The Road to Autonomous Vehicles

NSPE – 2021

Bob Feldmaier

About the Center for Advanced Automotive Technology (CAAT)

- Located at Macomb Community College South Campus
- Partnered with Wayne State University
- Became an Advanced Technological Education Center in 2010 funded by the National Science Foundation
- Mission
  - Advance the preparation of skilled technicians for the automotive industry's more environmentally friendly and safer vehicles.
  - Be a regional resource for developing and disseminating advanced automotive technology education.



CAV Main Questions

- Why the interest in autonomous vehicles?
- How does the technology work?
- What are the remaining challenges?

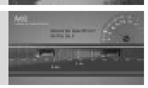
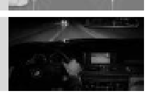
Some of Today's
Advanced Driver Assistance Technologies

ADAS system comprises of passive and active safety system depending on the level of human intervention in driving

Major ADAS systems

Active safety system: Actively engaging/ intervening driving to prevent accident

Passive safety system: Monitoring and warning drivers to prevent accidents

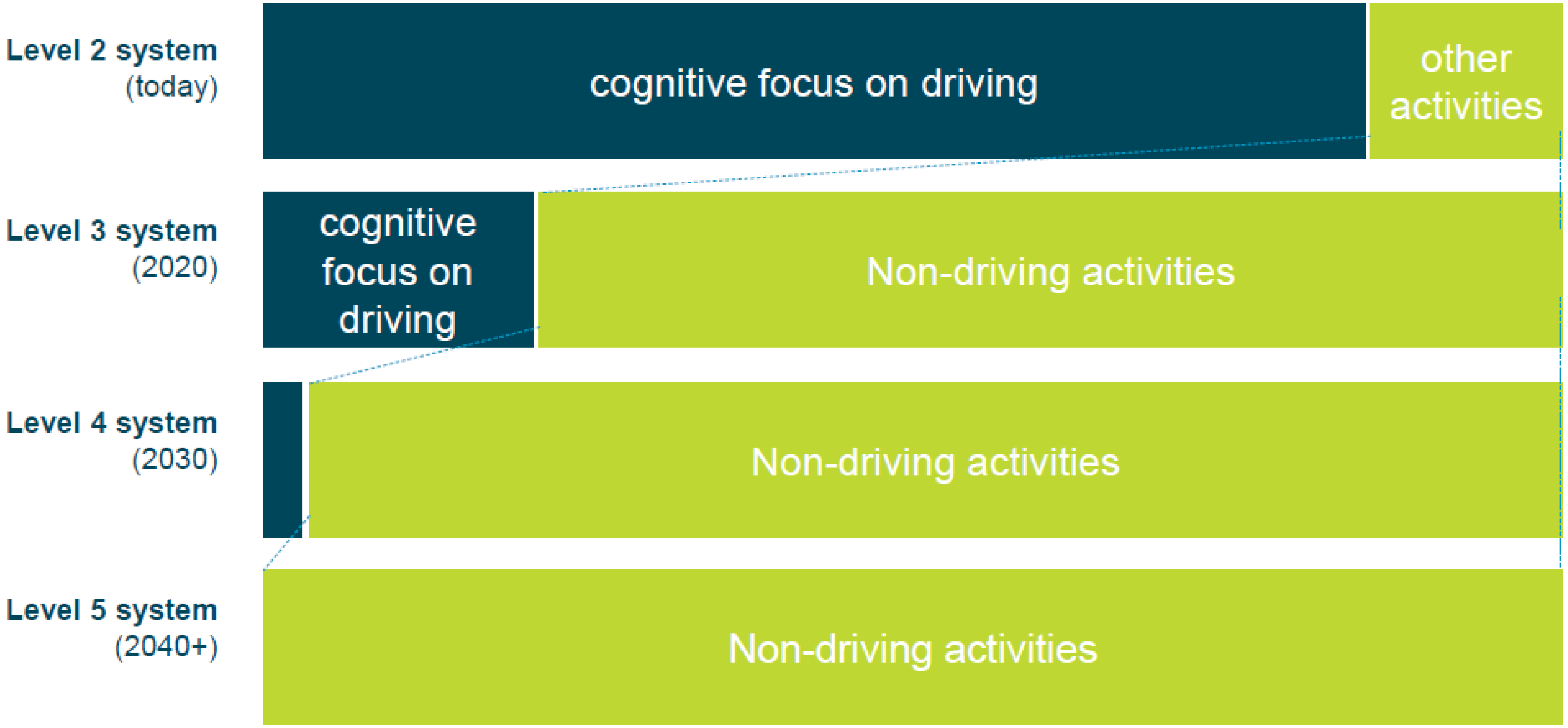
Autonomous emergency braking		▪ Activated when collision risk detected using same sensors as Adaptive Cruise Control
Adaptive cruise control		▪ Adjusts speed to maintain safe distance between cars using long & short distance radar sensors (e.g., LiDAR)
Forward collision warning		▪ Detects obstacles in front and issues warning on screens using same sensors as ACC
Lane departure warning		▪ Detects and warns against lane departure ▪ Some functions even offer autonomous return to original lane
Parking assistance		▪ Aids parking in varying degrees: simple warning against obstacles → complete autonomous parking
Blind spot monitoring		▪ Warns against lane departure by detecting blind sports during lane change
Rear cross traffic alert		▪ Warns for proximity to vehicle when backing up
Night vision & pedestrian detection		▪ Expands scope of detection via infrared camera installed under the bumper or rear view mirrors
Traffic sign recognition		▪ Reads speed limit signs using cameras mainly installed on back of rear view mirrors
Driver Monitoring		▪ Issues warnings on fatigue level using camera sensors that monitor driver and his/her driving patterns

There are Six Levels of Automation

Level	Name	Who is Driving?	Who is Monitoring?	Who Intervenes?
0	No Automation	😀	😀	😀
1	Driver Assist	😀🤖	😀	😀
2	Partial Automation	🤖😀	😀	😀
3	Conditional Automation	🤖	🤖	😀
4	High Automation	🤖	🤖	🤖😀
5	Full Automation	🤖	🤖	🤖

Source: Adapted from NHTSA and SAE J3016

How our Driving & Time spent in vehicle will Shift



The Impact of Car Crashes on the Economy beyond 34,000 Deaths per Year in the US Alone

~1 Million

Days spent in the hospital each year from crash injuries

~2.5 Million

People in the US that went to the ER for crash injuries in 2012 of which nearly 200,000 were hospitalized

$212 Billions

Cost of roadway crashes for the US economy each year[1]

$180-190 Billions

The maximum potential saving per year in the US if you believe that ADAS and AVs can succeed in reducing car accidents by 90%

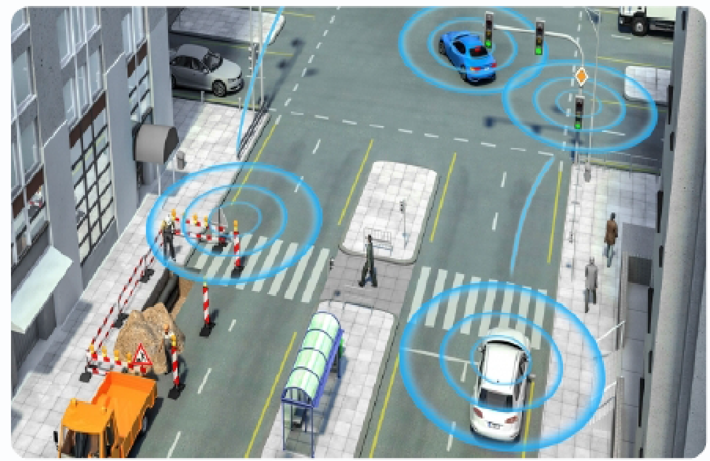
For every **1** person killed in a motor vehicle crash

8 people were hospitalized

100 people were treated and released from the Emergency Department

Highly Automated Vehicles

- We are in the midst of the most significant transformation in transportation since the engine merged with the horse and buggy
- The merger is technology with the vehicle
- Technology will change the way goods, services, and people move
- This will influence how communities are designed for decades to come by creating places that are sustainable, equitable, and economically vibrant



ITS AMERICA

THE ROAD AHEAD
Intelligent and Transformative Transportation
The Next Generation of Mobility – *A Public Policy Roadmap for 2017*

Dr. Gary Smyth, Executive Director, General Motors Research and Development Laboratories, presentation at 23rd Annual ITS Wisconsin Forum, November 8, 2017

Connected Vehicles

- While automated driving systems continue to advance, it is the combination of connected and automated driving that promises the greatest opportunity to dramatically reduce traffic fatalities and injuries and improve mobility.
- Allows vehicles to effectively see dangerous situations before they encounter them.
- Allows vehicles to coordinate their movements with infrastructure.

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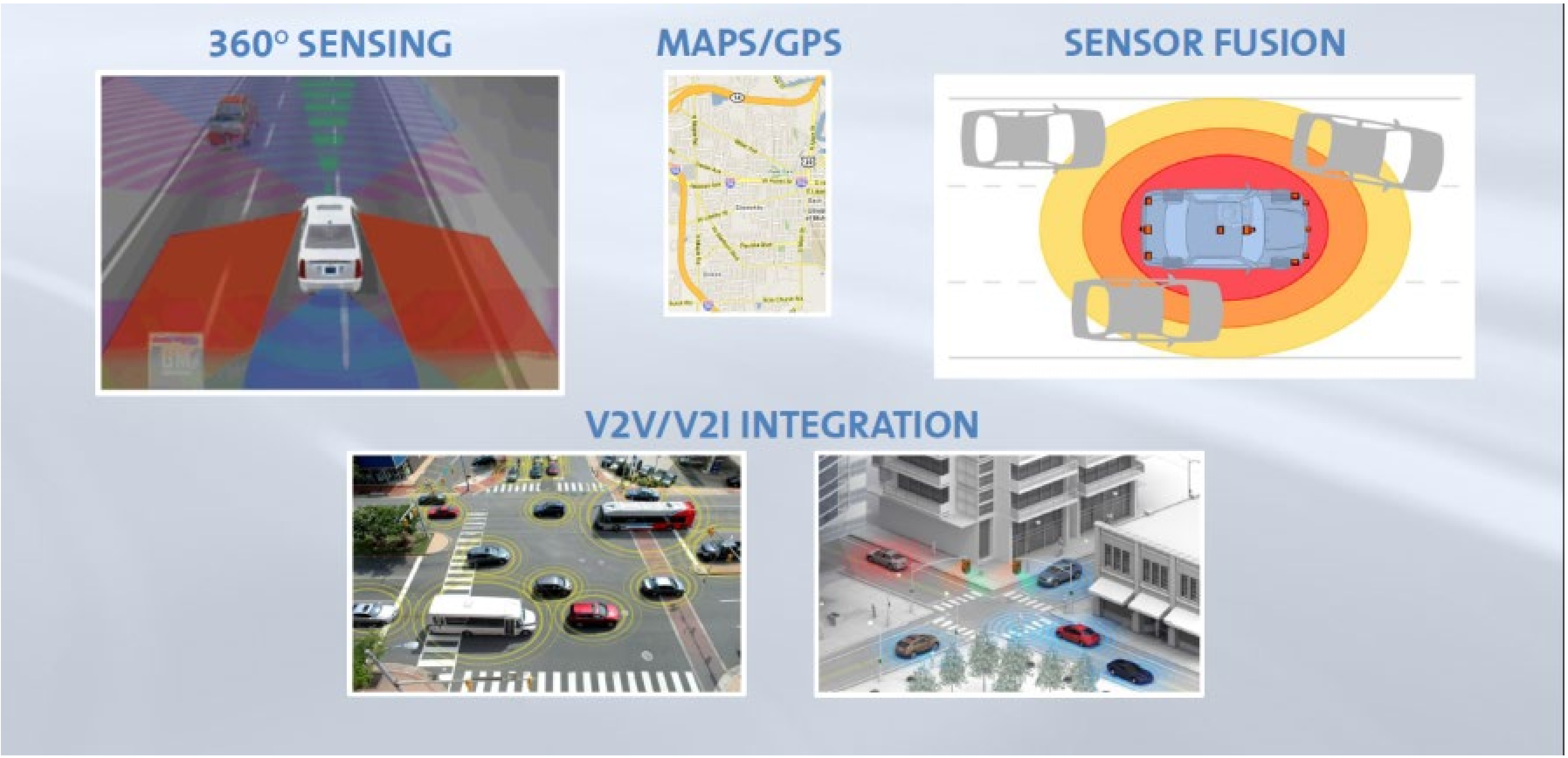
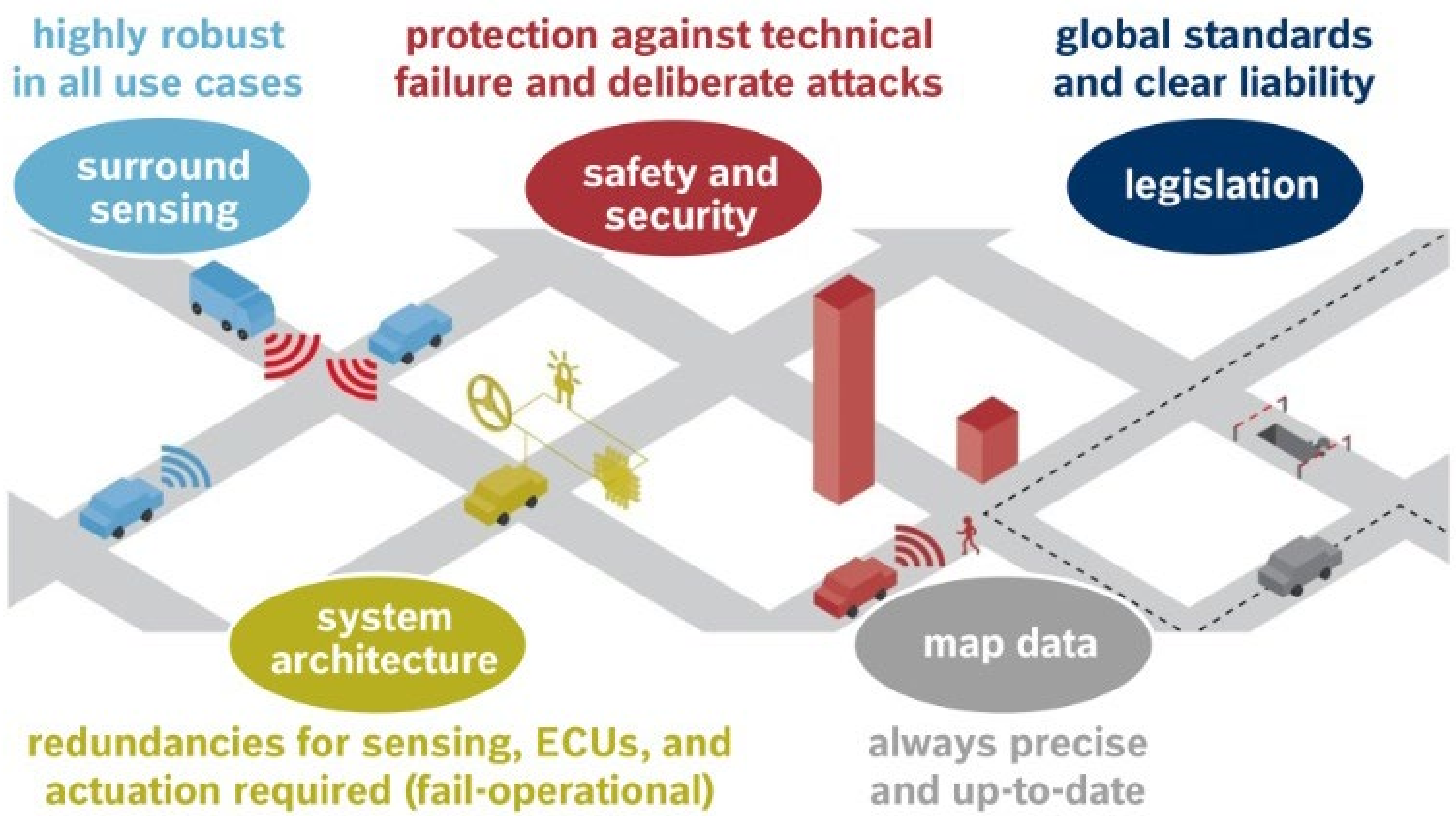
Integrated Systems Approach to Vehicle Automation



The Complexity of Automated Driving

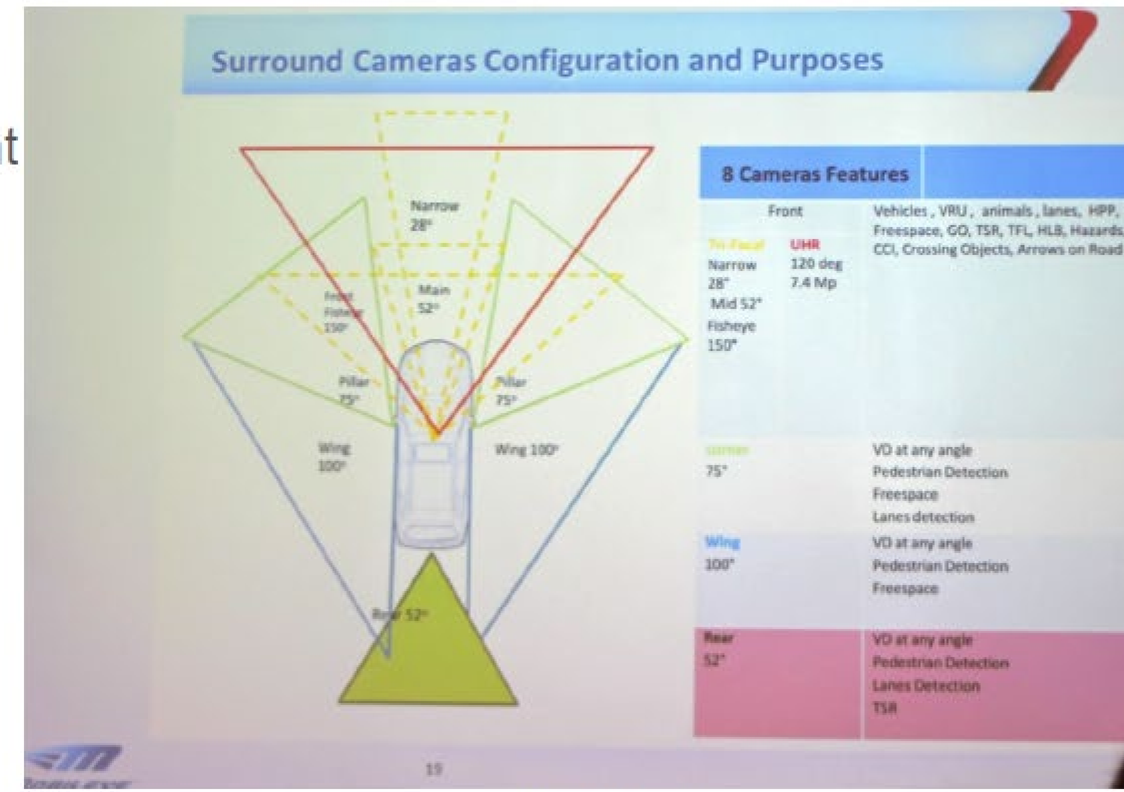


POLLING QUESTION #1

- How many levels of automated driving are there as defined by SAE?
- 1) 3
- 2) 6
- 3) 4

SENSORS ALONE AREN'T SUFFICIENT

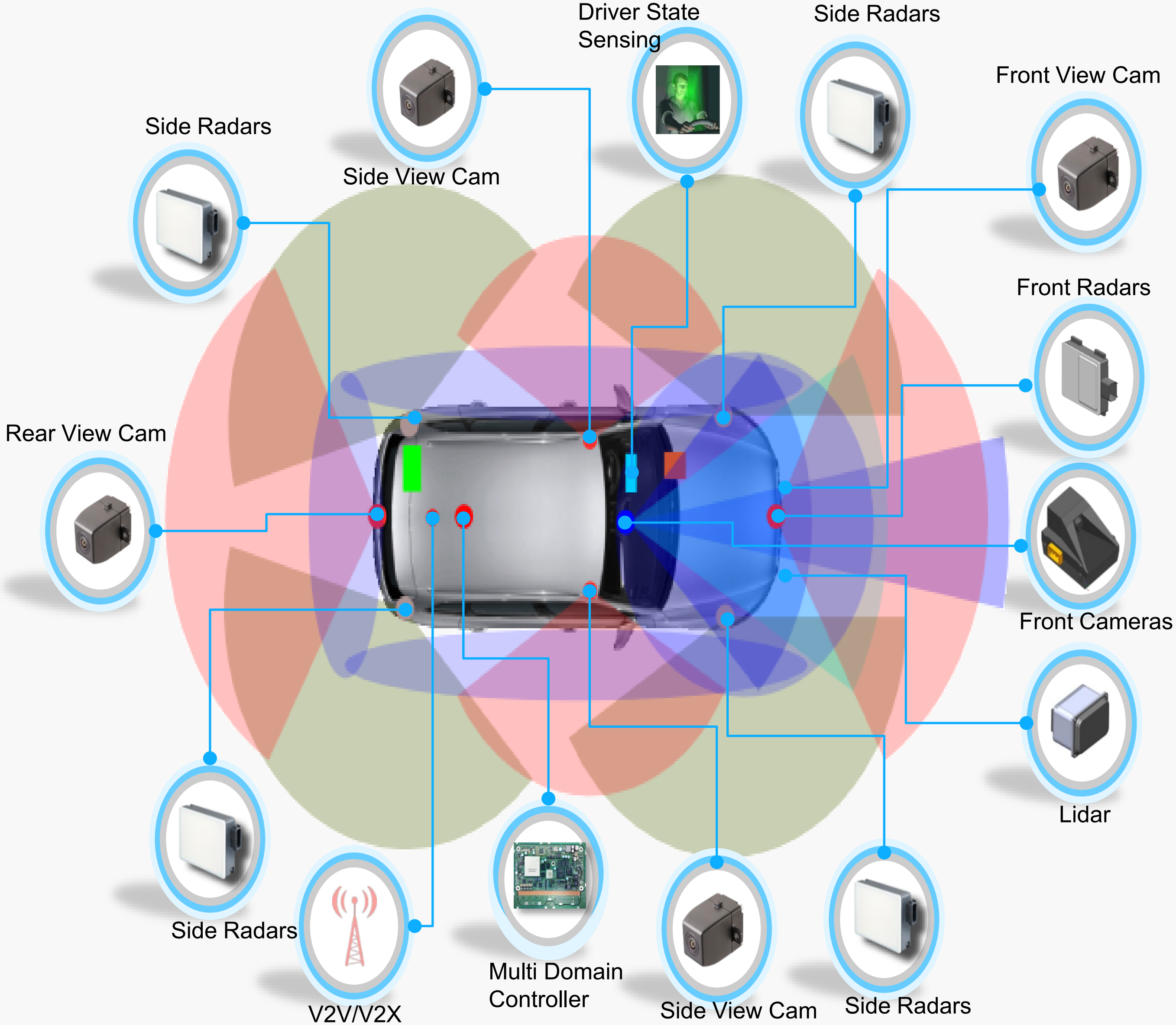
- Autonomous vehicles are being developed with sensors that provide a simultaneous 360 degree view, something no human can achieve
- Different types of sensors each have their own strengths and weaknesses
- Redundancy will be important to deal the variability of the real world including weather



(Source: Mobileeye)

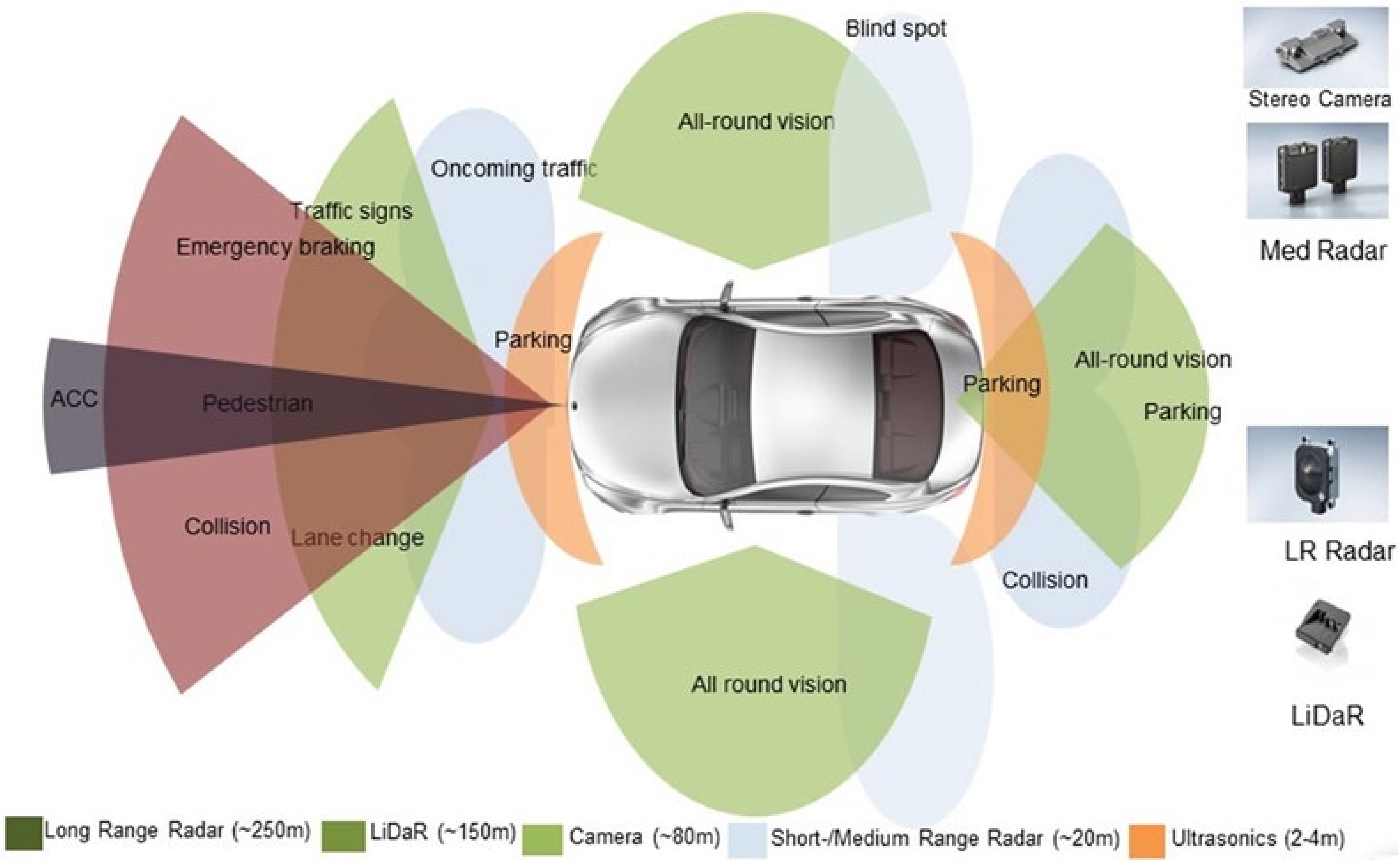
V2V/V2X
Controller
Side View Cam
Side Radars

ADAS and Automated Vehicle Sensors



Different Sensors Have Different Geometry and Range

F
R
O
N
T



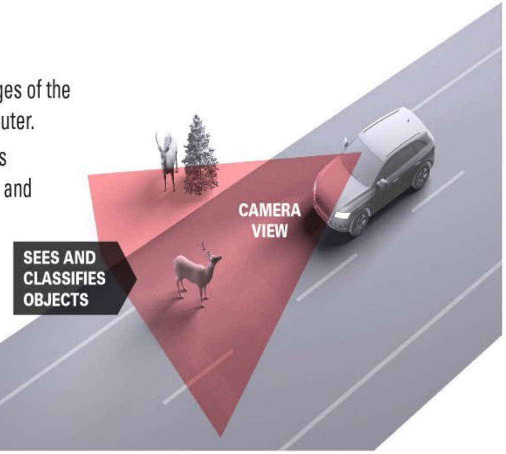
Vision/Radar/Lidar Operation and Fusion

Camera

How it works: A camera takes images of the road that are interpreted by a computer.

Strengths: Distinguish and classifies objects, such as traffic lights, tail lights, road lines and signs. It can also classify some objects, such as the deer being a large animal.

Weakness: Like us, what it can't see, it can't see — in the dark, into direct sunlight and when objects are hidden.

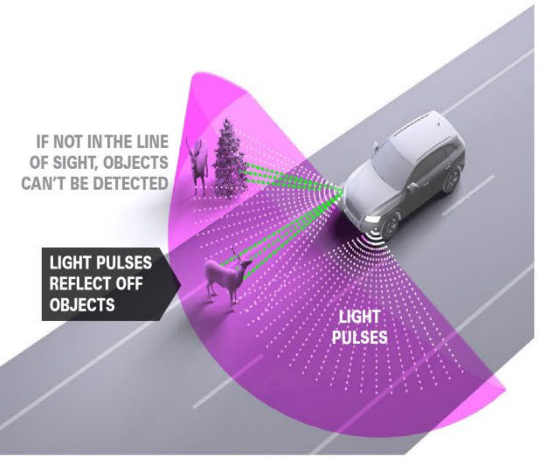


LiDAR

How it works: Light pulses are sent out, reflected off objects and received for interpretation.

Strengths: Can define specific objects, such as a deer and its distance. Can tell where lines are on the road. Works in the dark.

Weakness: In bad weather, the light reflects off fog, rain or snow, making objects hard to define.

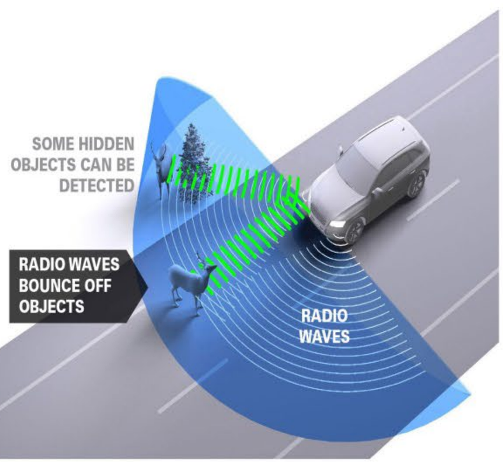


Radar

How it works: Radio waves are sent out, bounced off objects and received for interpretation.

Strengths: Knows there are large objects that could be a deer. Does a good job calculating the deer's speed and its distance. Can work in all weather, day or night. Can even fill in some hidden objects.

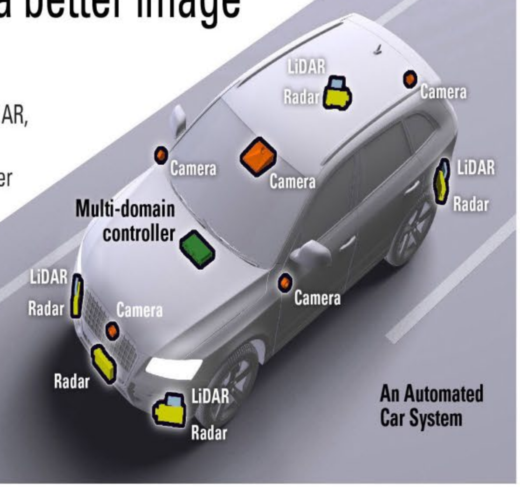
Weakness: Can't see color or differentiate objects, such as a deer from a big rock.



Working together for a better image

Multi-domain controller

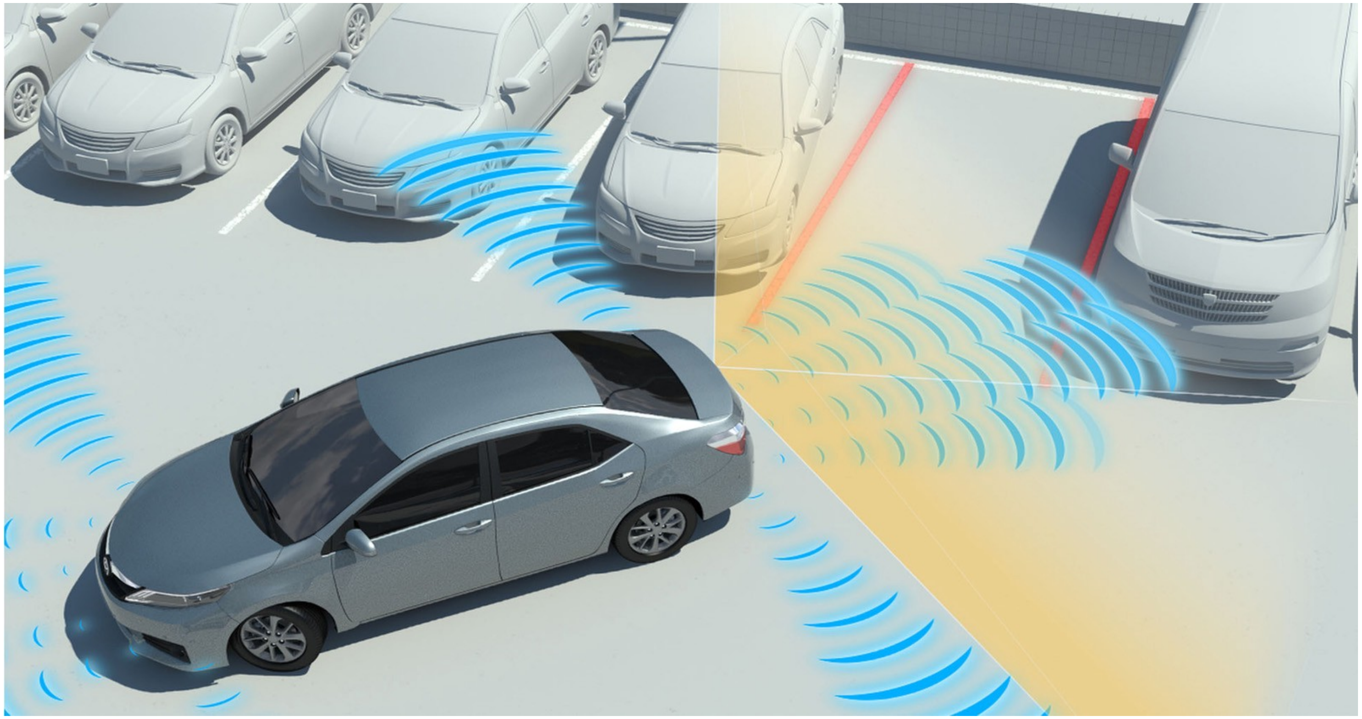
With cameras, Radar and LiDAR, you're getting three forms of input. Putting them all together is the multi-domain controller's job. It takes the best of all three. Add mapping and navigation information and you can confirm decisions in multiple ways.

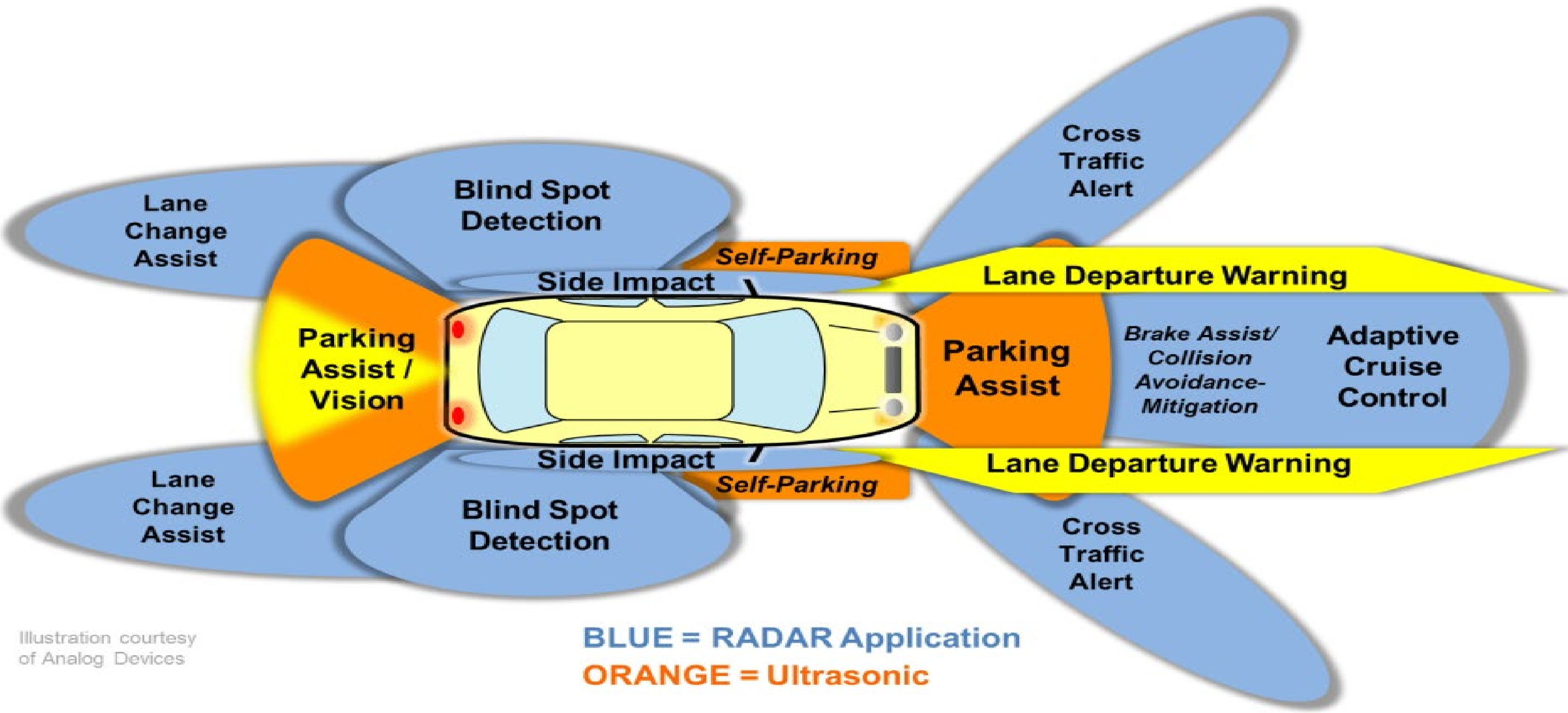


What is an ultrasound sensor

Sonar stands for Sound Navigation And Ranging. tasks

An ultrasonic sensor **measures the distance to an object using ultrasonic sound waves**. An ultrasonic sensor uses a transducer to send and receive ultrasonic pulses that relay back information about an object's proximity. It has been used in vehicles to assist drivers with their driving primarily for parking and obstacle detection.




Lane Change Assist
Blind Spot Detection
Self-Parking
Side Impact
Cross Traffic Alert
Lane Departure Warning
Parking Assist / Vision
Parking Assist
Brake Assist/ Collision Avoidance-Mitigation
Adaptive Cruise Control
Side Impact
Self-Parking
Lane Departure Warning
Lane Change Assist
Blind Spot Detection
Cross Traffic Alert
Illustration courtesy of Analog Devices
BLUE = RADAR Application
ORANGE = Ultrasonic

What is LIDAR?

LIDAR (also called lidar, **LiDAR**, and **LADAR**)

- surveying method that measures distance to a target by illuminating that target with a laser light

- acronym of *Light Detection And Ranging or Light Imaging, Detection, And Ranging*

- popularly used to make high-resolution maps
- sometimes is called *laser scanning* and *3D scanning*, with terrestrial, airborne, and mobile applications
- uses ultraviolet, visible, or near infrared light to image objects.

It can target a wide range of materials, including non-metallic objects, rocks, rain, and chemical compounds.

LIDAR for transportation systems

LIDAR systems

- understanding vehicle and surrounding environment
- mapping and estimation

Basics overview

- rotating hexagonal mirrors split the laser beam
- upper three beams for vehicle and obstacles ahead
- lower beams detect lane markings and road features
- major advantage is the spatial structure is obtained and can be fused with other sensors like radar to get a better picture of the vehicle environment in terms of static and dynamic properties of the objects present in the environment.

What is Sensor Fusion ?

- Definition

  « Information Fusion is to combine information from multiple sour
  in order to improve decision making» **Isabelle Bloch**

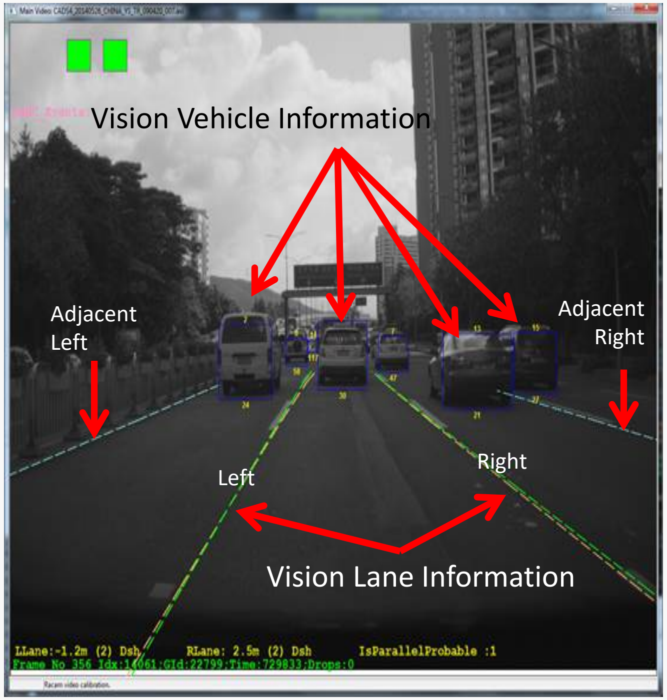
- For Autonomous Driving

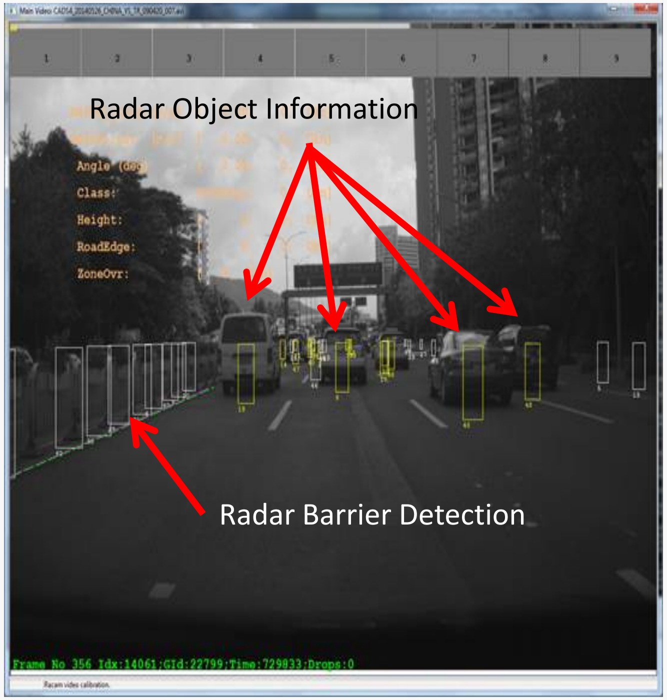
  Combination of the output data of various sensors to provide an autonomous driving system with a complete perception of its environment and current driving state

- Approaches

Probability Bayesian fusion	Possibility theory Fuzzy Logic	Evidence theory Dempster-Shafer

Sensor Fusion Improves Performance





Advantages of Redundant Sensor Fusion

- Probability of correct detection and classification[1]
  - Increases with additional sensors and redundancy
  - Utilize sensors with highest signal to noise ratio (S/N) under the ambient conditions
  - Disregard sensors that have low S/N under the ambient conditions
  - Marginal gains decrease for more than 5 sensors
- Reliability of systems[2]
  - Adding more sensors increases the reliability of the overall system
  - Mean time to failure of a system with more sensors is increased

References:
[1]Hall, David L., "Mathematical Techniques in Multisensor Data Fusion", Artech House Information Warfare Library, February 26, 2004
[2]Deyst, John, "Real Time Systems for Aerospace Vehicles", MIT 16.840 Aeronautics & Astronautics Course Notes, Spring 1999

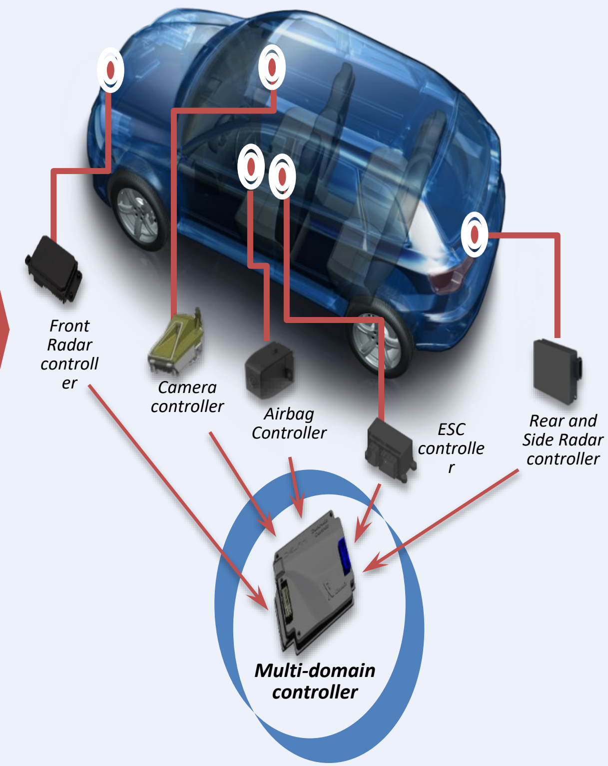
Multi-domain Controller

Active Safety Multi-domain controller

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

Production launch in 2017

Centralized Sensor Fusion/Control



Enables future system optimization/upgradability

Typical Software Applications: Lines of Code

12 million lines of code
Android Operating System

44 million lines of code
Microsoft Office 2013

Premium vehicle

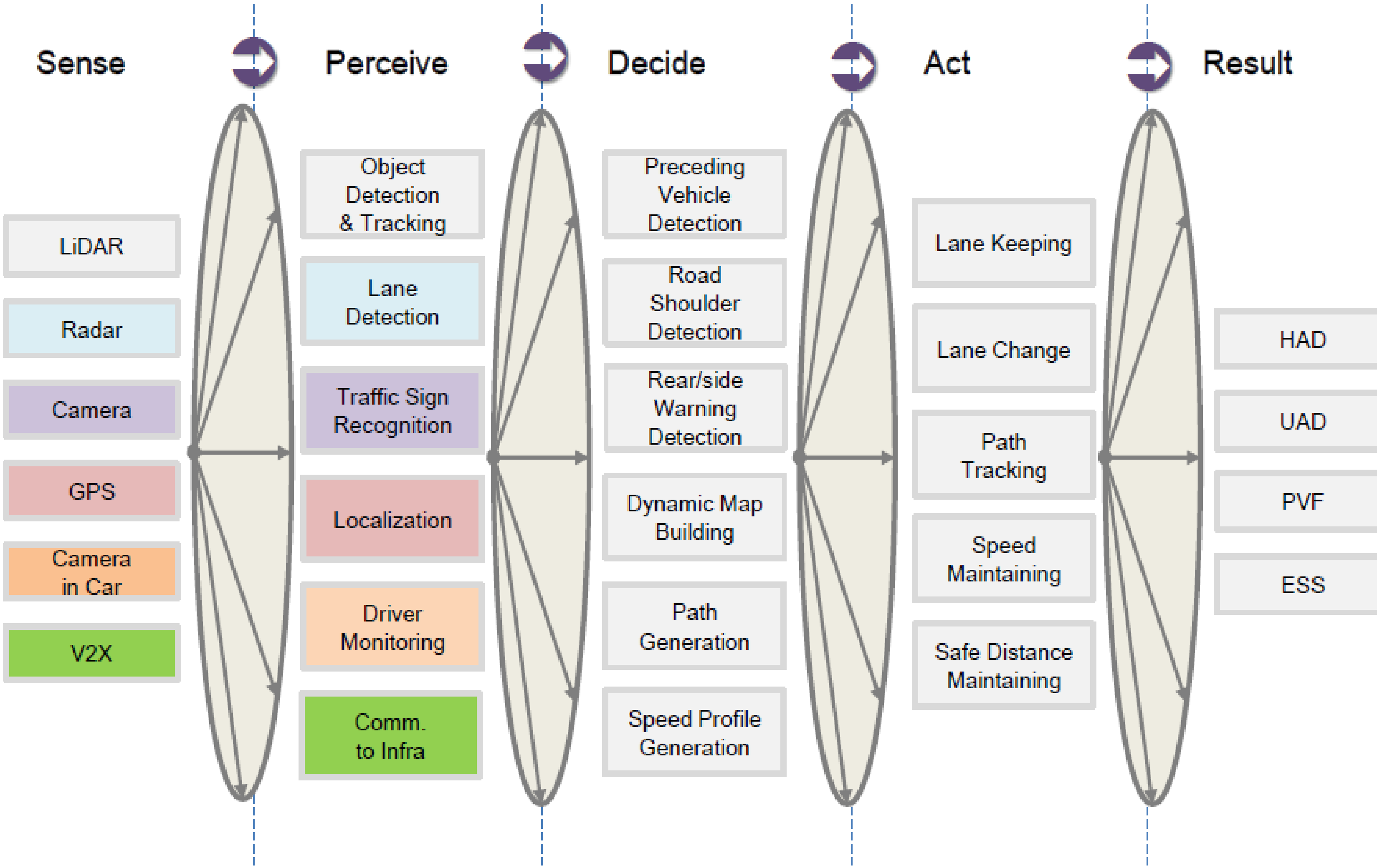
50+ computers
To deliver a world-class user experience, active safety and high performance drivability

24 million lines of code
F-35 fighter jet

61 million lines of code
Facebook

Premium vehicles today operate with <u>over 100 million+ lines of code</u>

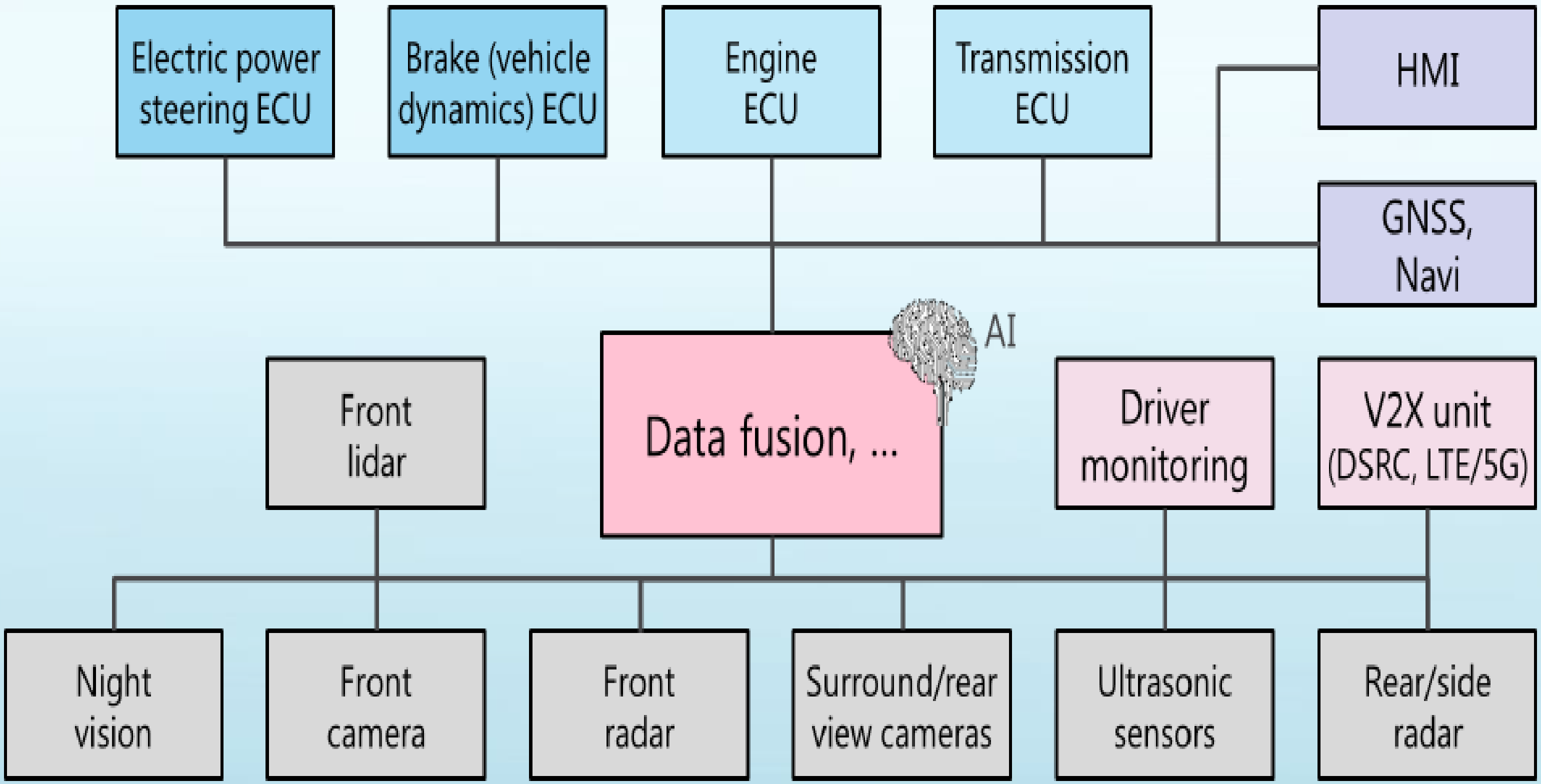
System Flow


Sense
Perceive
Decide
Act
Result
LiDAR
Radar
Camera
GPS
Camera in Car
V2X
Object Detection & Tracking
Lane Detection
Traffic Sign Recognition
Localization
Driver Monitoring
Comm. to Infra
Preceding Vehicle Detection
Road Shoulder Detection
Rear/side Warning Detection
Dynamic Map Building
Path Generation
Speed Profile Generation
Lane Keeping
Lane Change
Path Tracking
Speed Maintaining
Safe Distance Maintaining
HAD
UAD
PVF
ESS

Changing ECU Architecture ...

From a decentralized architecture following the general paradigm "one ECU for one ADAS-related functionality" ...

... to a centralized architecture with central sensor data fusion, predictive 360° redundant sensing and artificial intelligence (AI).



POLLING QUESTION #2

LIDAR, RADAR, and Cameras are all used for autonomous driving?

1) True
2) False

Electrical Consumption

What type of propulsion system will power the highly automated (SAE Level 4) and fully autonomous (SAE Level 5) vehicles of the future?

The 1.5 kW to 2.75 kW needed just to process the increasing deluge of incoming and in-vehicle. For a typical B-segment vehicle, for example, about 39 W of electricity consumed is equivalent to about one gram of CO_2 emitted.

New dedicated processors from will help reduce electrical consumption by up to 90%. That means a typical vehicle’s processing power demand may be 200 to 350 W.

The best case-scenario is that there will be about a 10-g to 20-g CO_2 penalty per autonomous vehicle, translating into a 3-6% burden for the propulsion system.

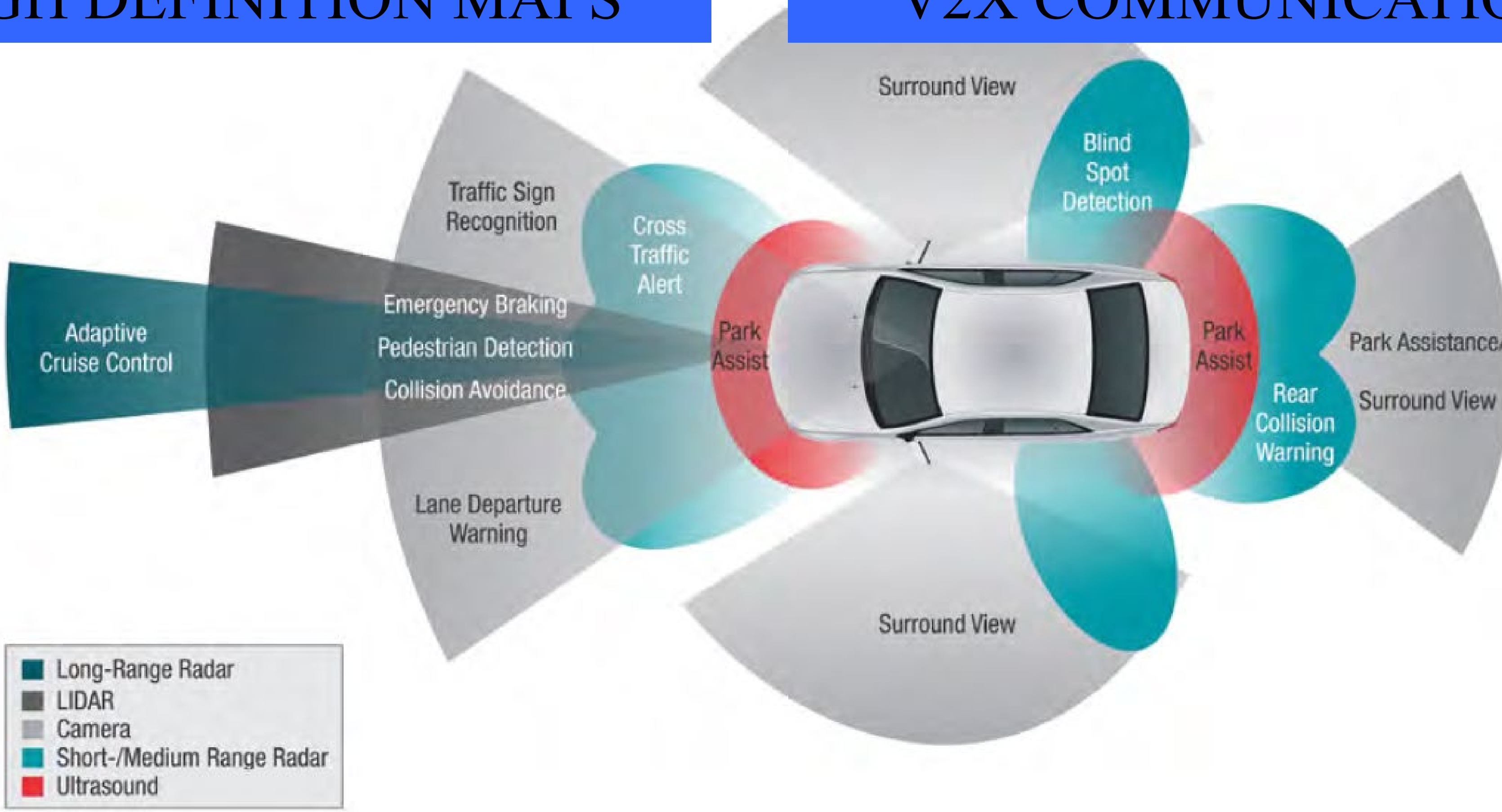
Autonomous vehicles can be “propulsion agnostic,” the need for redundant braking systems (and redundant batteries) makes plug-in hybrids the practical prime-mover in this area for perhaps the next 20 years. Battery-electric vehicles won’t play a major role in autonomous use during that period.

The increased uptime of autonomous vehicles could mean more than 10 hours per day of operation, in which a significant amount of charging would be required.

Automated Driving:
Enabling and *Supporting* Technology

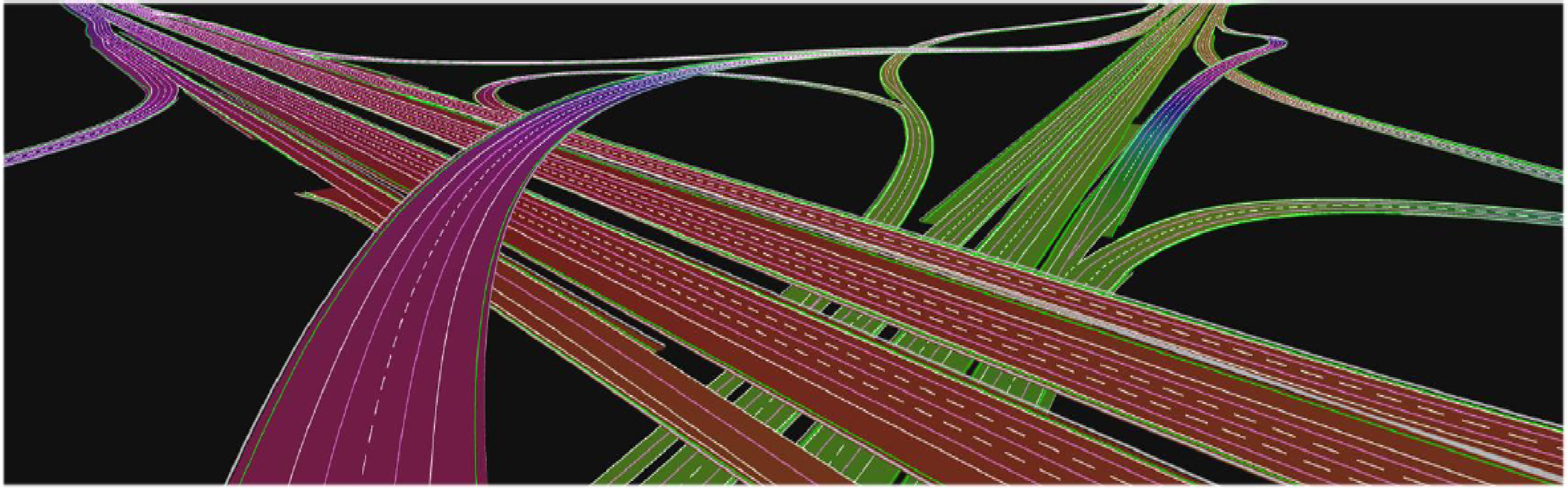
HIGH DEFINITION MAPS

V2X COMMUNICATIONS



Source: Texas Instruments ADAS Solutions Guide

Adding HD Map layers for Automated Driving



Highly Detailed

3D Lane Geometry

- markings
- centerlines
- road boundaries

Highly Accurate

Sub-meter absolute

Decimeter-level relative

Richly Attributed

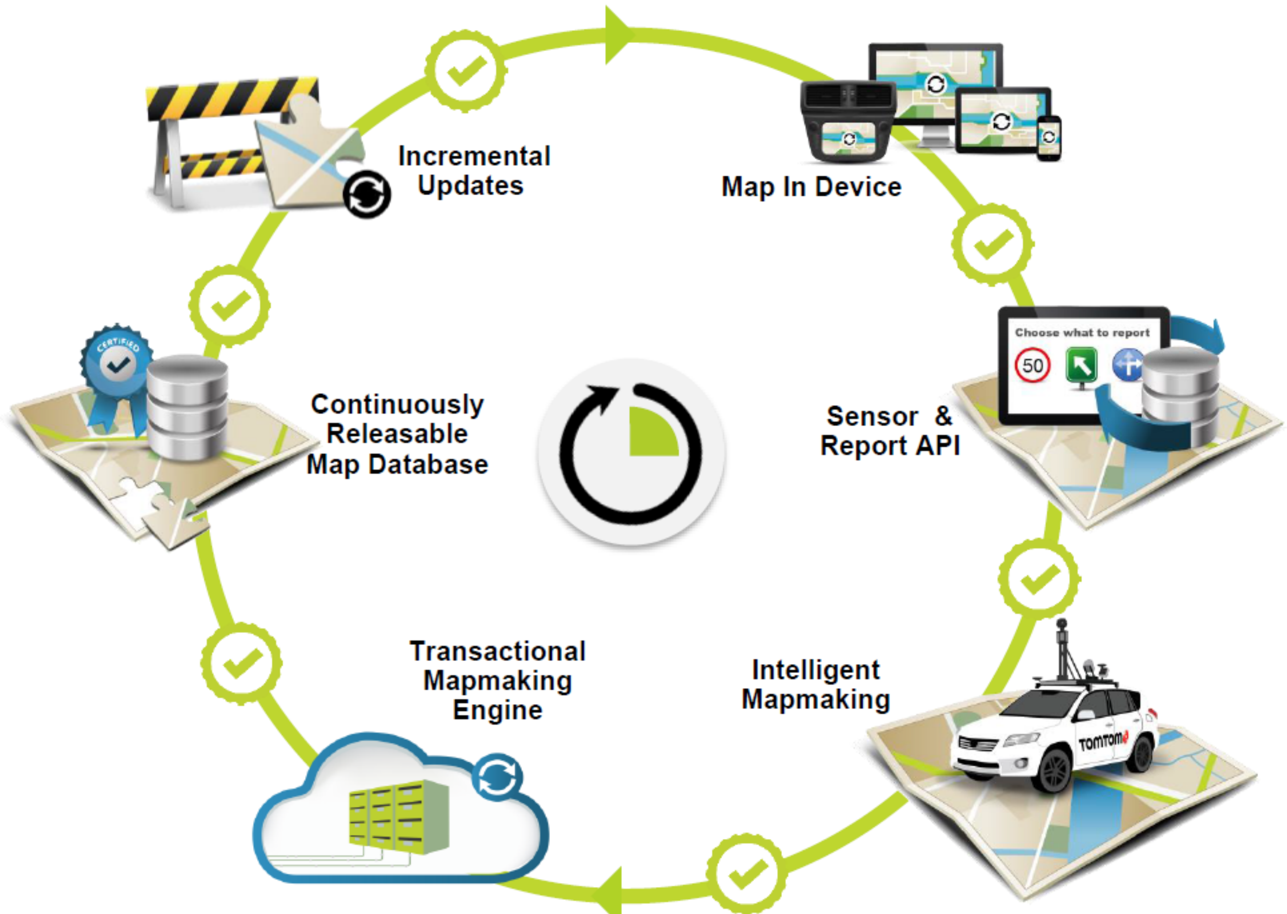
Lane-level attributes

Position Landmarks

RoadDNA

The Process of Delivering Real-Time Maps

Delivering
real-time maps



Quality Assurance

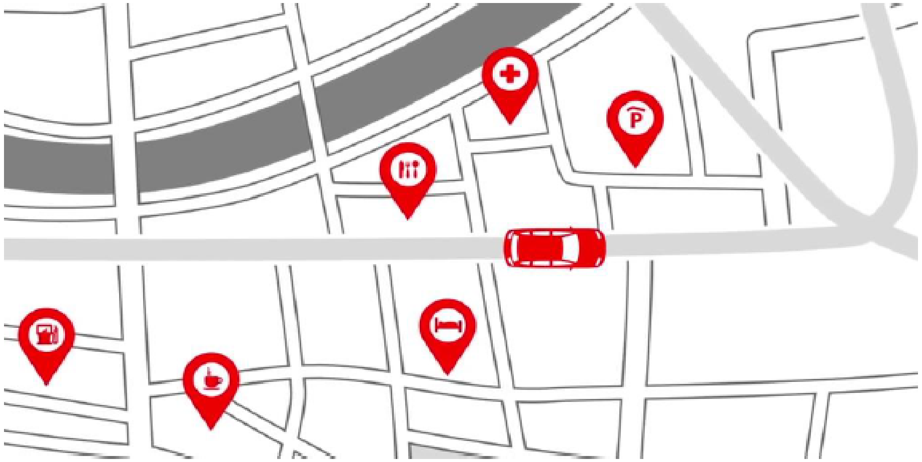
TOMTOM

Introducing the Concept of "Connected" Vehicles

What's the difference: Connected versus Autonomous Car?

An Autonomous Car needs information – lot's of it!

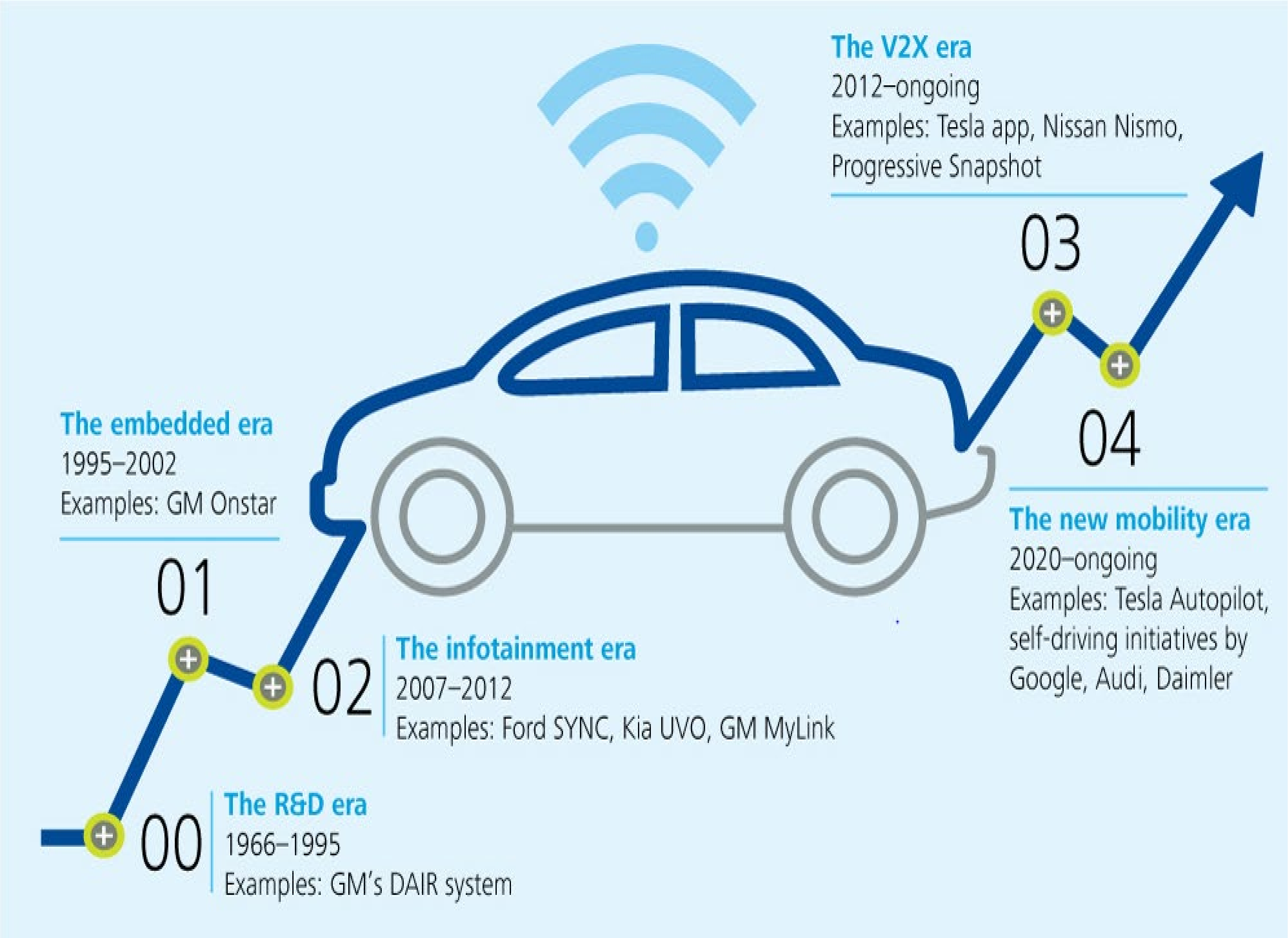
- Location and positioning
- Map data
- Traffic information
- Weather data
- V2X
    - Car2Car
    - Traffic lights
    - Local road conditions
    - Police and emergency vehicles



This information is fused with the local sensors and processed to drive the car, autonomously.

The Autonomous Car IS Connected!

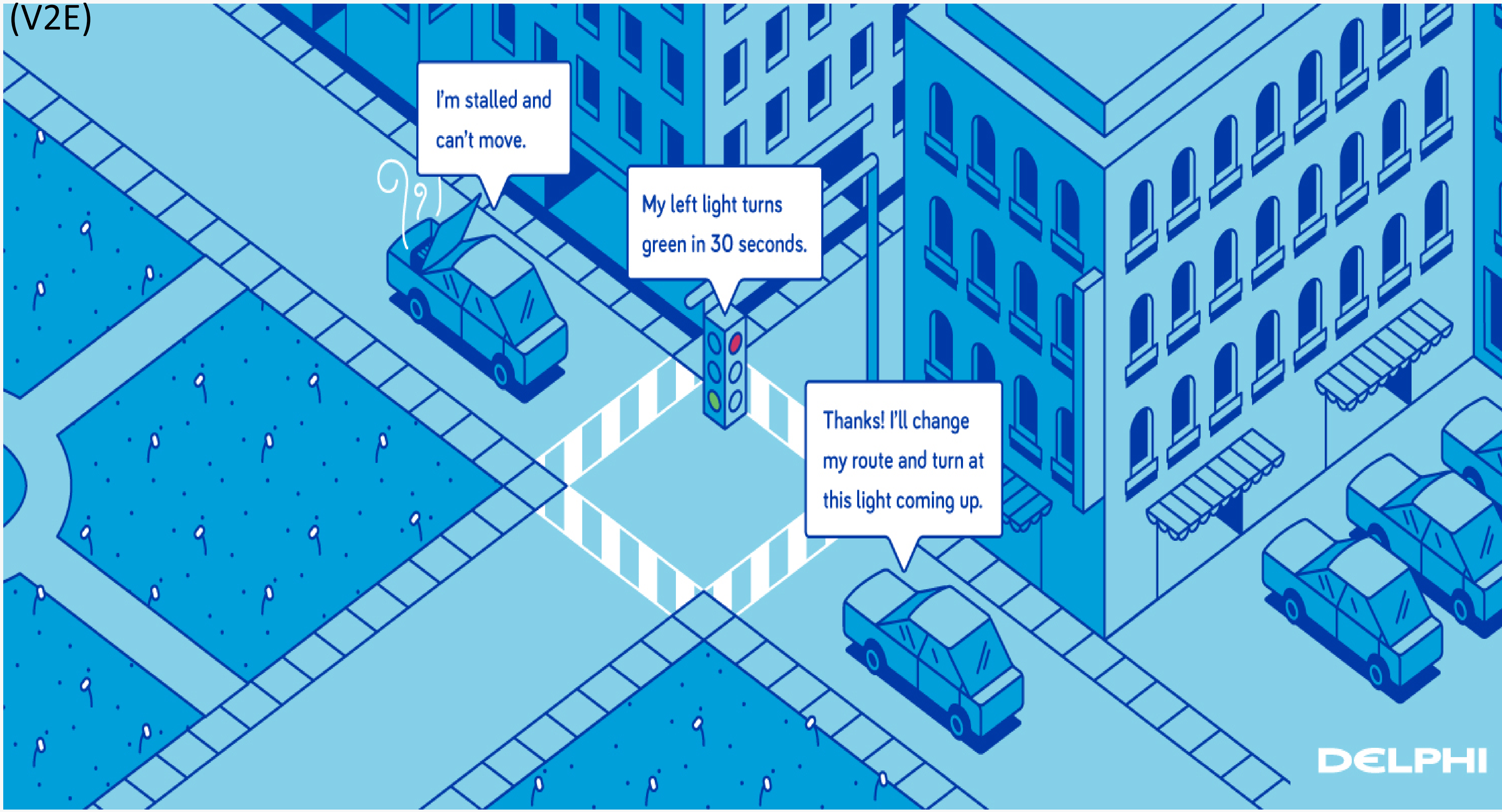
The Connected Car Evolves…



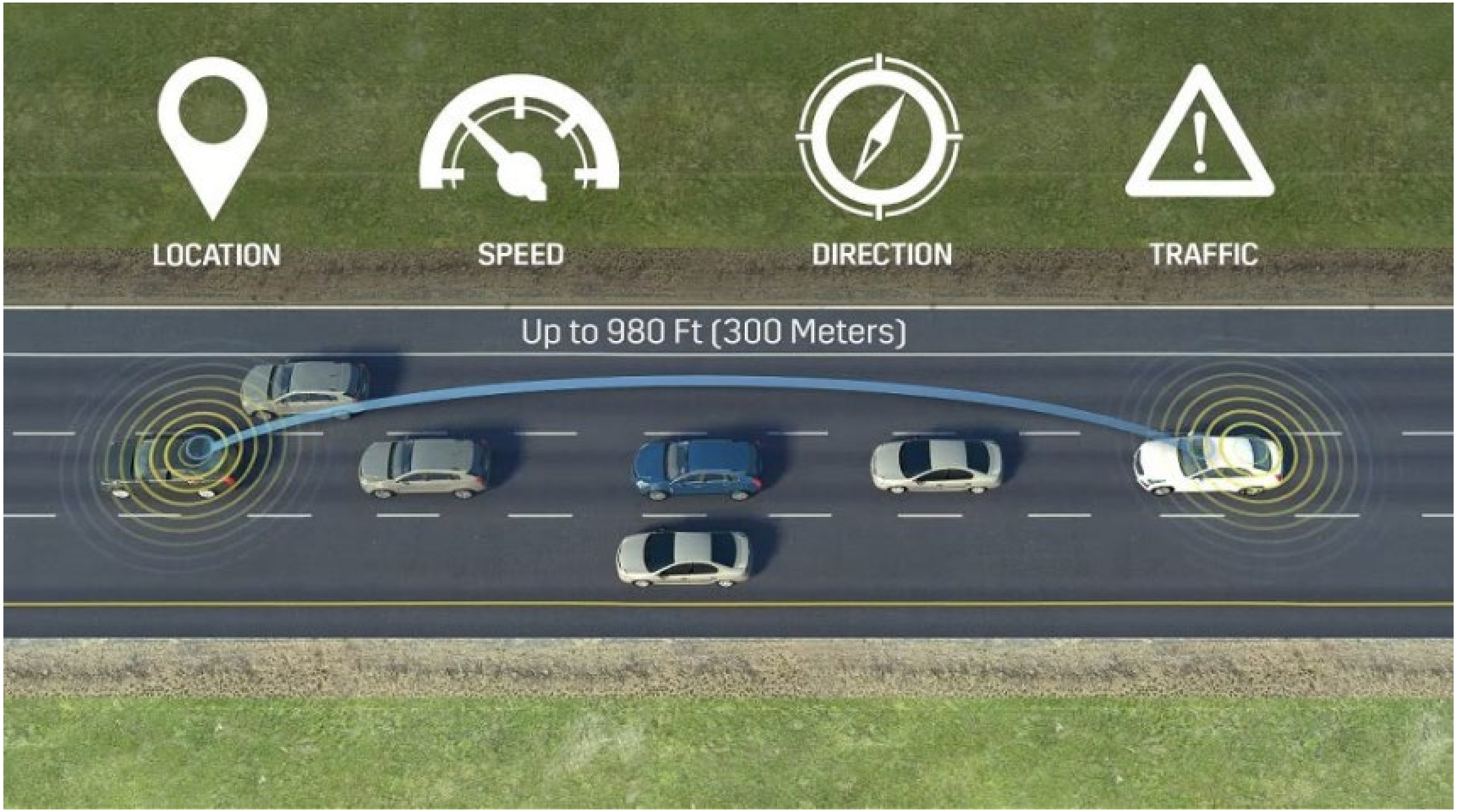
Source: Deloitte University Press

Cars talking with surrounding infrastructure…

Vehicle-to-Everything (V2E)



Dedicated Short Range Communications (DSRC) and Vehicle Ad-Hoc Networks for V2V Communications



- DSRC uses 5.9 GHz frequency and 75 MHz bandwidth (seven 10 MHz channels) plus 5 MHz guard band
- 2017 Cadillac CTS is first to have DSRC

Connected car is not the future, but a mainstream reality

Most new light vehicles estimated to be cloud-connected by 2021

Drivers for connectivity

Consumer demand
Telematics, hotspot, connected infotainment, remote vehicle management, safety

Regulatory requirements
Emergency call, stolen vehicle tracking, V2X, road usage, smog certification

Manufacturer benefits
Remote diagnostics, subscription services, over-the-air updates, data analytics

Societal benefits
Increased safety, traffic management

Penetration in new light vehicle sales by 2021

60%	81%	37%
Cellular	Bluetooth	Wi-Fi

With Connectivity, Data Becomes "Bigger"

OEMs & Dealerships

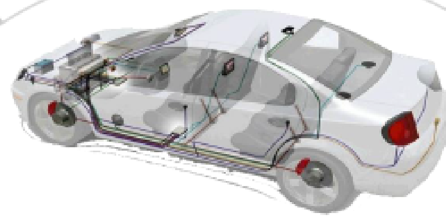
- Vehicle diagnostics, location,
- In-car consumption of services
- Aggregated cross-OEM reference

Insurance Companies

- Aggregated / Anonymized driving data, car break-down data, incident data

Smart Cities

- Real Time traffic flow
- Incident alert
- Parking



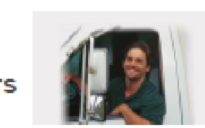
Data Source

- Connected car data
- Network, data
- App Data
- Enterprise Data
- Contextual Data
- Demographic overlays

Federal / State DoT

- Aggregated / Anonymous driving data, car break-down data, accident data, etc
- Environmental data

Fleet customers



- Fleet performance
- Compare against competition (anonymous)
- Traffic, incident data

Other B2B

- Content usage, frequency, length etc
- Other svc occurrence (Road-side assistance)

Ad. Companies

- Customer / passenger demographics

With More Data and Connectivity Comes More Vulnerability of Cybersecurity

Security involves multiple layers

Governance, Risk and Compliance

Prepare to Manage Risk

- Access Governance
- Threat Vector Analysis
- Penetration Testing
- Partner Security Program
- PCI Compliance Program

Threat Management

Protect the Perimeter

- Security Configuration Management
- Vulnerability Scanning
- Application Scanning
- Content Scanning
- Cloud- assessment

Authentication and Privacy

Trust the Ecosystem

- Data Discovery
- M2M Security
- Managed Certificate
- Application Security
- Smart Credentials
- SSL Certificates

Professional Security Services

Respond to the Threats

- Rapid Response Services
- Digital Forensics

POLLING QUESTION #3

- An autonomous car is not a connected car?

- 1) True
- 2) False

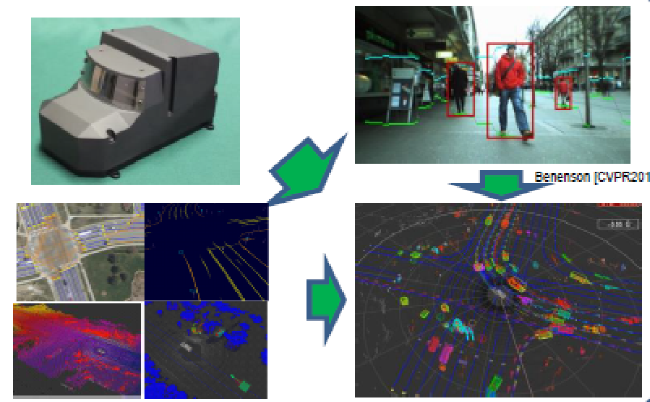
Toyota's Assessment of Automated Vehicle Technology

Important Challenges Toward the Goal

1. In-car Intelligence

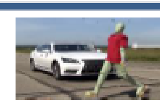
Highly Reliable Perception and Understanding

① Advanced sensors (Lidar, Radar and Camera)
② 3D maps for real time driving control
③ State-of-the-art Recognition Technologies
④ Decision making for safety
⑤ Complementary information (ITS, Infrastructure)



2. Human Factors

CSRC
Collaborative Safety Research Center
TOYOTA



Cooperation of driver and system
for Highly automated system and Complex traffic situations

① Avoid overconfidence and misleading
② Mind sharing between driver and system
③ Handover process from/to human driver and system

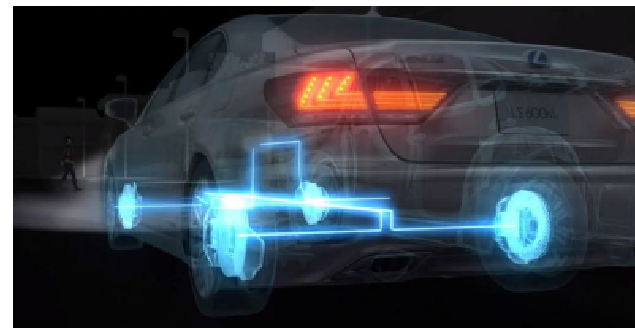
Toyota’s Assessment (Continued)

Important Challenges Toward the Goal

3. Vehicle system

Vehicle Dynamics control, System Reliability and ECUs

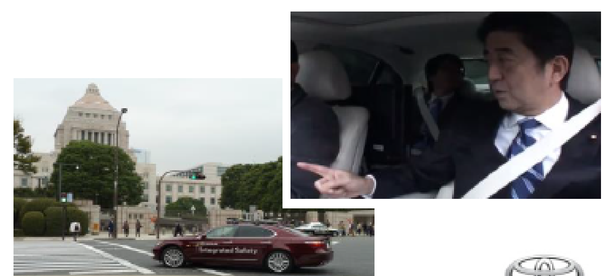
① Advanced vehicle control system
② Highly reliable system design and components
③ Advanced electronics platform (CPU, Communication etc.)
④ Safe Operation System and Cyber Security



4. Social involvements

Need wide discussions with stakeholders

① Public understanding of the technology
② Rules and regulations
③ Harmonization



Let’s Go Places

Challenges: Sense

Weather can blind sensors

Challenges: Sense

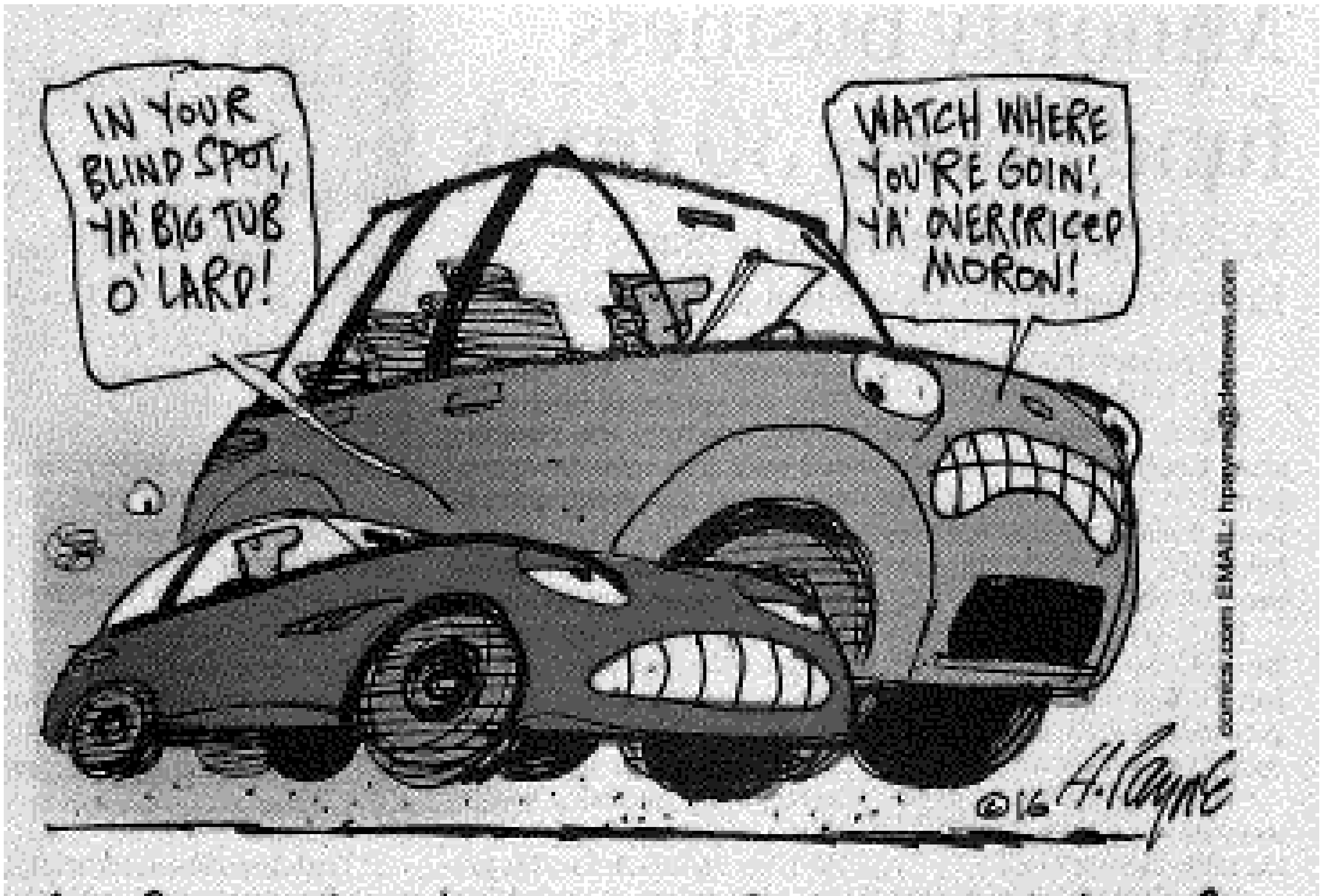
Challenges: Plan

Artificial Intelligence

Three main pillars of automated:

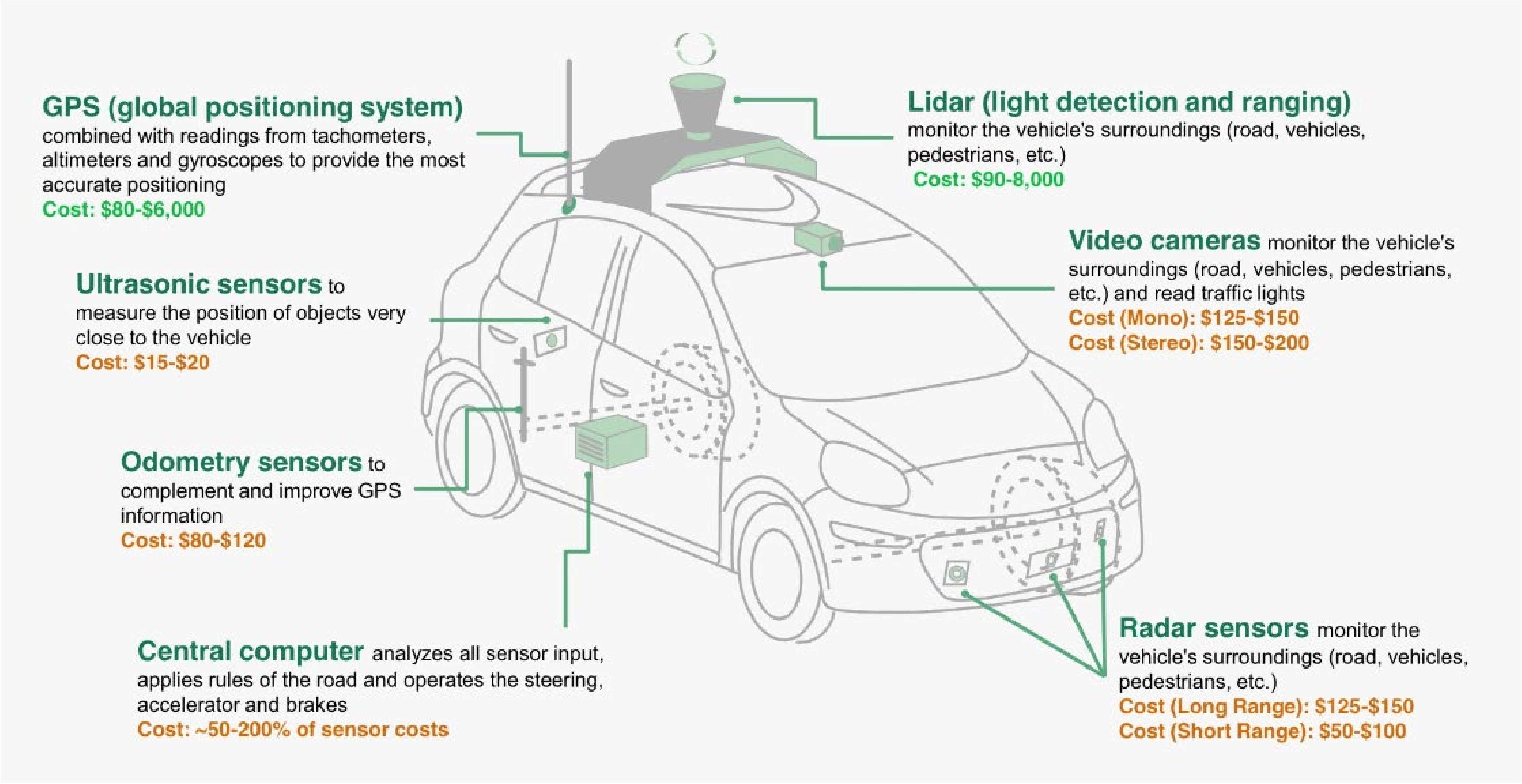
- Sensing
- Thinking
- Acting

Artificial intelligence being used to mimic human ability to reason and decide.



GOVERNMENT WANTS AUTONOMOUS CARS TO TALK TO EACH OTHER.

Challenges: Cost



Testing Level 3, 4, and 5 Vehicles

- Test tracks
  - Michigan
    - M-City (Ann Arbor)
    - American Center for Mobility (Willow Run)
  - DOT, 10 sites (including ACM)
  - Korea, “the biggest test facility”
- On Road
  - Google - let’s go right to level 5
    - Mountain View, CA -- the pod with no driver controls
    - FCA and Waymo, Pacifica Minivans
  - GM, Chevy Bolt, “test vehicles from the factory”
- Computer simulations

MEGACITIES

Ride Sharing Influence

Carma
BlaBlaCar
Lyft
Car2Go
Relay Rides
Sidecar
Uber
Ridejoy
Getaround
JustShareIt

Autonomous electric cars that you share?

Thank You!

Questions?