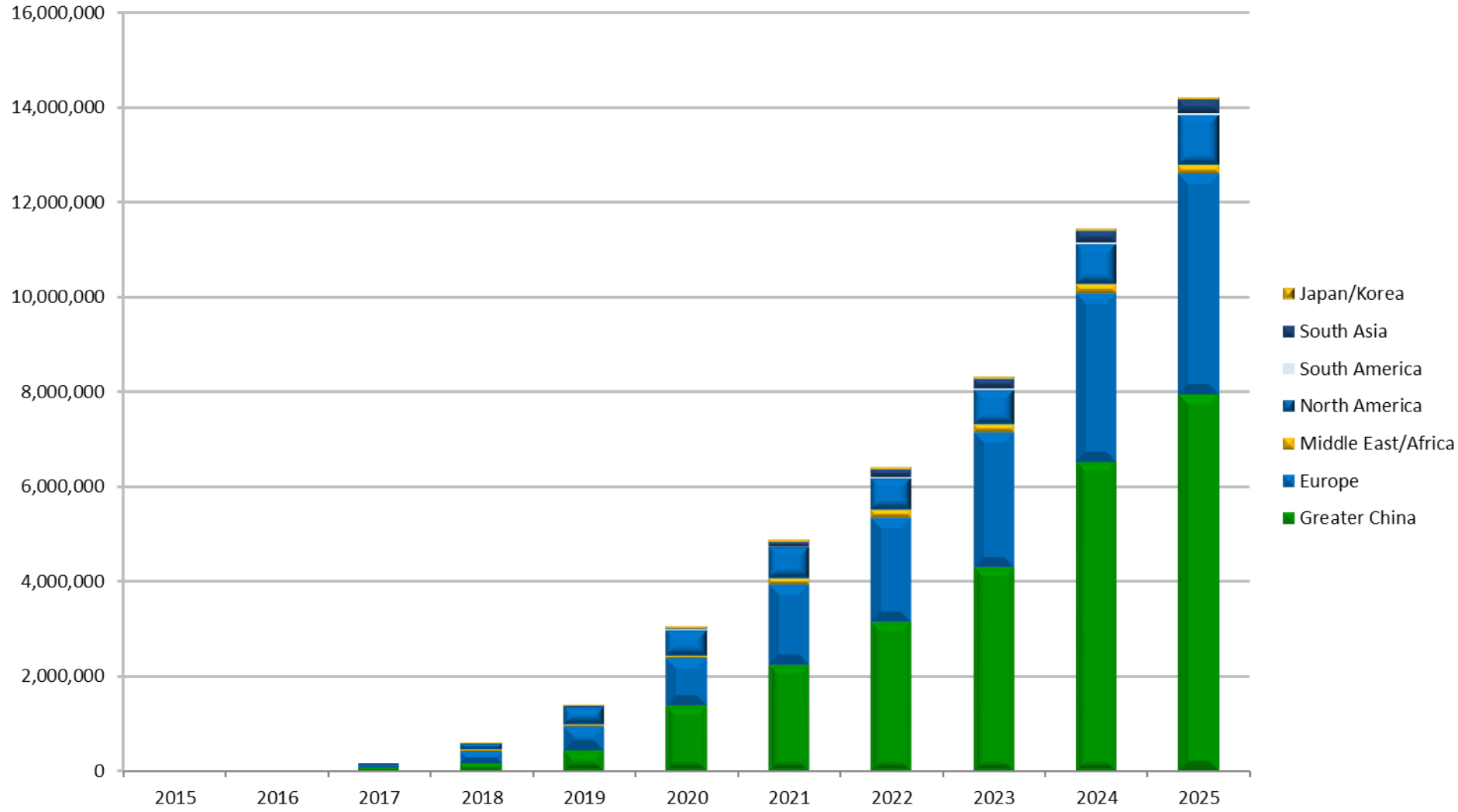
Intelligent Driving

Safe, green & connected converge with intelligent software solutions

Making it possible.



48-volt mild hybrid growth forecast by region



Source: IHS October 2016

Delphi 48V mild hybrid system solutions

Strategic focus

NA gasoline demo vehicle

- NA OEMs market follower
- Two VW Passet demos (2016 Q4)
- Combine with Dynamic Skip Fire (2017 Q1)



Europe diesel demo vehicle

- Two Honda Civic diesel demos complete
- Engaging with customers on solutions
- OEMs prefer 48V optimized solution



AP (China) gasoline demo vehicle

- Chang An CS 75 demo (2017 Q2)
- Regional hardware & software portfolio
- OEMs prefer 48V optimized solution



Value proposition

- Optimized electrical architecture & engine management control
- ~ 15% fuel economy savings

Strong volume growth ~13.6M vehicles* / year by 2025

Cross divisional collaboration… the "Power of Delphi"

*July 2016 IHS

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Gasoline Engine Management System (EMS) solutions

EMS solutions	
Turbo GDi fuel systems	• Increased fuel pressure (400 bar) to meet Euro 6c emissions • High-precision fuel delivery for optimized combustion and low toxic emissions
Variable Valve Actuation (VVA)	• 2-step VVA complements turbo GDi technology • Each 6-cylinder engine with 2-step tech. includes 12 roller finger followers and 4 oil control valves
Electronics and software	• Adv. electronics and software controls to deliver enhanced EMS solutions, including 48V hybrids • Key enabler of CO_2 reduction and system performance improvements

Emissions reduction results

Turbo GDi yields: ~15% ↓ CO_2

+

2-step VVA yields: ~5% ↓ CO_2

+

48V hybrid yields: ~10% ↓ CO_2

=

Superior emissions management



Complementary ICE solutions enhance CO_2 reduction potential

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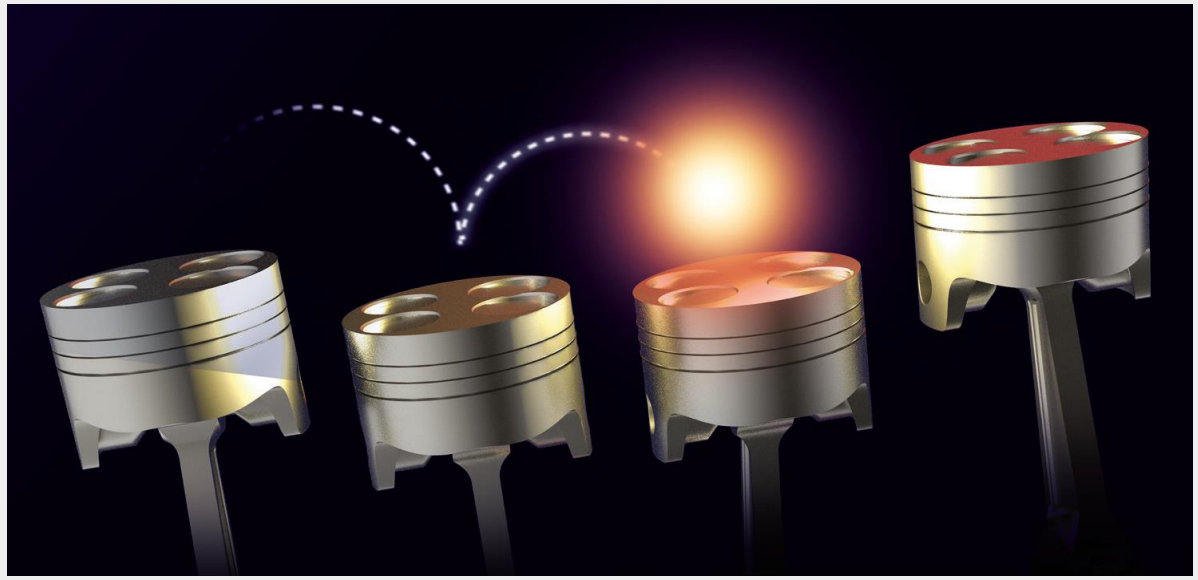
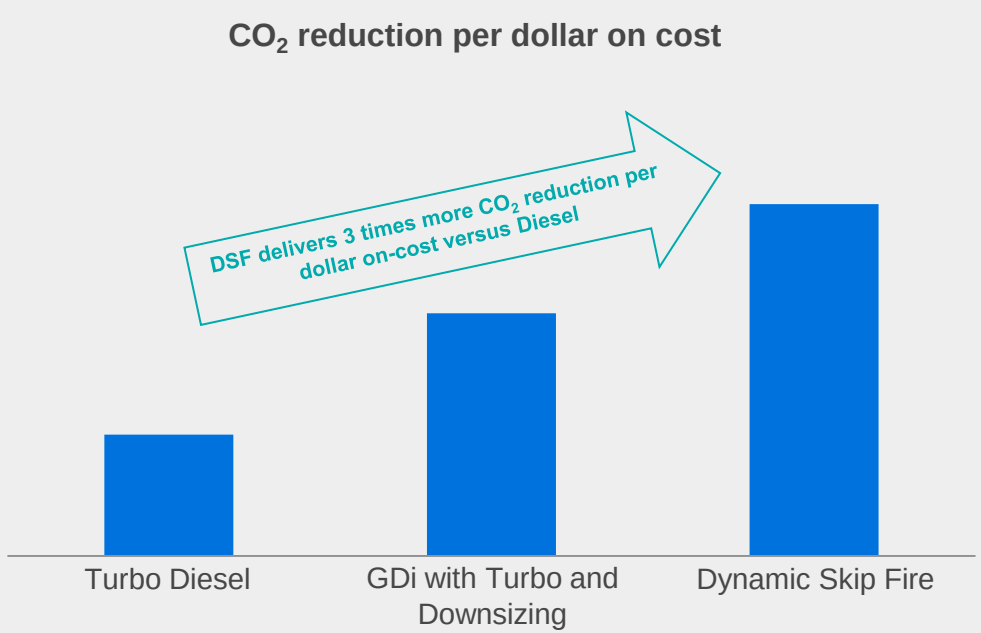
Tula Dynamic Skip Fire (DSF)

Enhancing 2-step technology with dynamically adapting software



Baseline: 4-cyl. PFI engine



- Demonstrated 15% CO_2 reduction in an 8-cylinder GMC Denali
- VW Jetta 4-cylinder turbo GDi in development: Targeting > 8% CO_2 reduction vs. 4 cyl. turbo GDi baseline

Significant fuel efficiency gains through optimized engine operation

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Unmatched technical sophistication

12 million lines of code
Android Operating System



44 million lines of code
Microsoft Office 2013



Premium Vehicle



50+ computers
To deliver a world-class user experience, active safety and high performance drivability

24 million lines of code
F-35 Fighter Jet



61 million lines of code
Facebook



Premium vehicles today operate with 100 million+ lines of code

*Software lines of code information courtesy of informationisbeautiful.net

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More safe, more green, more connected…

Influence of Silicon Valley



Delphi's technology acceleration

	2010	2015	2020
Lines of code shipped daily	200M	20B	200B
Software revenue	<$50M	$500M	$1.5B
Software engineers	2,000	5,000	8,000
Key partnerships	15+	30+	60+
Software launches	150+	300+	400+

… Requires more advanced software capabilities

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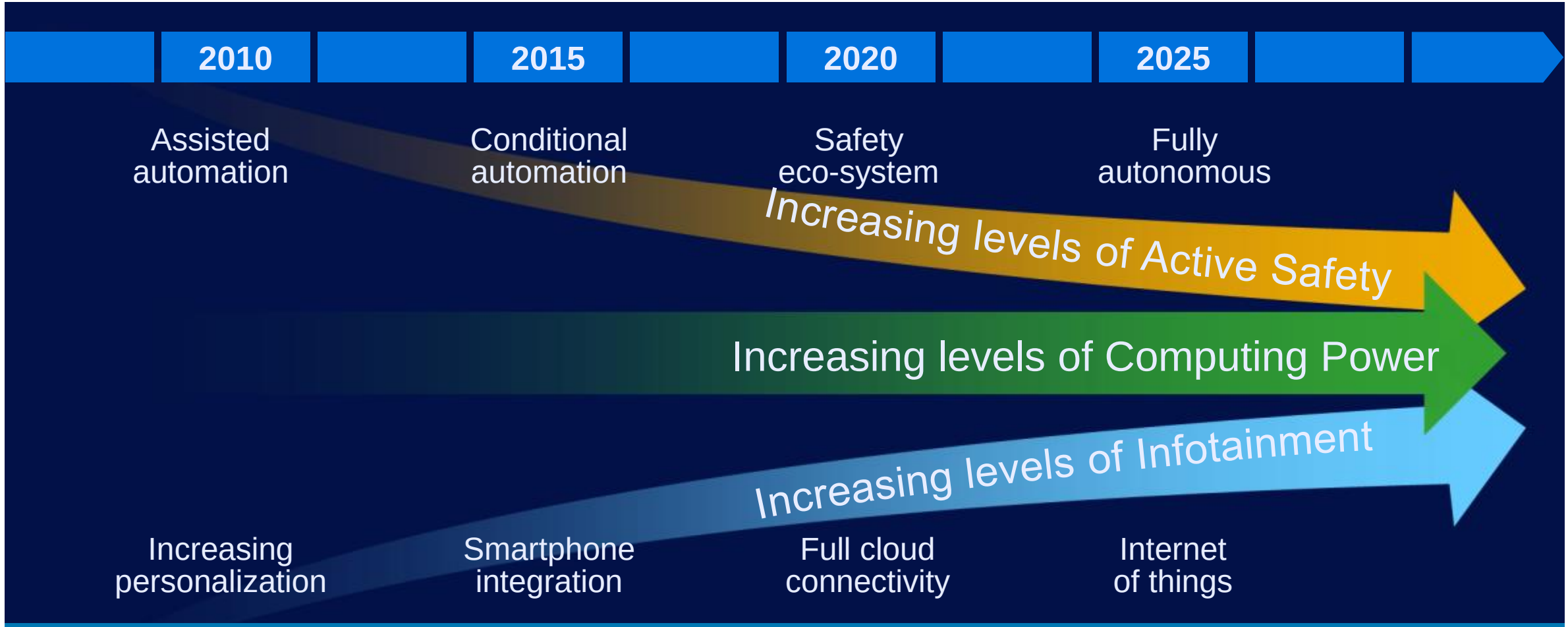
Convergence of Active Safety & Infotainment

Driving increased levels of Computing Power



Convergence of domains enables strong market position for Delphi

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Evolution of vehicle sensors

Component solutions

- Initial “smart-cameras” with integrated data processing
- First programs transitioning to satellite technology, LVDS connection



Classical smart-cameras

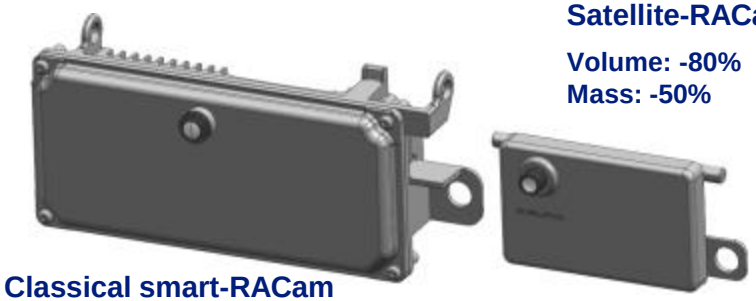


Satellite-cameras

Volume: -80%
Mass: -70%

System solutions

- Additional camera, radar and lidar sensors move to satellite-technology
  - Reduced size and cost
  - High speed bus connection
  - No / limited data processing capabilities



Classical smart-RACam

Satellite-RACam

Volume: -80%
Mass: -50%

Sensors are moving from Smart to Remote and Scalable

Enables high performance centralized computing platforms and cost optimized sensors

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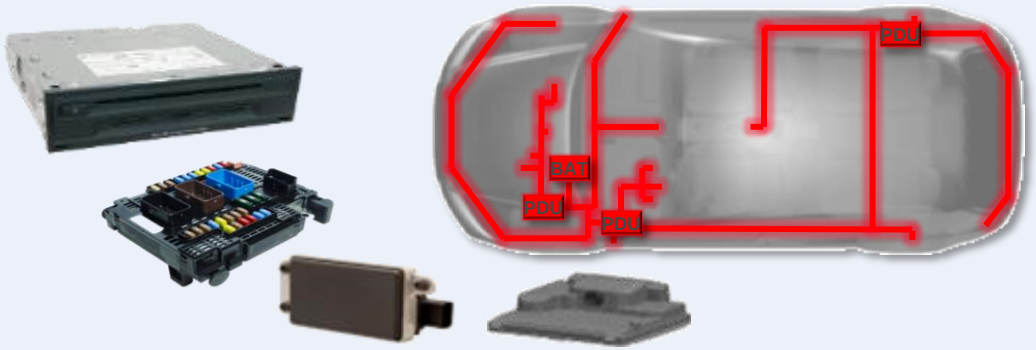

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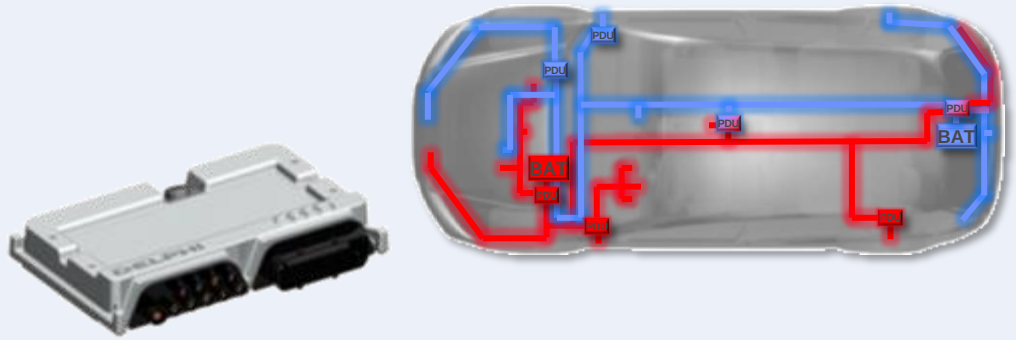

- Adaptive Autosar and multi-OS (Hypervisor)
- Scalable computing platform processing power
- Cybersecurity “built-in” with intrusion detection & OTA

Processing is moving from remote ECU’s to:

High end performance processors with scalability and hardware abstraction

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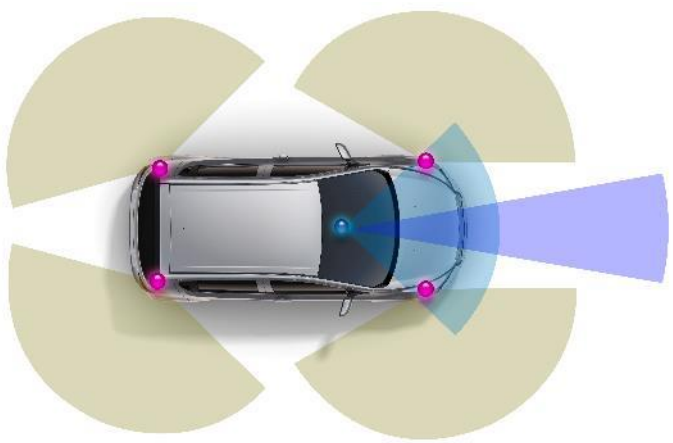
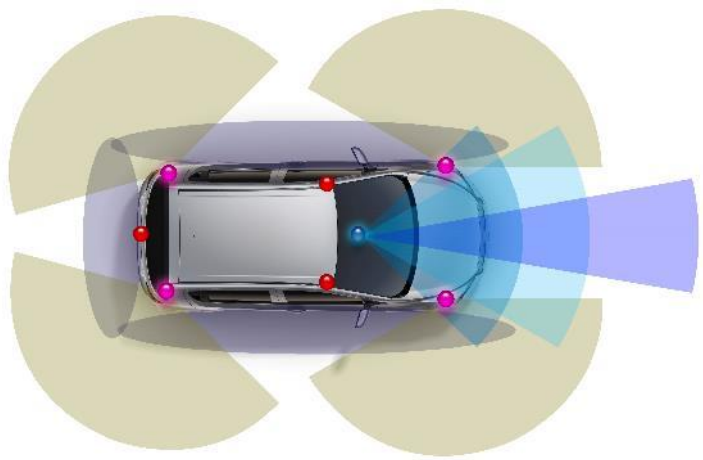
Creating a safer driving experience

Sensor fusion combines data from multiple sensors to enable safety features:

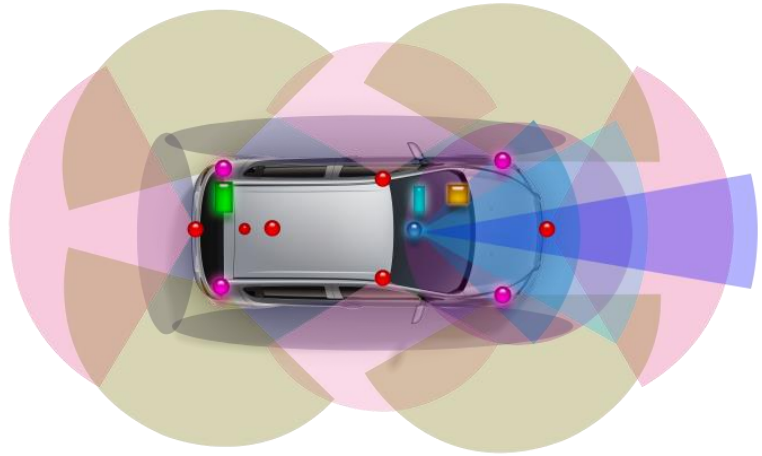
Blind spot warning Collision Mitigation Lane Departure Warning Lane Departure Prevention
Adaptive Cruise Control Forward Collision Warning Automatic Emergency Braking



Radar



Radar + Vision



Radar + Vision + Lidar

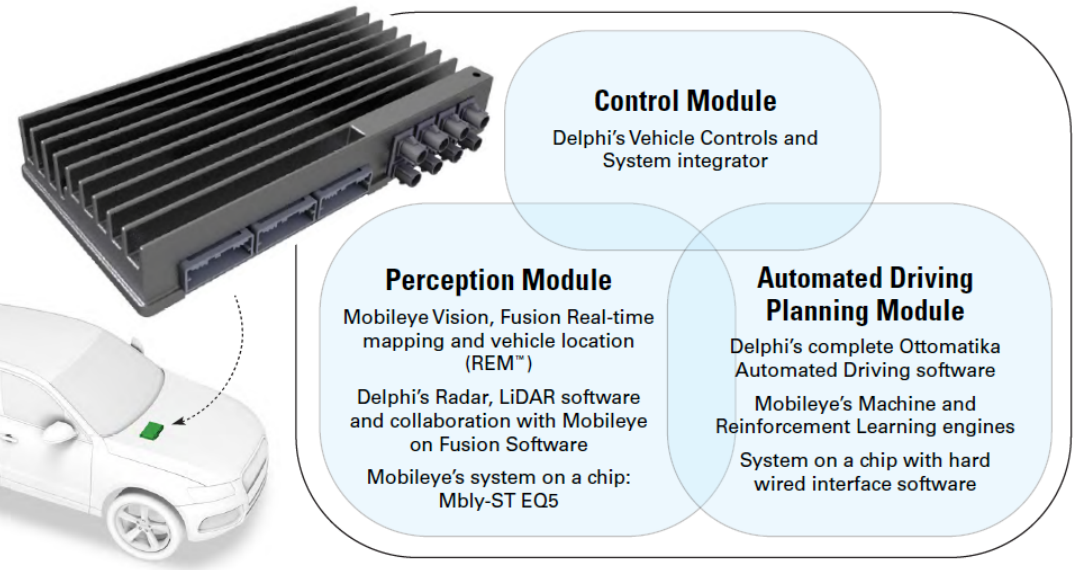
Active Safety portfolio enables 360° coverage

DELPHI

Automated Driving Partnership Architecture

Mobileye Tech inside Delphi's Multi-Domain Controller

Mobileye will add new software and hardware into Delphi's existing Automated Driving Multi-Domain Controller. Here's a breakdown of what's inside:



Control Module

Delphi's Vehicle Controls and System integrator

Perception Module

Mobileye Vision, Fusion Real-time mapping and vehicle location (REM™)

Delphi's Radar, LiDAR software and collaboration with Mobileye on Fusion Software

Mobileye's system on a chip: Mbly-ST EQ5

Automated Driving Planning Module

Delphi's complete Ottomatika Automated Driving software

Mobileye's Machine and Reinforcement Learning engines

System on a chip with hard wired interface software

Mobileye

- EyeQ® 4/5 System on a Chip (SOC)
- Road Experience Management (REM™) mapping system
- Policy and Reinforcement Learning system

Delphi

- Automated Driving software algorithms from Ottomatika
- Multi-Domain Controller
- Forward-looking and full-surround Radar and LiDAR sensors

Central Sensing Localization and Planning (CSLP) Platform

Unmatched, most cost-effective Automated Driving solution

Production Ready for 2019

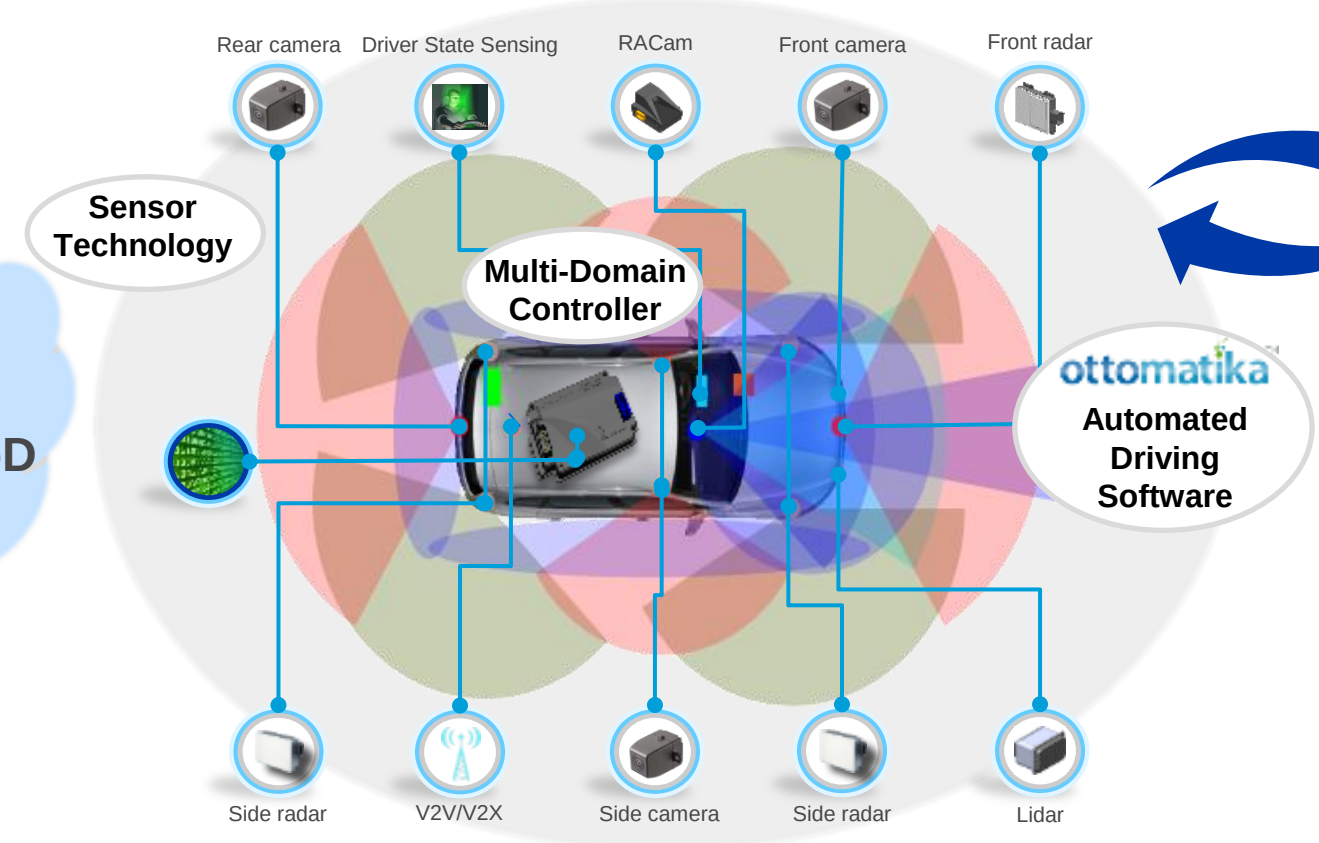
MOBILEYE®

DELPHI

Singapore Automated Mobility Pilot

Delphi integrates active safety and automated features

Delphi Cloud provides key data and service connections to MoD ecosystem



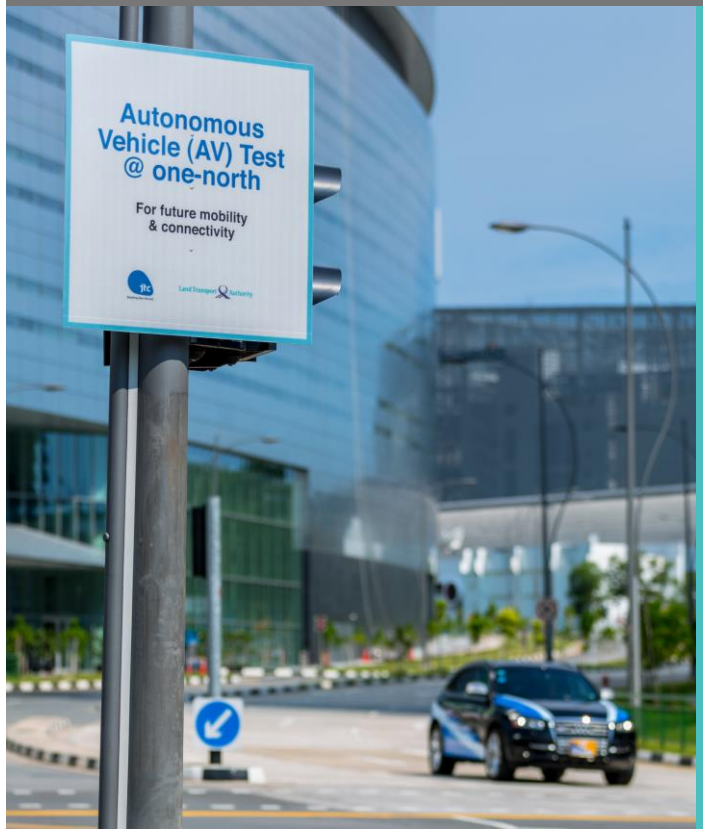


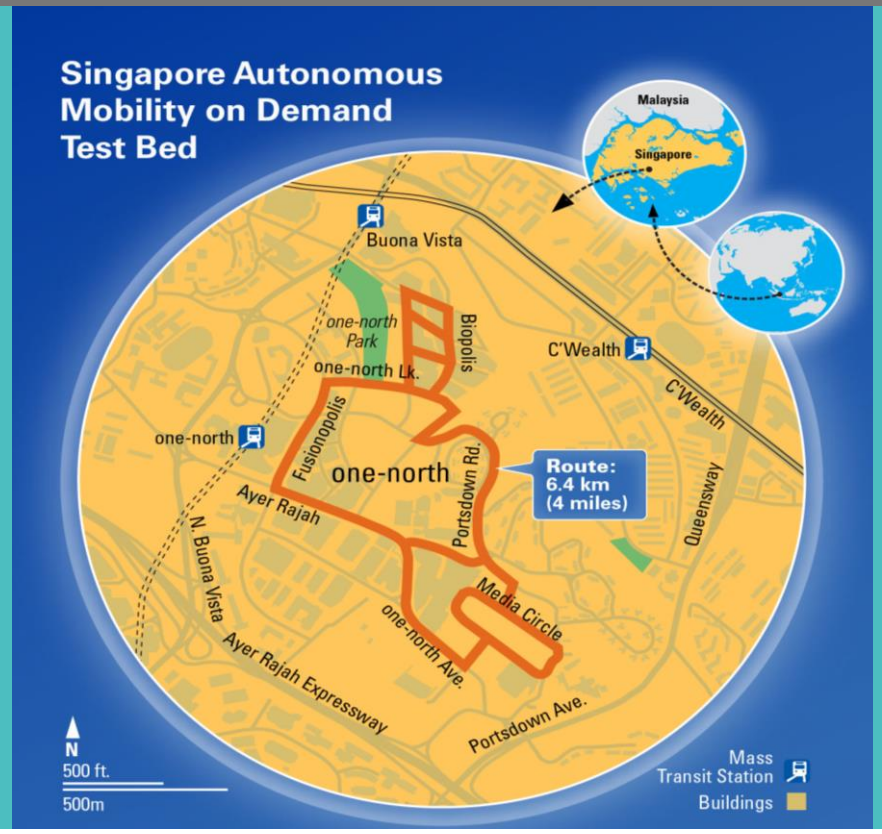
Leveraging our automated driving platform solutions

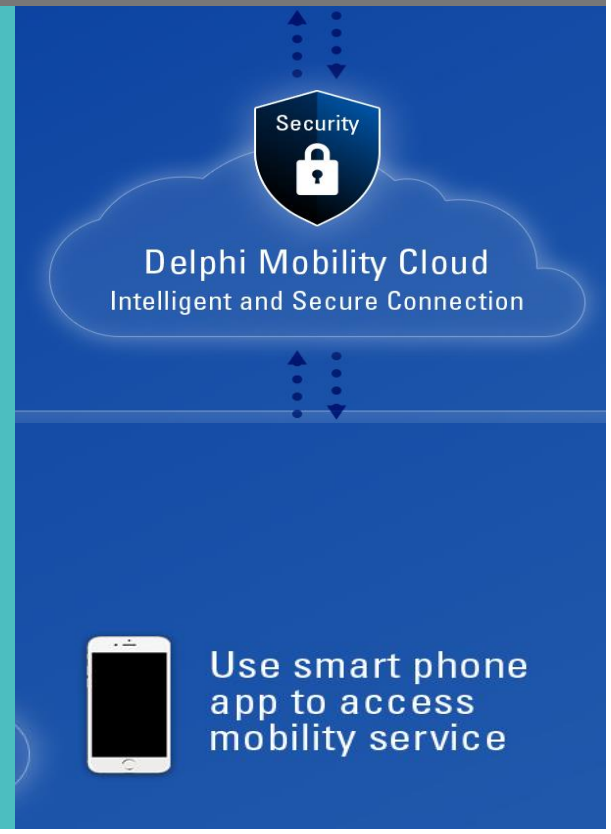
DELPHI

Singapore AMoD pilot: Standing up the ecosystem

Addressing first mile, last mile challenges







3 year pilot to be operational service by 2022

DELPHI

Macro trends create OEM challenges…

Cause	Effect	OEM challenge	Delphi opportunity
Exponential computing power	• More software • More content • More requirements	• Automotive grade • Future-proof designs • Affordable complexity	
Expansion of the IoT	• More brought-in devices • Connectivity expansion • "Out-of-vehicle" access	• Flawless connections • Safe & secure operation • Affordable connectivity	
Convergence of safe, green & connected	• More software • More functionality • High speed data	• Integrated solutions • Regulatory compliance • Affordable features	

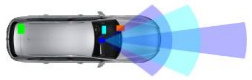
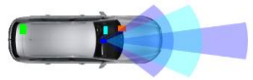
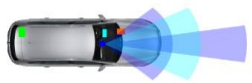
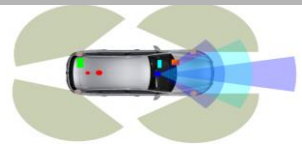
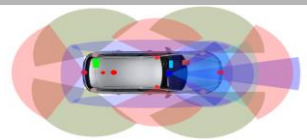
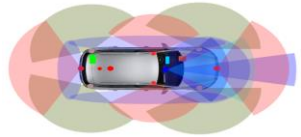


…and opportunities for Delphi

DELPHI

ADAS to Automated Driving SAE Levels (0-5)

ADAS | **Automated Driving**

	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
	No Automation	**Driver Assistance**	**Partial Automation**	**Conditional Automation**	**High Automation**	**Full Automation**
Feature	Forward Collision Warning	AEB	Traffic jam assist	Steering Collision Avoidance	Valet self-parking	Automated Mobility on Demand
	Lane Departure Warning	Lane Keep Assist	Highway Assist	Highway Pilot	Automated highway	Highway point-to-point
	Blind Spot Warning	Active Blind Spot	Self-parking (with driver)	Traffic Jam Pilot	Automated urban	Urban point-to-point
Technology						
	Forward Radar Side Radar	Forward Radar Side Radar	Forward Radar Side Radar	Forward Radar 360 Radar	Imaging Radar 360 Radar	Imaging Radar 360 Radar
	Forward Vision	Forward Vision	Forward Vision	Forward Vision Surround Vision	Forward Vision Surround Vision	Forward Vision Surround Vision
				Forward LiDAR	Forward LiDAR 360 LiDAR	Forward LiDAR 360 LiDAR
			Domain controller	Multi-domain controller	Multi-domain controller	Multi-domain controller
				Driver State Camera	Driver State Camera	(No Driver)
			V2X	V2X	V2X	V2X

DELPHI

Strategic software partnerships enhance capability

Algorithms

AVL, SoftKinetic, Mobileye, FEV, ottomatika, Smart Eye

Firmware

NVIDIA, NXP, Linux, Texas Instruments, Infineon, vector, freescale, ETAS, QNX

Applications

verizon, at&t, NUANCE, Pandora, Sprint, TomTom, promptu, Apple CarPlay, android auto, Google

Partnerships accelerate technology integration in the automotive sector

DELPHI