# The Road to Autonomous Vehicles

Bob Feldmaier
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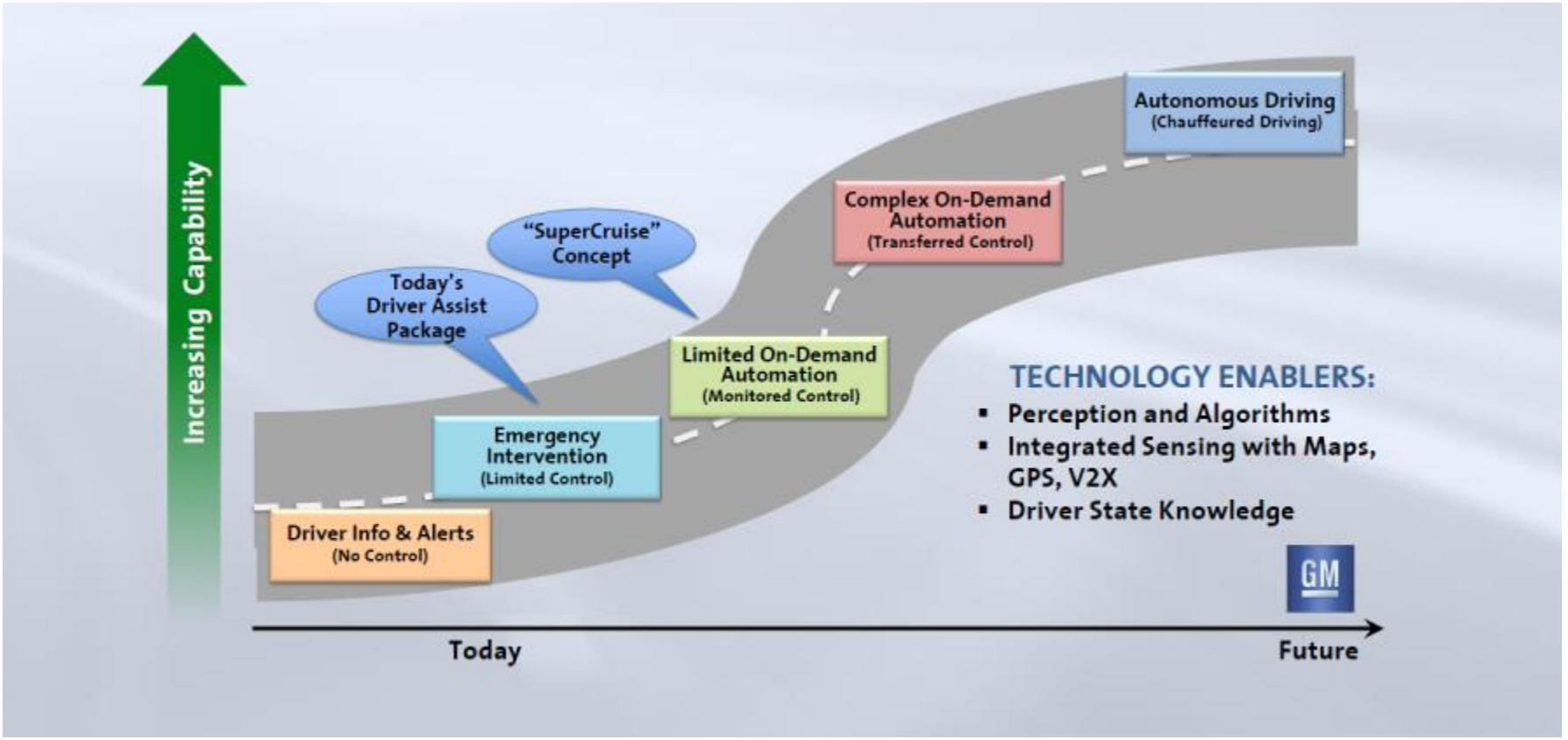
Macomb Community College

# Main Questions

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

# GM's Road to Automated Driving



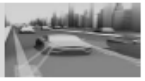
# Some of Today's Advanced Driver Assistance Technologies

## 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

| | | |
|---|---|---|
| **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<br>▪ 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 |

Passive safety system

Monitoring and warning drivers to prevent accidents

# NHTSA Automated Driving Levels (0-4)

| | Level 0 | Level 1 | Level 2 | Level 3 | Level 4 |
|---|---|---|---|---|---|
| | **Driver only** | **Assisted** | **Partial** | **Conditional** | **Full** |
| Feature | | **Active high beam**<br>**Collision imminent braking**<br>**Cruise control** | **Traffic jam assist**<br>**Adaptive cruise & lane keeping**<br>**Self-parking (with driver)** | **Collision avoidance**<br>**Automated highway**<br>**Automated urban** | **Valet self-parking**<br>**Highway point-to-point**<br>**Urban point-to-point** |
| | |  |  |  |  |
| Technology | | Forward Radar<br>Forward Vision | Forward Radar<br>Forward Vision<br>Multi-domain controller<br>Driver State Sensor (DSS)<br>V2X | Lidar & 360° Radar<br>High accuracy GPS<br>Multi-domain controller<br>Forward Vision cameras, DSS<br>V2X<br>IMU | Lidar & 360° Radar<br>High accuracy GPS<br>Multi-domain controller<br>Forward Vision cameras, DSS<br>V2X<br>IMU |

# Potential Benefits of Vehicle Automation

"Autonomous cars may seem like a gimmick, he begins, but when you consider all the **time** that people won't be devoting to their rear view mirrors, and all the **efficiencies** that come from cars that could be zipping between errands rather than idling in parking lots, the world looks like a very different place. Car ownership would be unnecessary, because your car (maybe **shared** with your neighbors) will act like a taxi that's summoned when needed. The **elderly** and the **blind** could be thoroughly integrated into society. **Traffic deaths could be eradicated**. Every person could gain lost hours back for working, reading, talking, or searching the Internet."

Google co-founder Sergey Brin as reported by Brad Stone of Bloomberg Business Week – May 22, 2013


Correspondence > Bryan Reimer, Ph.D. > reimer@mit.edu

# 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]

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

**8** people were hospitalized

**100** people were treated and released from the Emergency Department

**$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%

# The Past & Present: Automotive Safety…

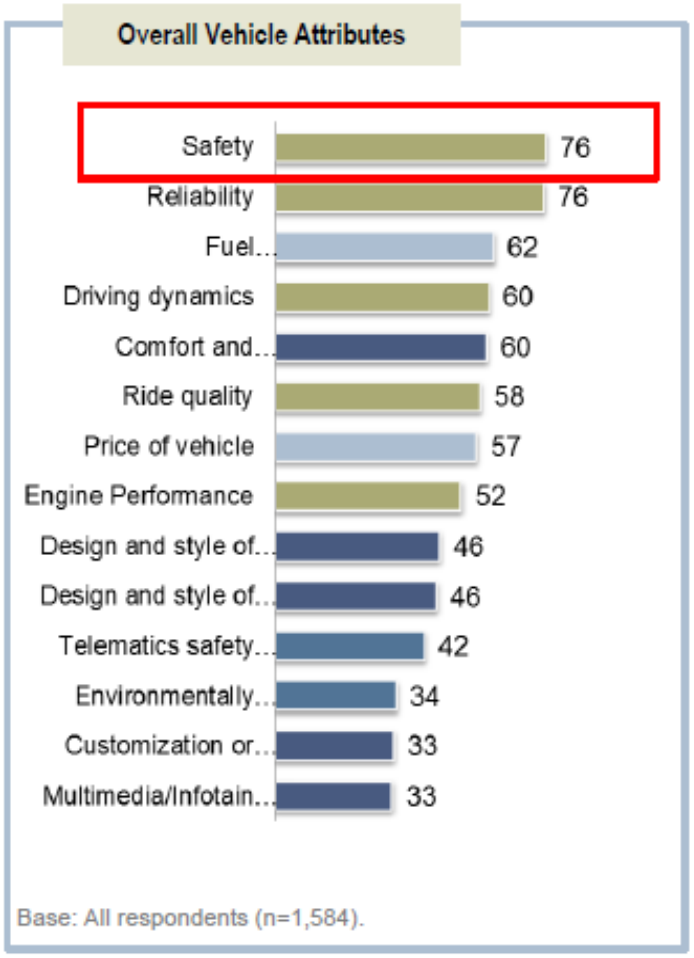


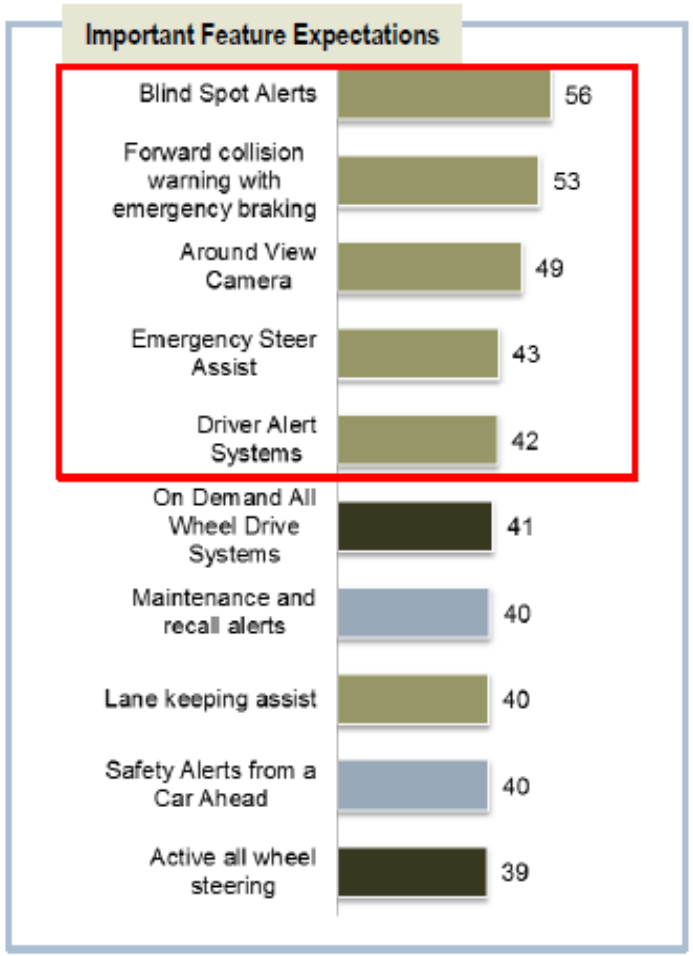


National Highway Traffic Safety Administration (NHTSA)

Source: http://www.iihs.org/iihs/topics/t/general-statistics/fatalityfacts/overview-of-fatality-facts

# US Consumers Rate Safety and Advanced Driver Assistance Technologies Most Important



# Perspectives On Driverless Vehicles

## Later

- Buffett (BH):
  "Aren't coming soon"
- Mertens (Volvo):
  "Very, very long-term vision"
- Lauckner (GM):
  "Into the future a good distance"
- Insurance Info. Institute:
  "Between 15 and 20 years away"
- Zetsche (Daimler):
  "By 2025"

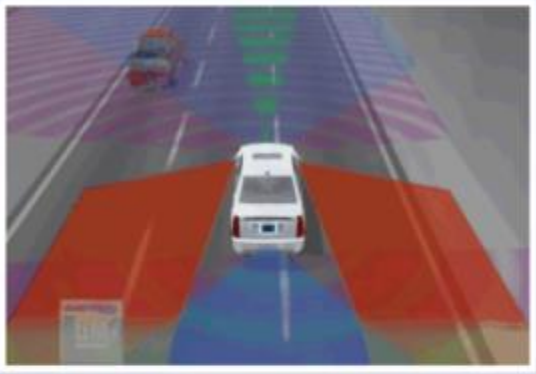
## Sooner

- Musk (Tesla):
  "A solved problem....in a few years"
- Fields (Ford):
  "Within 5 years"
- Brin (Google):
  "By 2018"
- Ghosn (Renault-Nissan):
  "By 2020"
- Zetsche (Daimler):
  "Might not have a steering wheel"

Dr. Lawrence D. Burns, 2015

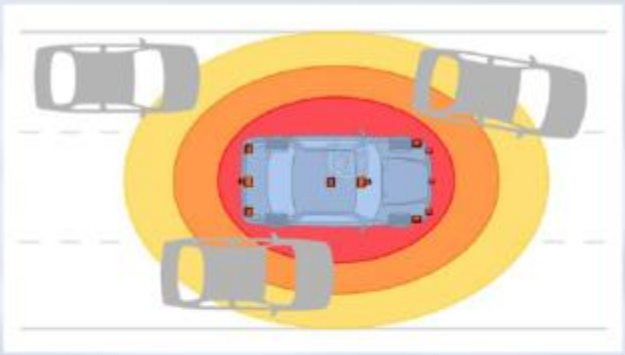
# Integrated Systems Approach to Vehicle Automation

360° SENSING



MAPS/GPS

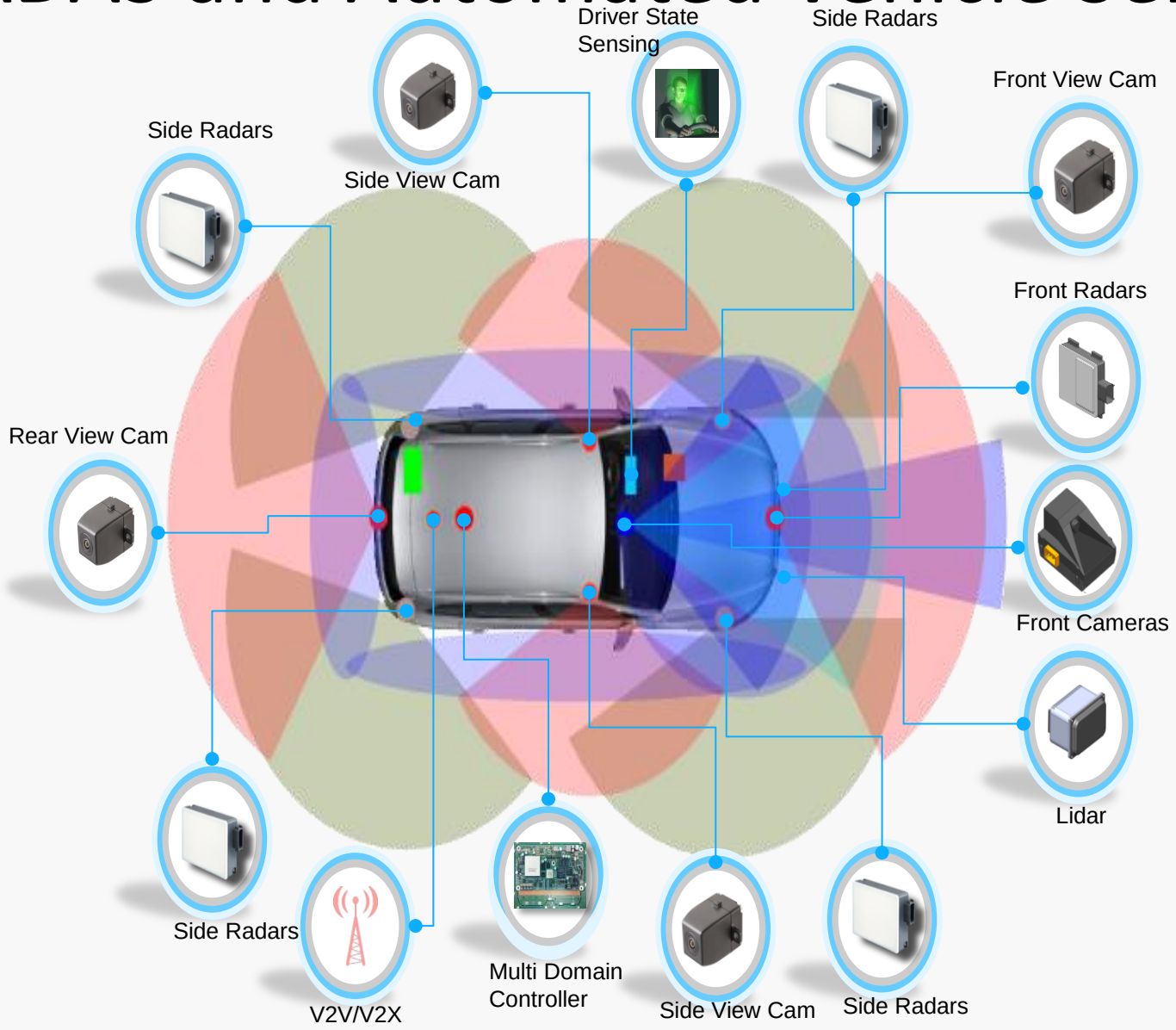
SENSOR FUSION



V2V/V2I INTEGRATION

Coming application: 2017 Cadillac “Super Cruise”

# ADAS and Automated Vehicle Sensors



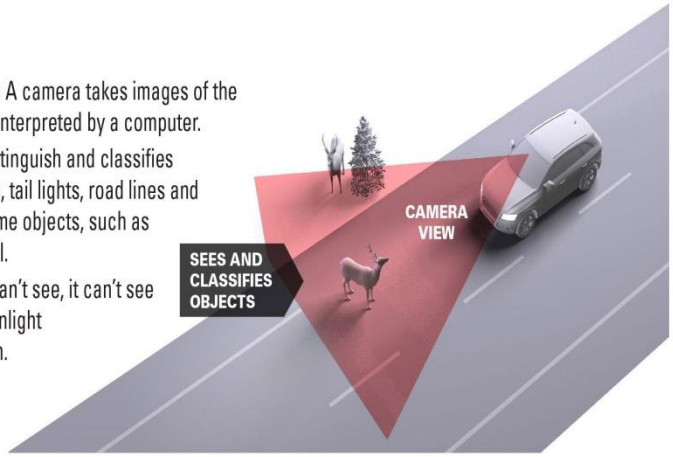
# Vision/Radar/Lidar Operation and Fusion

## 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.

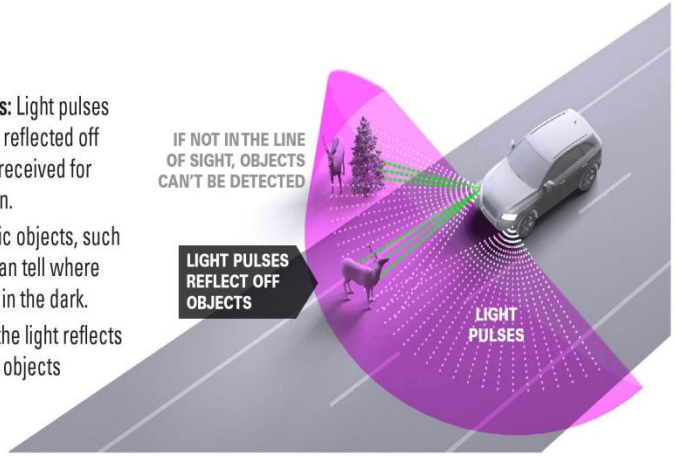



## LiDAR

**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.

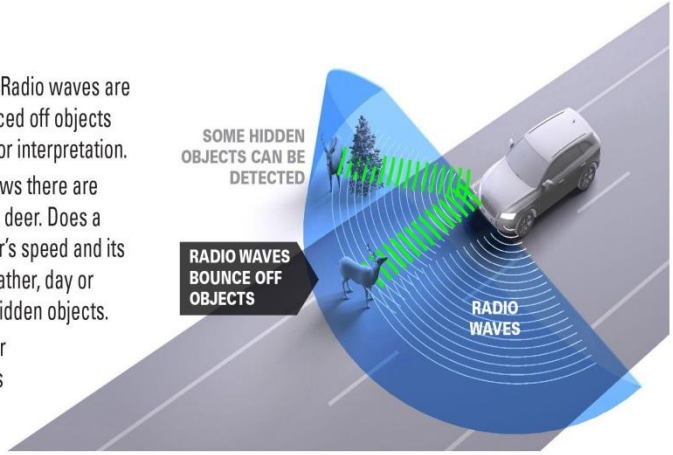



## Radar

**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

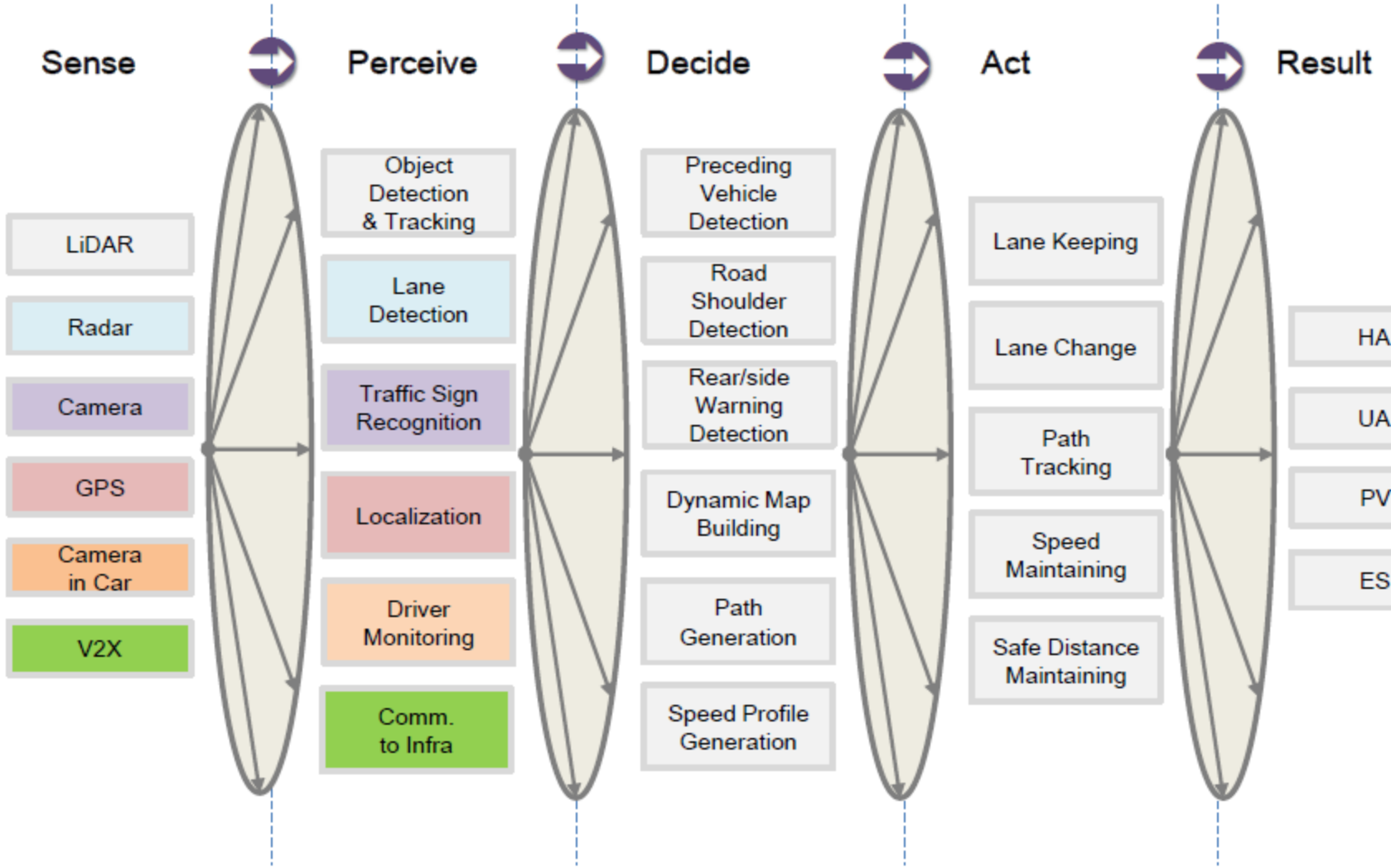
### Multi-domain controller

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.

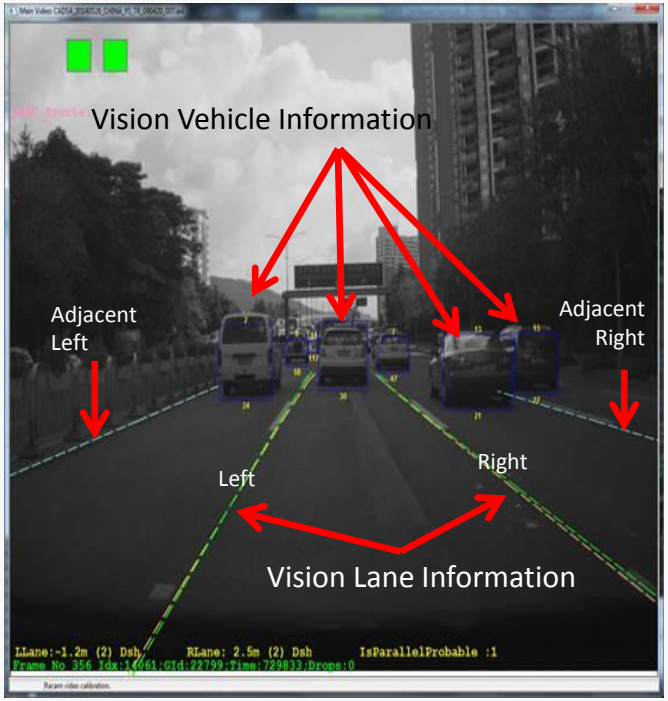


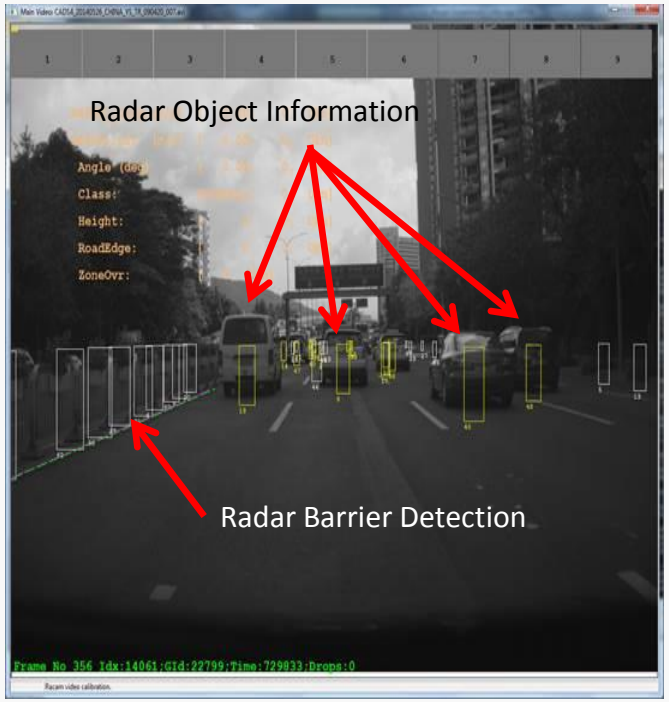

DELPHI

# 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
HA
UA
PV
ES

# 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

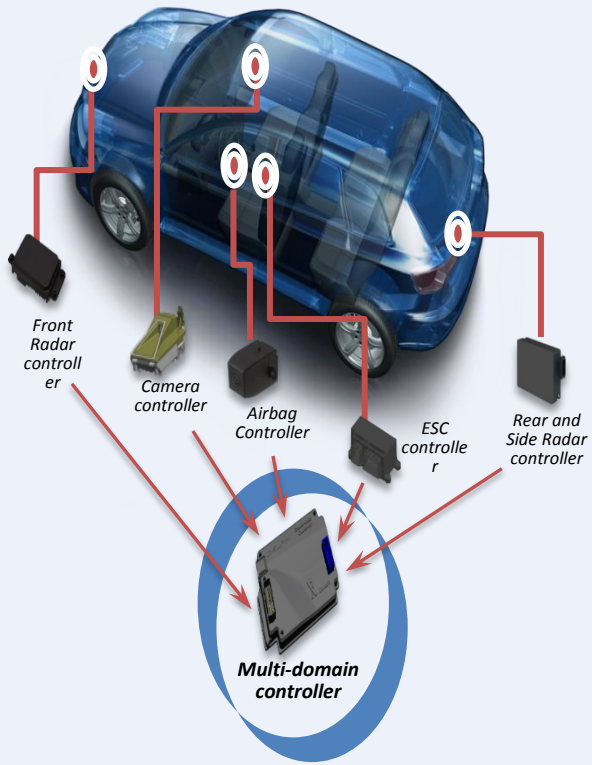
# Multi-domain Controller

## 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

**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

**44 million lines of code**
Microsoft Office 2013


**61 million lines of code**
Facebook

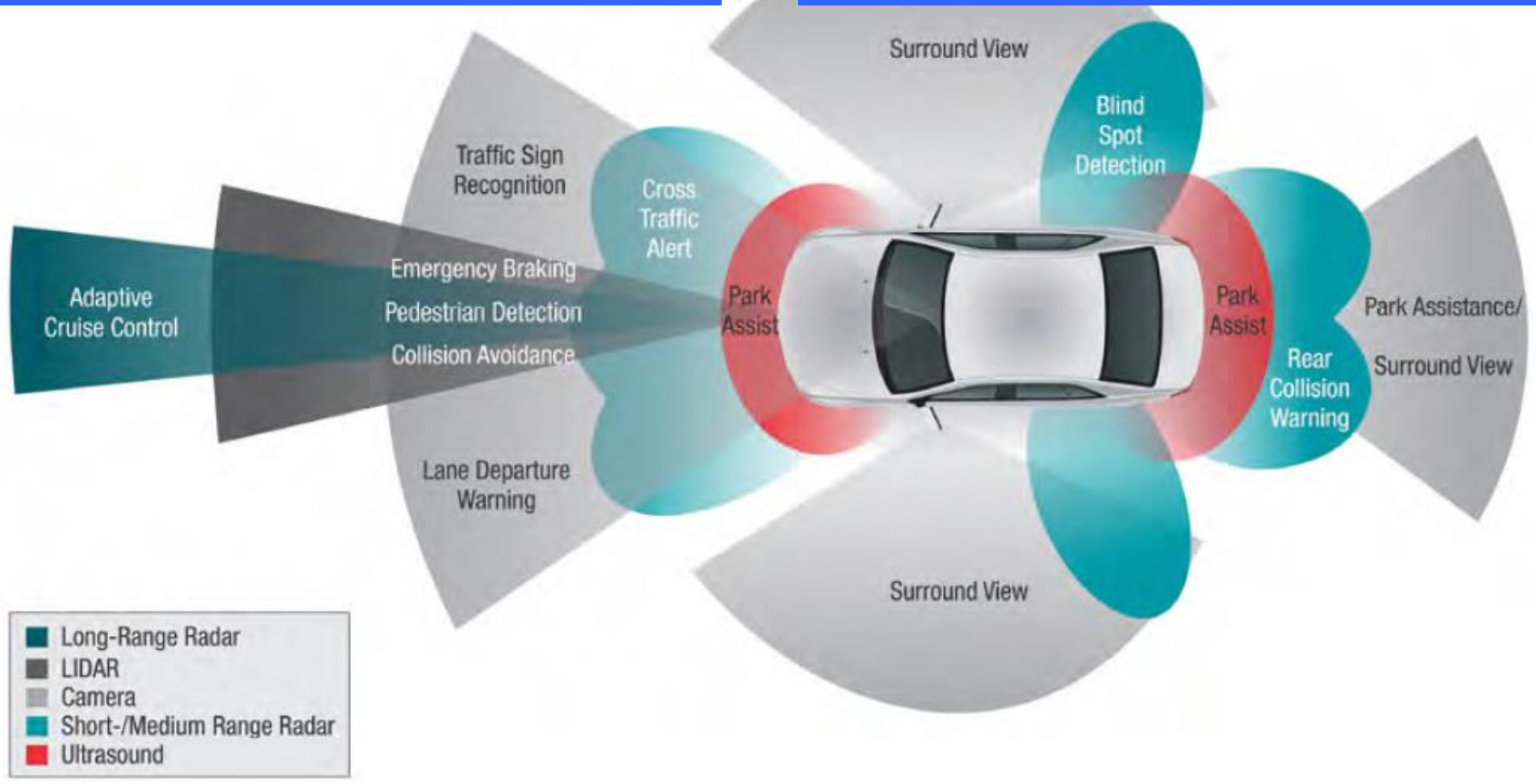

**Premium vehicles today operate with over 100 million+ lines of code**

*Software lines of code information courtesy of informationisbeautiful.net

# Automated Driving:
# Enabling and *Supporting* Technology

HIGH DEFINITION MAPS

V2X COMMUNICATIONS




Source: Texas Instruments ADAS Solutions Guide

# Introducing the Concept of "Connected" Vehicles

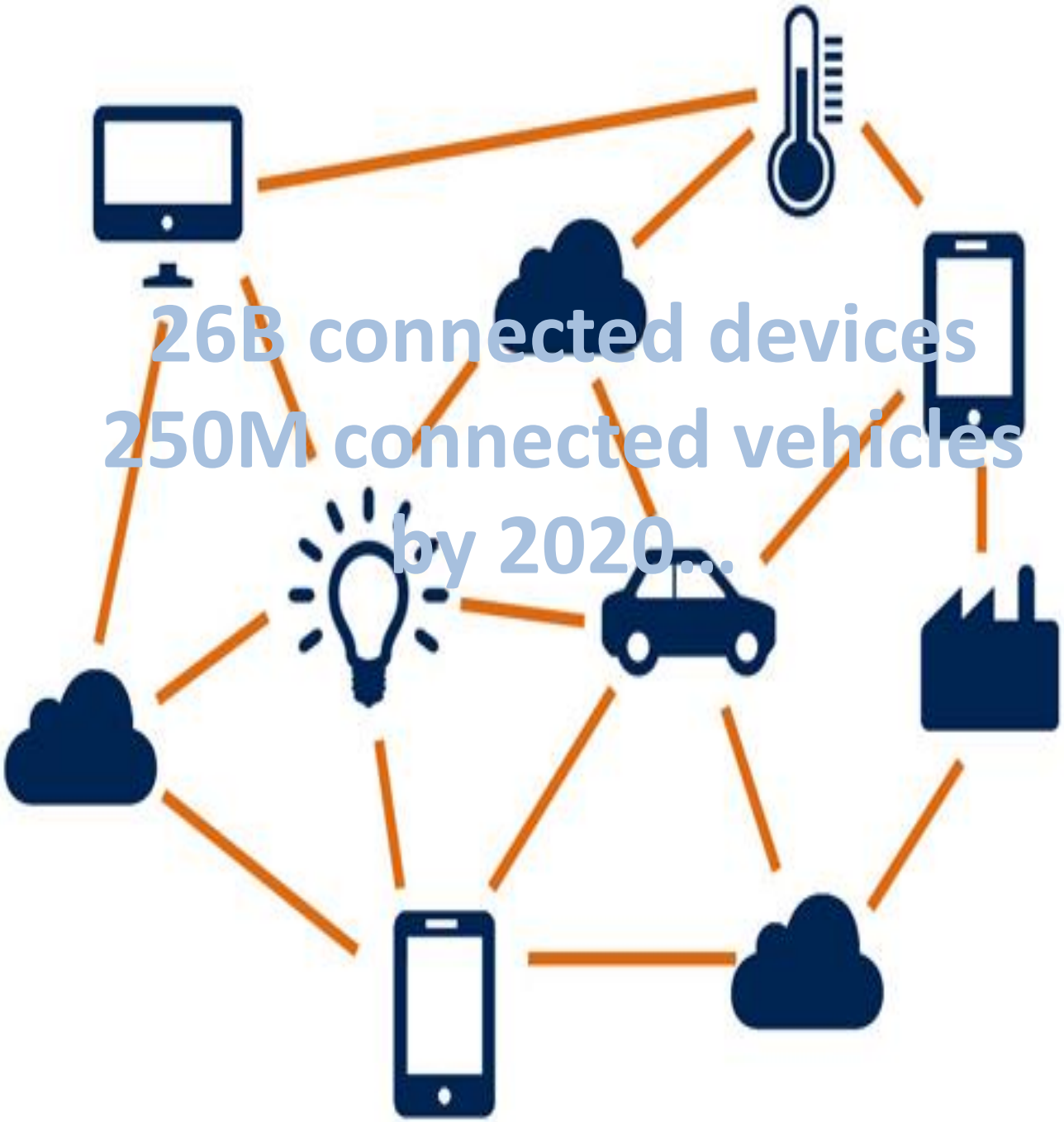
## What's the difference: Connected versus Autonomous Car?

**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

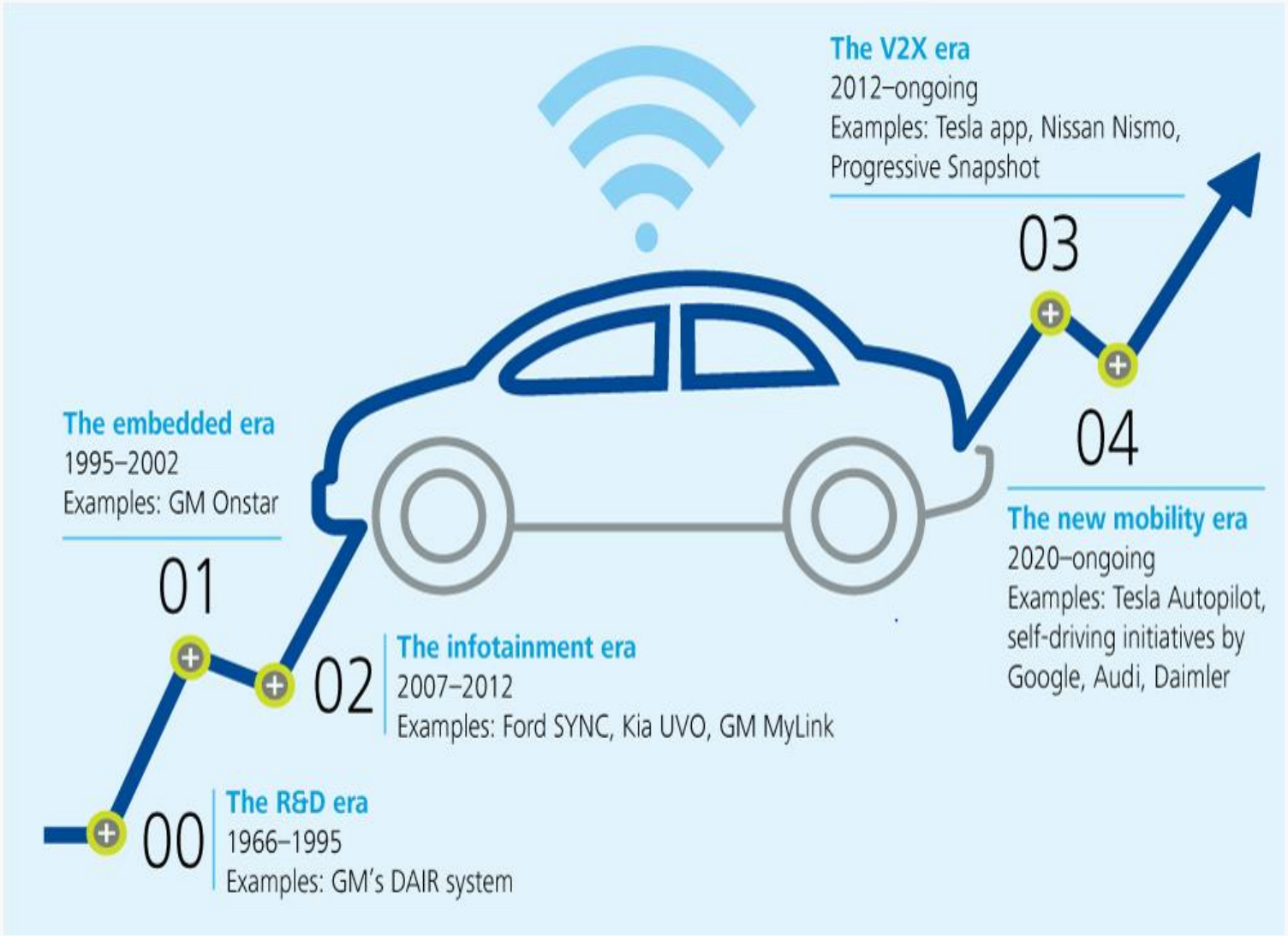
This information is fused with the local sensors and processed to drive the car, autonomously.

**The Autonomous Car IS Connected!**




Source: Gartner

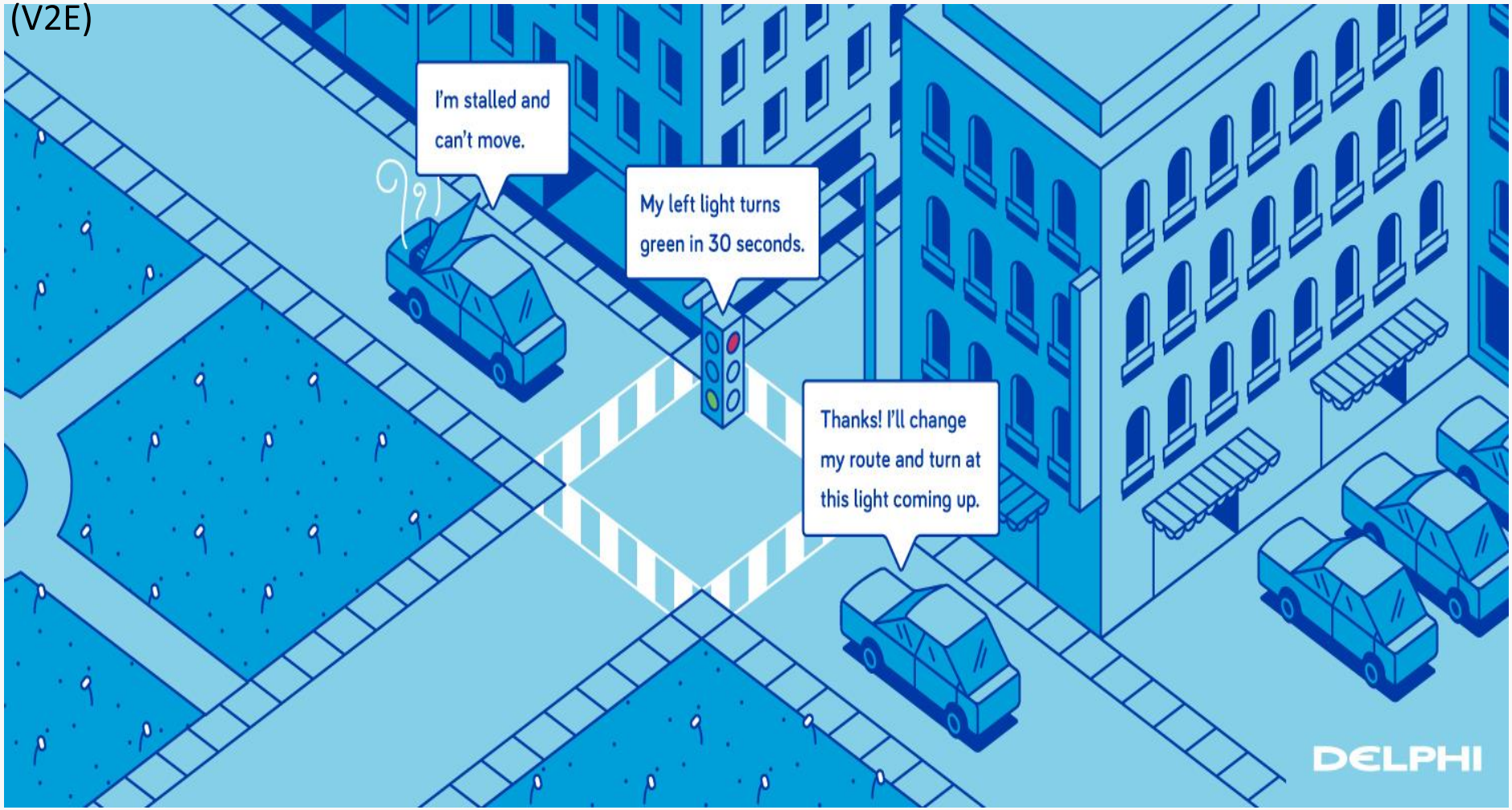
# The Connected Car Evolves…



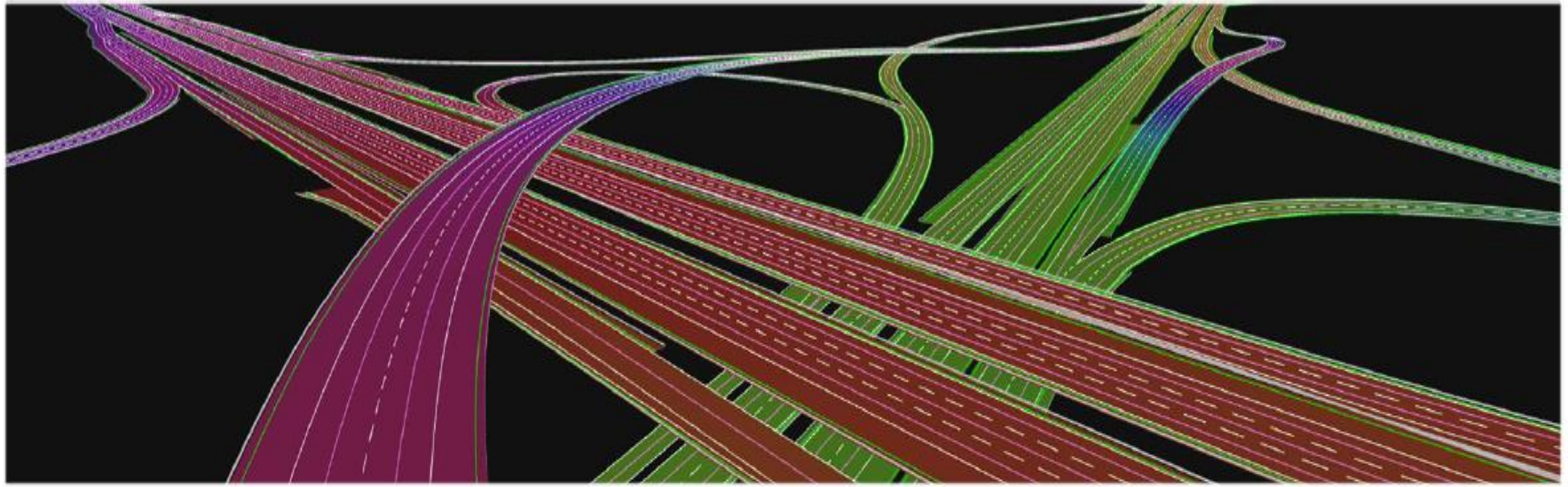

Source: Deloitte University Press

# Cars talking with surrounding infrastructure…

Vehicle-to-Everything (V2E)



# 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

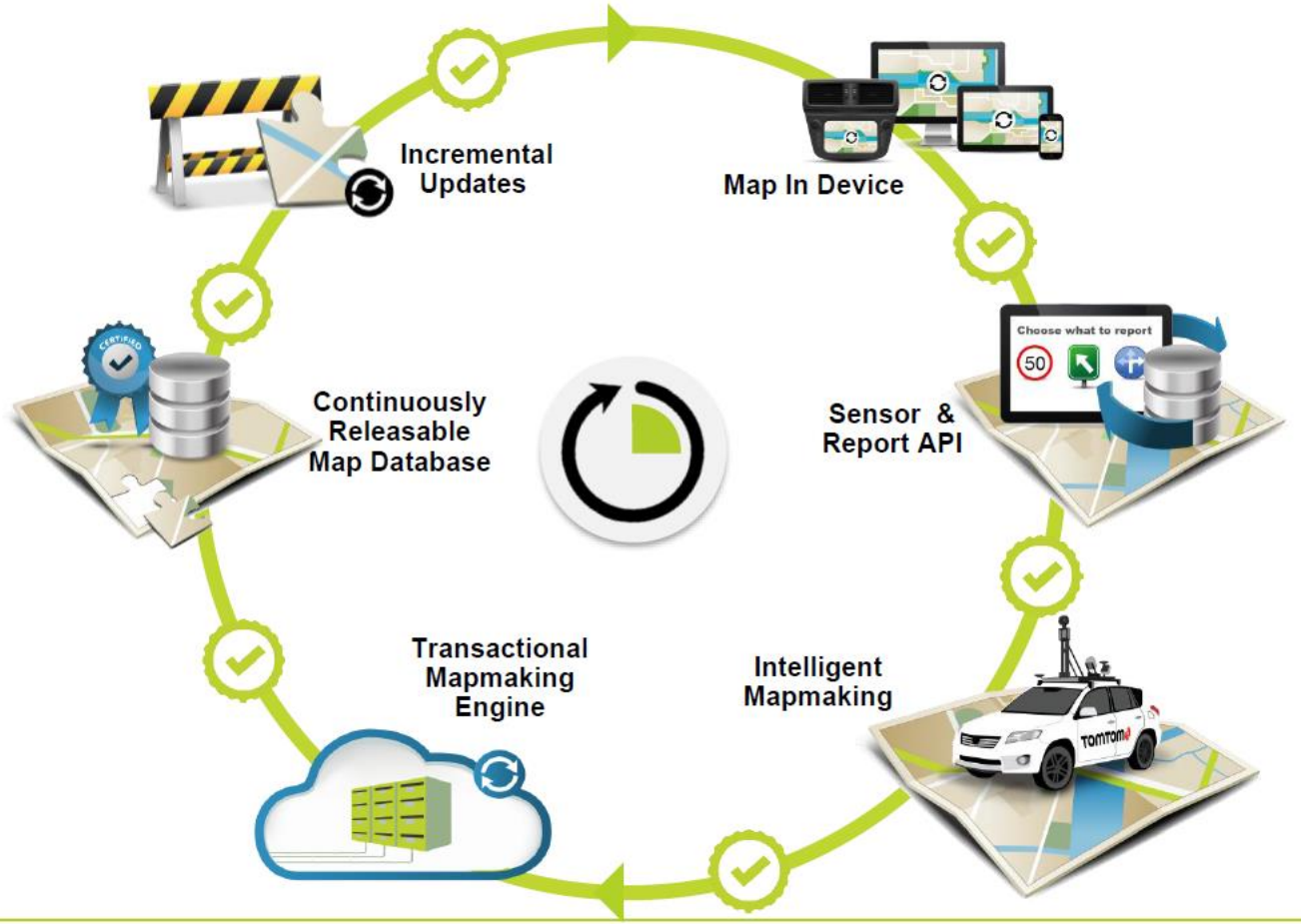
Lane-level attributes

Position Landmarks

RoadDNA

# The Process of Delivering Real-Time Maps

Delivering real-time maps




Quality Assurance



TOMTOM

# Once a Vehicle is Connected, Many More Features Become Available

## Connected Car bonuses

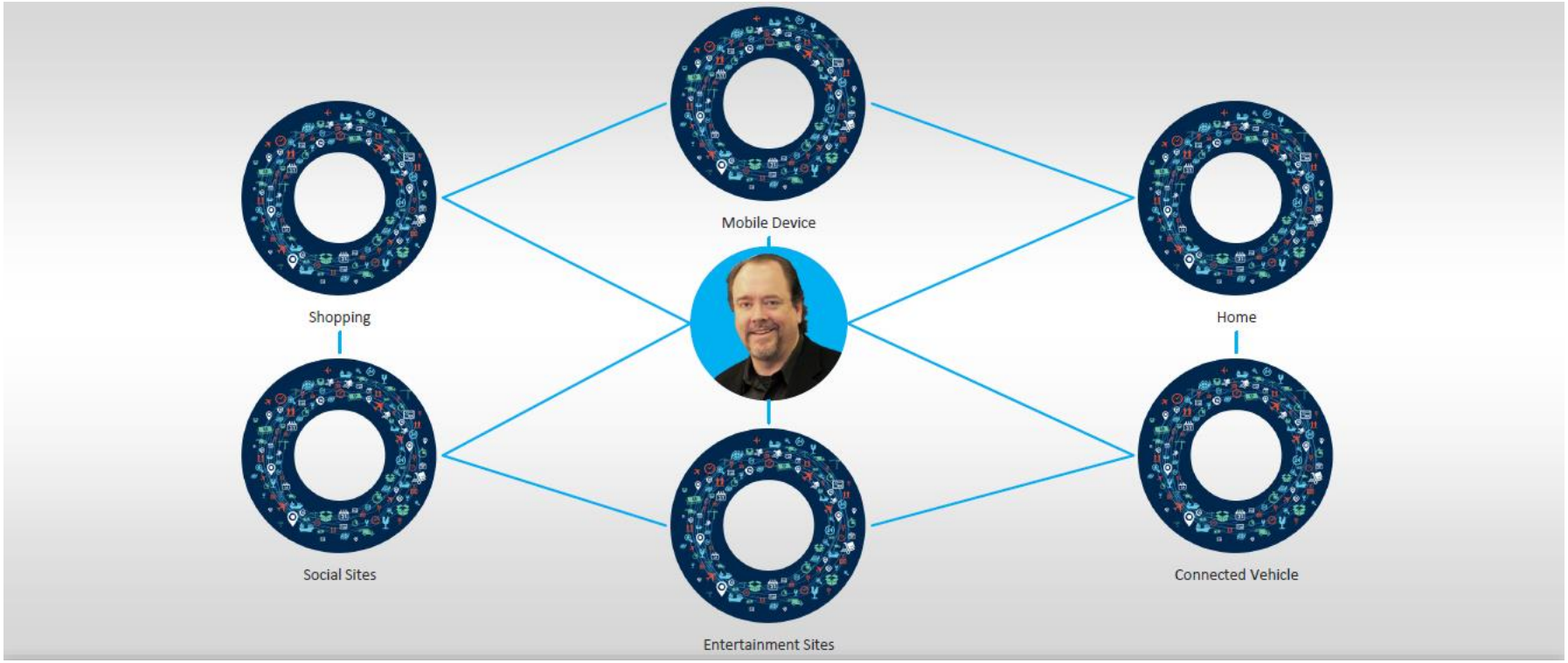
- Communication technologies enables...
  - Connected Car
  - Infotainment
  - Productivity systems
  - Traditional telematics
    - eCall/bCall/Diagnostics
  - Hands free calling
- Same technologies for many tasks =
  ease of use, integration and cost effectiveness





**Autonomous Car users will demand even more productivity and entertainment as they are free from the task of driving**

# The Vehicle Becomes Integrated with the Web of Everything



# 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 |

# Underneath is the convergence of mobile & auto

## Mobile ecosystem brings key technologies at scale; accelerated rate of innovation

### Automotive

- Investment
- Sensors
- Systems/Expertise
- Applications
- Integration
- Experiences
- Collaboration

**The Connected Car of the Future**

### Mobile

- Cloud
- Secure Connectivity
- Mobility
- Graphics/Image Processing
- SoC
- Technology Blocks
- Scale

# 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

verizon

## Security involves multiple layers

| Governance, Risk and Compliance | Threat Management | Authentication and Privacy | Professional Security Services |
|---|---|---|---|
| **Prepare to Manage Risk** | **Protect the Perimeter** | **Trust the Ecosystem** | **Respond to the Threats** |
|  |  |  |  |
| • Access Governance<br>• Threat Vector Analysis<br>• Penetration Testing<br>• Partner Security Program<br>• PCI Compliance Program | • Security Configuration Management<br>• Vulnerability Scanning<br>• Application Scanning<br>• Content Scanning<br>• Cloud- assessment | • Data Discovery<br>• M2M Security<br>• Managed Certificate<br>• Application Security<br>• Smart Credentials<br>• SSL Certificates | • Rapid Response Services<br>• Digital Forensics |

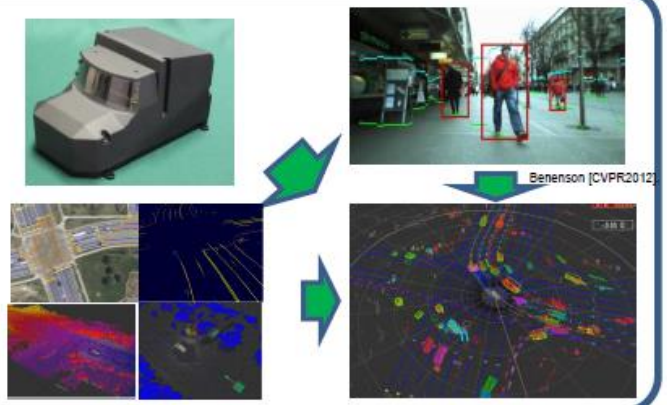
# Toyota's Assessment of Automated Vehicle Technology

## *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

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

CSRC
Collaborative Safety Research Center
TOYOTA

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

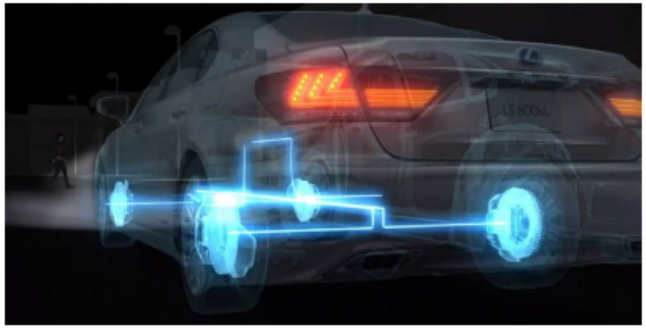
# Toyota's Assessment (Continued)

## *Important Challenges Toward the Goal*

### 3. Vehicle system

Vehicle Dynamics control, System Reliability and ECUs

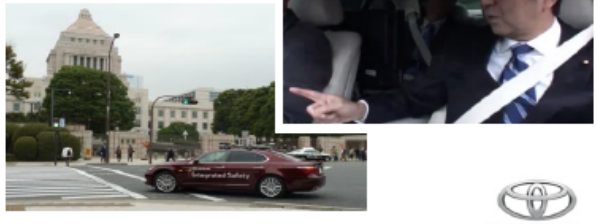
① Advanced vehicle control system
② Highly reliable system design and components
③ Advanced electronics platform (CPU, Communication etc.)
④ Safe Operation System and Cyber Security



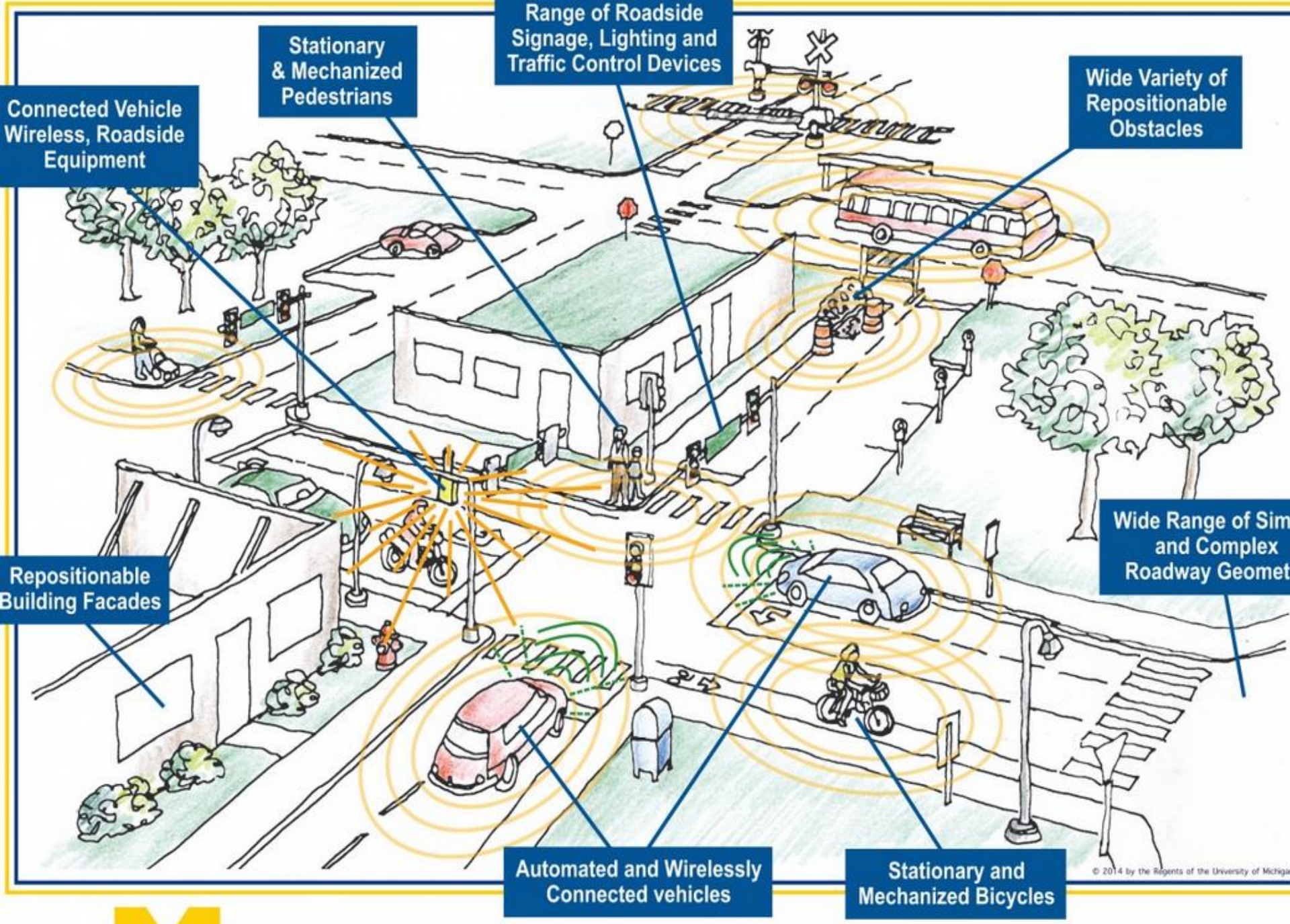
### 4. Social involvements

Need wide discussions with stakeholders

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



TOYOTA | Let's Go Places


Range of Roadside Signage, Lighting and Traffic Control Devices
Stationary & Mechanized Pedestrians
Connected Vehicle Wireless, Roadside Equipment
Wide Variety of Repositionable Obstacles
Wide Range of Sim and Complex Roadway Geomet
Repositionable Building Facades
Automated and Wirelessly Connected vehicles
Stationary and Mechanized Bicycles
© 2014 by the Regents of the University of Michiga

# Summary of Major Advantages

- Fewer traffic collisions
- Increased roadway capacity and reduced congestion
- Relief for occupants from driving and navigation
- Removal of constraints on occupants' state or handicaps
- Lighter more fuel efficient vehicles
- Reduced insurance costs
- Higher speed limits
- Increased productivity

# Summary of Major Concerns

- Assignment of liability for errors
- Resistance to loss of vehicle control
- Hardware function in bad weather
- Software decision protocols
- Software reliability
- Cybersecurity
- Loss of privacy
- Managing the transition from automated control to driver control

# Typical Technician Skills Required in the Field of Automated Vehicles

- Basic automotive and prototype shop knowledge (teardown vehicles, build harnesses, basic fabrication skills, troubleshoot auto systems without manuals)
- Electronics skills (ECMs, sensors and sensor fusion, antennas, CAN and cable protocols, displays, soldering, shielding, troubleshooting)
- Software Skills (embedded systems, basic programming, networks, security systems, user interfaces)
- Understanding of Communication protocols (Satellite, LTE/cellular, WiFi, DSRC, Bluetooth)
- Lab testing, data acquisition and analysis

# Stay Connected with the CAAT

- Visit our website at www.autocaat.org
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- Follow us on social media
- Contact us with your seed funding project ideas!
  - Connected/Automated Vehicles
  - Lightweighting
  - Testing
  - http://autocaat.org/Educators/Seed_Funding/

CAAT Tracks

Center for Advanced Automotive Technology

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August 2015

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Featured Information

What's New on the CAAT website?

The CAAT is pleased to announce that our FREE Resource Library now offers users the ability to provide a rating and review for all resource library items!

If you haven't yet visited the FREE CAAT Resource Library, we encourage you to check it out today. If you provide us with an email address (optional) when downloading a resource, you will receive an email from us about a week later inviting you to share your thoughts about the resource with us by providing a rating and

Register Now for the CAAT's Next Webinar: The Technology of Automated & Connected Vehicles!

Self-driving vehicles? Are they for real in our lifetimes?

Please join the Center for Advanced Automotive Technology (CAAT) of Macomb Community College for a webinar on August 26, 2015, entitled "The Technology of Connected, Automated, and Self-Driving Vehicles." Many of the technologies required to enable automobiles to be self-driving and connected in multiple ways to other vehicles, the cloud, and roadside infrastructure, are already here, and will become even more complex and advanced in coming years. What will this mean for the education and preparation of the technicians who will be needed to develop, build, and service these technically advanced vehicles?

The webinar will lay out the basic definitions and concepts needed

# Thank You!

Questions?