Connected, Automated, and Intelligent Vehicles

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10-4-18

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B. S. Chemistry	Miami University (Ohio)
Ph.D. Physical Chemistry	Pennsylvania State University
Research Scientist	General Motors R&D Center
Macomb Community College	Adjunct Instructor
CAAT	Assistant Director, Energy and Automotive Technology

My background includes conducting research on the chemistry of photochemical smog formation, vehicle emissions, foundry emissions, airbag emissions, hydrogen production and storage, renewable hydrogen production, and battery charging using solar energy. I have published approximately 60 technical papers, have 17 patents, and recently wrote a book chapter on electrolytic hydrogen.

The Center for Advanced Automotive Technology (CAAT)

- Located at Macomb Community College, South Campus in Warren, MI
- Mission
  - Develop and disseminate advanced automotive technology curricula
    - Connected, automated , intelligent vehicles
    - Light-weight materials for vehicles
    - Electric and hybrid vehicles and alternative fuels
      - www.autocaat.org
  - Provide outreach activities to middle and high school students (STEAM)

Seed Funding Courses Fit in Three General Areas of Emerging Automotive Technologies

	Institution	Hybrid or Electric Vehicles	Light Weighting	Connected Automated Vehicles	Completion Date
1	Lawrence Technological University	X			2011
2	Lewis and Clark CC	X			2011
3	Grand Rapids CC	X			2012
4	Lansing CC	X			2012
5	Grand Valley State University & Muskegon Community College	X			2013
6	Ivy Tech CC	X			2014
7	Kent Intermediate School District	STEM			2014
8	Utica Community Schools	STEM			2014
9	Wayne State University	X			2015
10	University of Alabama at Birmingham	X			2015
11	Jackson State University			X	2016
12	Kettering University		X		2016
13	Roane State Community College		X		2017
14	Kettering University		X		2016
15	Springfield Technical Community College			X	2017
16	Kettering University		X		2016
17	University of Alabama Birmingham			Exp. Test	2017

Hypothetical ASE Test Question

A vehicle comes into the repair shop with no driver. Technician A says this is normal for an intelligent vehicle and the correct procedure is to get into the car and ask, “what can I do for you”. Technician B says call the police and have them find the driver. Who is right?

A. Technician A
B. Technician B
C. Both Technician A and B
D. Neither Technician A or B

Today’s Main Questions

1. Why the interest in autonomous vehicles?
2. How does the technology work?
3. What are the remaining challenges?
4. How does this affect automotive technician education?

1. Why the Interest?
Answer: Safety and Convenience

- Safety – Traffic Deaths are Increasing
  - 40,000 deaths per year in U.S. -- like a 747 crashing every week
  - Advanced Driver Assistance Systems (ADAS) can help
    - Automatic Emergency Braking (AEB) and Forward Collision Warning (FCW) voluntary standard by 2022

- Convenience
  - ADAS (i.e. backup camera, adaptive cruise control)
  - Automation ultimately leading to the driver riding shotgun

There is a competitive advantage to offering the most advanced technology

The Impact of Car Crashes on the Economy beyond 40,000 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

National Highway Traffic Safety Administration (NHTSA)

https://www.nhtsa.gov/technology-innovation/automated-vehicles

2. How Does It Work?

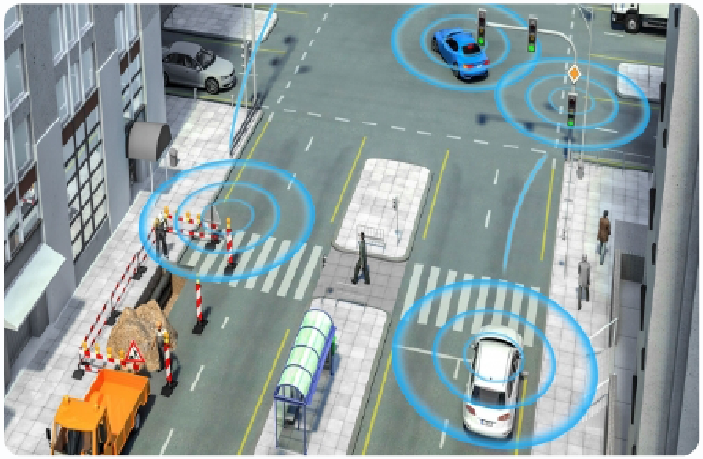
- Sensors, positioning information, and communication = perception data

- Computers using algorithms crunch the data = processing and data fusion

- Actuators, relays, solenoids are commanded by the computer = actions

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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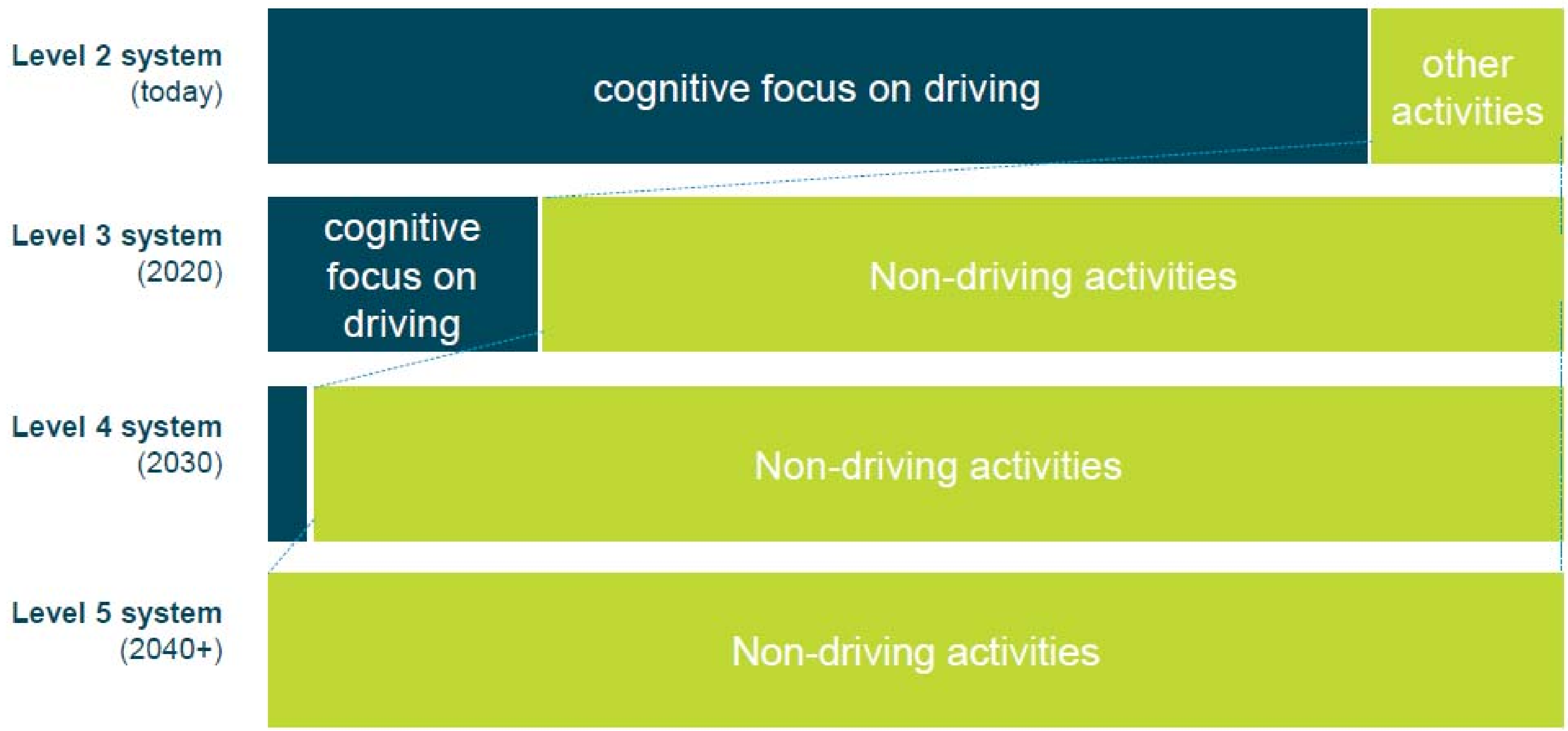
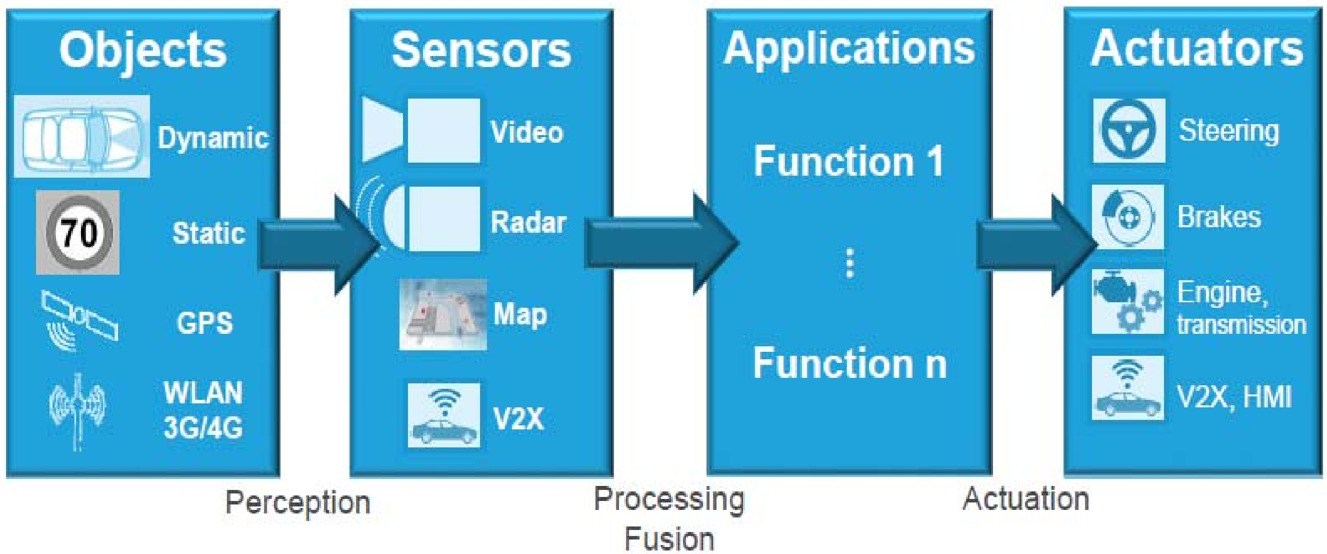
There are Six Levels of Automation

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





Objects
Dynamic
70
Static
GPS
WLAN
3G/4G
Sensors
Video
Radar
Map
V2X
Applications
Function 1
⋮
Function n
Actuators
Steering
Brakes
Engine, transmission
V2X, HMI
Perception
Processing
Fusion
Actuation

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

WHAT IT LOOKS LIKE TODAY

Safety

FCW: Forward Collision Warning
AEB: Advanced Emergency Braking
LDW: Lane Departure Warning
LKA: Lane Keeping Assistant
BSD: Blind Spot Assist
CTA: Cross-Traffic Assist
PD: Pedestrian Detection
CD: Cyclist Detection
MD: Motorcyclist Detection
AD: Animal Detection

Comfort

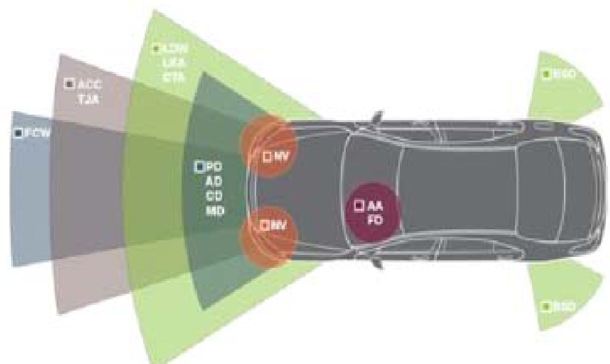
ACC: Adaptive Cruise Control
TJA: Traffic Jam Assist
RSR: Road Sign Recognition
ISA: Intelligent Speed Assistance
AP: Active Parking
HBA: High Beam Assist
AH: Adaptive Headlights

Driver Monitoring

FD: Fatigue Detection
AA: Attention Assist

Vision

NV: Night Vision
360° / RV: Surround / Rear View Cameras



AN INTEL COMPANY

Where are we right now with respect to the six levels of automation?

- Level 1 and 2 are ADAS -- “assist” technology
- ADAS level 2 “assist” technology
  - Tesla Autopilot (2014 Model S)
  - Cadillac Super Cruise (2018 Cadillac CT6)
  - Nissan ProPilot (2018 Leaf)
- Driver is responsible for being engaged (certainly not in the back seat!)
- No Level 3 systems yet on the market but Level 3 and beyond is being tested
  - Musk: 2016 Tesla’s are hardware equipped for level 5 (but not software)

Hands-Free for 700 Miles

Automotive Engineering, November 2017

Hyundai self-driven fuel-cell electric vehicles hit milestone

Hyundai's next-generation fuel cell electric vehicles completed a self-driven 190-km journey.

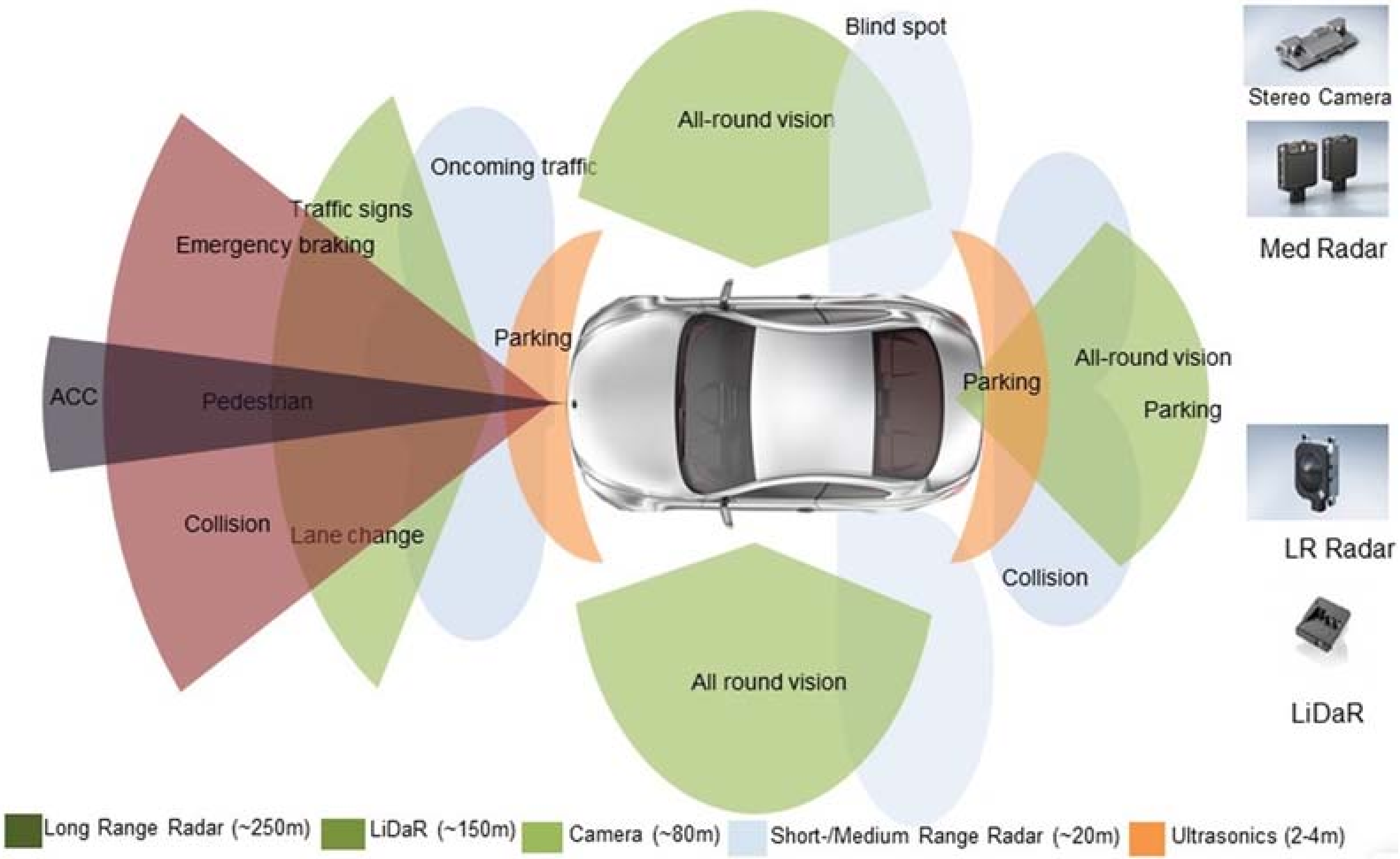
Source: Autonomous Vehicle Technology magazine, March 2018

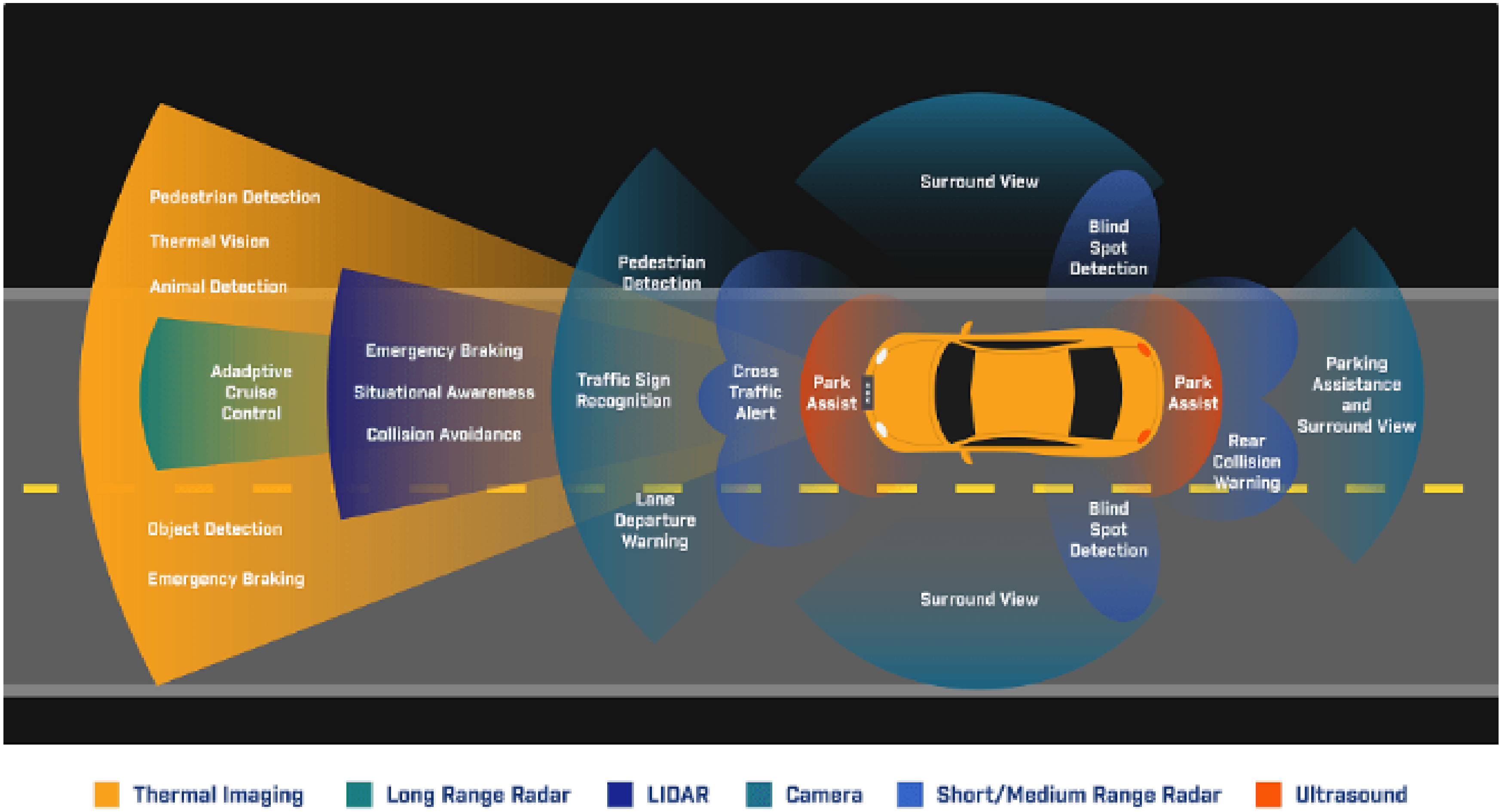
Comparison of Tesla Autopilot and Cadillac Super Cruise

- Autopilot
  - Level 2
  - Hands on
  - Uses “fleet learning”
  - Highway recommended but not enforced
- Super Cruise
  - Level 2
  - Hands off
  - Uses LiDAR maps of highways obtained by Cadillac personnel
  - Highway only
  - No driver response – vehicle controlled stop

Different Sensors Have Different Geometry and Range

F
R
O
N
T





Pedestrian Detection
Thermal Vision
Animal Detection
Adadptive Cruise Control
Emergency Braking
Situational Awareness
Collision Avoidance
Object Detection
Emergency Braking
Pedestrian Detection
Traffic Sign Recognition
Lane Departure Warning
Cross Traffic Alert
Park Assist
Surround View
Blind Spot Detection
Park Assist
Blind Spot Detection
Surround View
Rear Collision Warning
Parking Assistance and Surround View
Thermal Imaging
Long Range Radar
LIDAR
Camera
Short/Medium Range Radar
Ultrasound

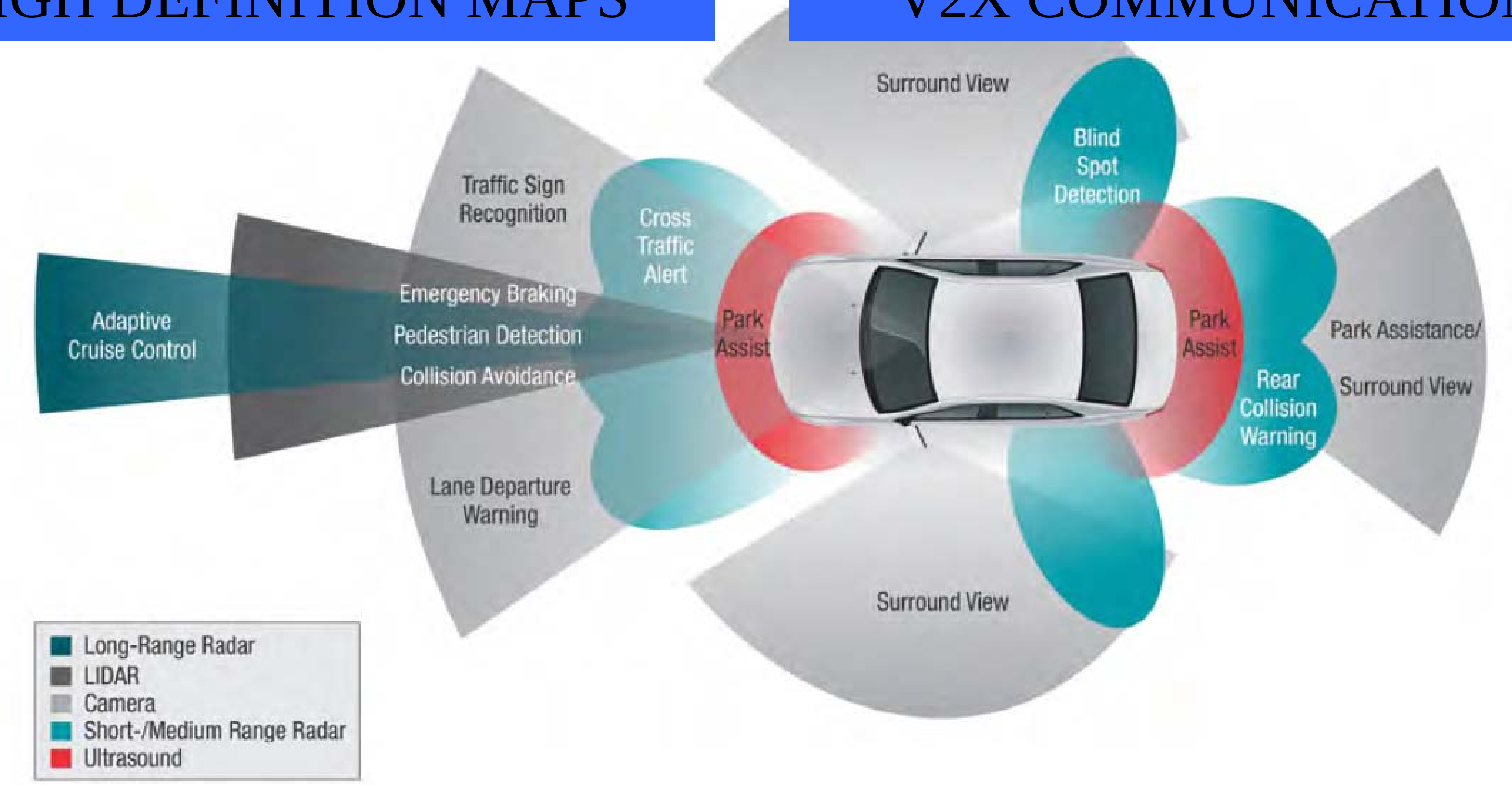
Sensor Characteristics

- Camera
  - Visible light comes into camera, can classify objects, but can’t see in fog/snow/smoke or in the dark
- Radar
  - Radio waves are sent out, reflected and received
  - Knows location and speed of object, but not what it is
  - Works in fog/snow/smoke
- LiDAR
  - IR (invisible) pulses sent out, reflected, and received
  - Will not work in fog/snow/smoke but works in the dark

Automated Driving:
Enabling and *Supporting* Technology

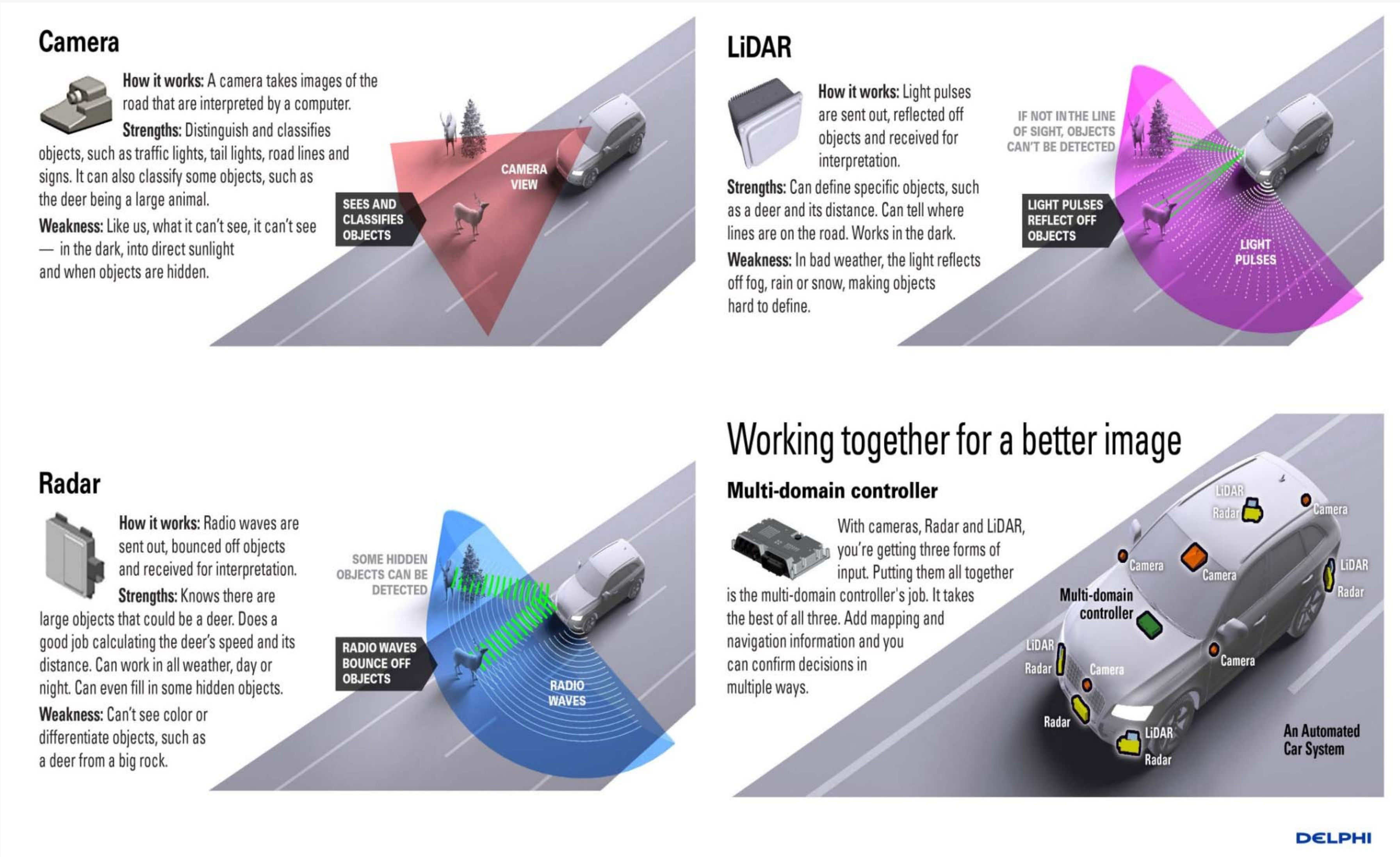
HIGH DEFINITION MAPS

V2X COMMUNICATIONS



Source: Texas Instruments ADAS Solutions Guide

Camera/Radar/Lidar Operation and Sensor Fusion

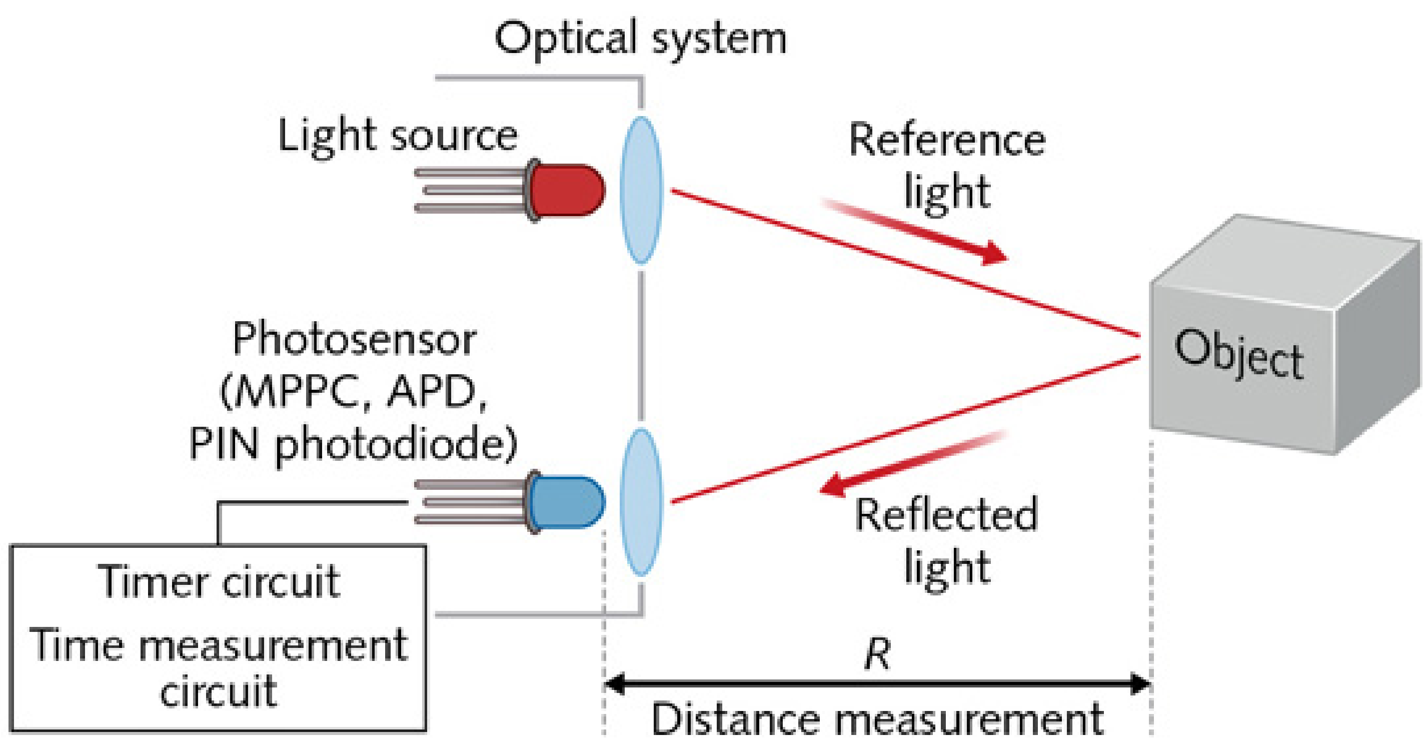


Competing Sensor Technologies using Time of Flight to Determine Distance to an Object

- Sonar
  - Ultrasonic, >40 kHz
- Radar
  - Radio waves (24 GHz, 77-82 GHz)
  - 2 meter resolution at 100 meters
- LIDAR
  - Infrared (905 nm, 1550 nm)
  - 4 cm resolution at 100 meters

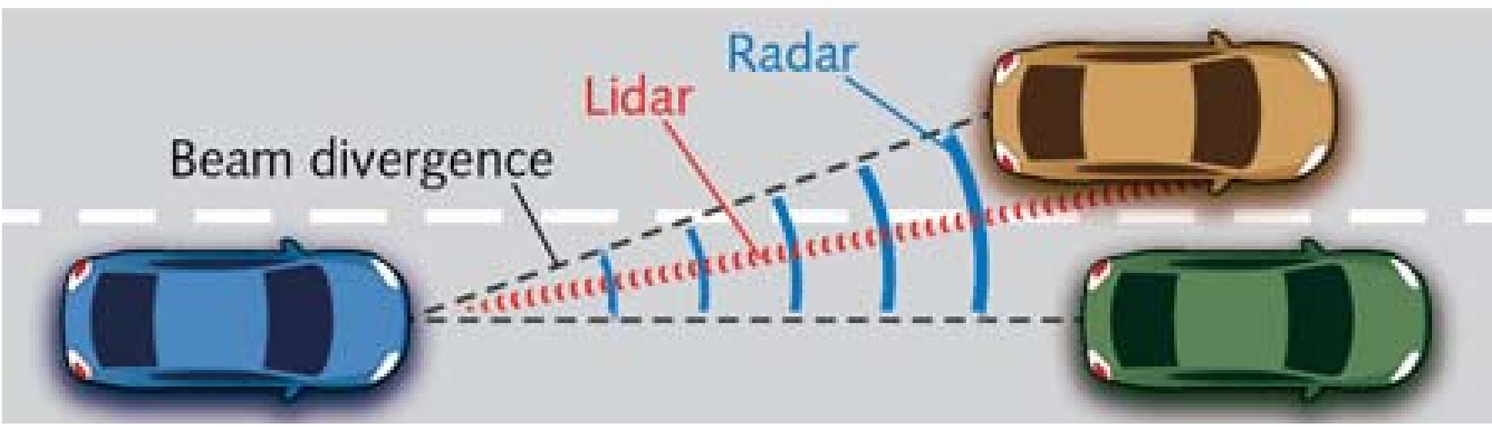
Time-of-flight (ToF) LIDAR

Reference and Reflected Light Pulses are Used to Compute Distance to an Object



Source: LIDAR: A photonics guide to the autonomous vehicle market, *by Slawomir Piatek and Jake Li,* **Hamamatsu**

Beam Divergence is Less for LIDAR than for Radar



Source: LIDAR: A photonics guide to the autonomous vehicle market, *by Slawomir Piatek and Jake Li,* **Hamamatsu**

Why Sensor Fusion ?

- **Available Information**

  Increasingly rich and complex data…
  …Of very different nature and reliability

  → A variety of sensors provide an autonomous driving system
  with a complete perception of its environment and current driving state

- **What type of knowledge do we want to acquire?**
  - Accurate determination and prediction of vehicle's environment, static and dynamic
  - Precise localization, to use high definition offline maps
  - Information about reliability of parts of a system

- **Sensor fusion already used for years in vehicles systems including ADAS**
  - Engine management, ABS, ESP, etc
  - Combination of individual parking sensors to a full sensor array supporting automated parking functions
  - Use of vehicle speed and yaw data to create functions in smart sensors

Advantages of Redundant Sensor Fusion

- Probability of correct detection and classification
  - 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
- Reliability of systems
  - Adding more sensors increases the reliability of the overall system
  - Mean time to failure of a system with more sensors is increased

The Multi-Domain Controller
A Very Powerful Computer

Sensor Fusion for Automated Driving

- Combine sensor inputs, maps, GPS, V2X communications
  - Where am I, what is around me, where do I want to go?
- Use sensors inputs with algorithms to produce outputs to control steering, braking, power
  - Safely take me forward and tell others what I'm doing

Technology background*

- About 50% of car manufacturing cost is in electronics
- Global data collection from connected cars could rise to 545 petabytes by 2020 up from 345 terabytes in 2013**
- OTA enabled vehicle sales per year will likely rise to 26.7 million in 2020 from 2.6 million in 2014
- Global sales of connected passenger vehicles projected to grow to 77 million units annually by 2022 from about 19 million in 2014 - 73% of vehicles sold will be connected in some way.
- Space shuttle - 500k lines of code
- Boeing 777 - 3-4 million lines of code
- Ford Taurus 2012 - 50+ million lines of code
- Today cars - 100 millions lines of code

** Various forecast sources* *** petabyte=1 million gigabytes, terabyte=1,000 gigabytes)*

Typical Software Applications: Lines of Code

12 million lines of code
Android Operating System

Premium vehicle

24 million lines of code
F-35 fighter jet

44 million lines of code
Microsoft Office 2013

Office
Excel
OneNote
Outlook
Word
PowerPoint
Tech. In Total.

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

61 million lines of code
Facebook

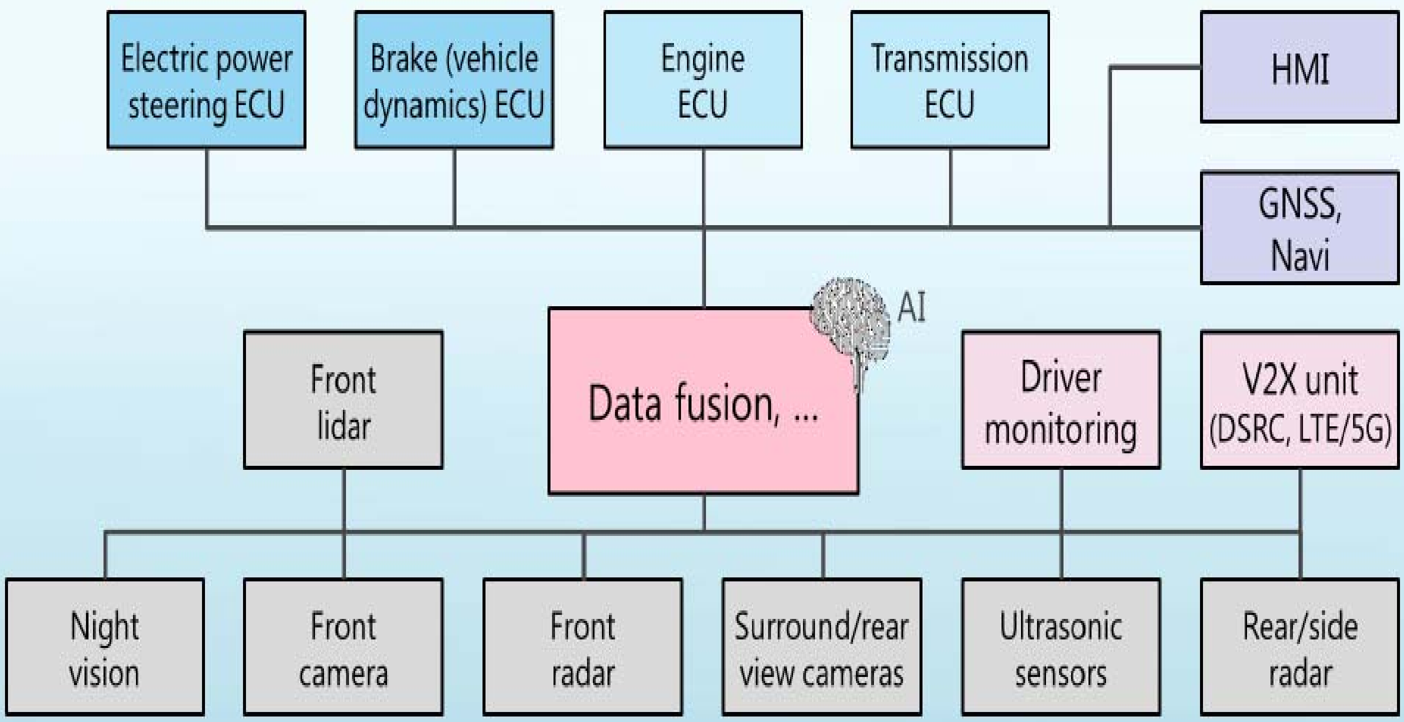
facebook

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

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).

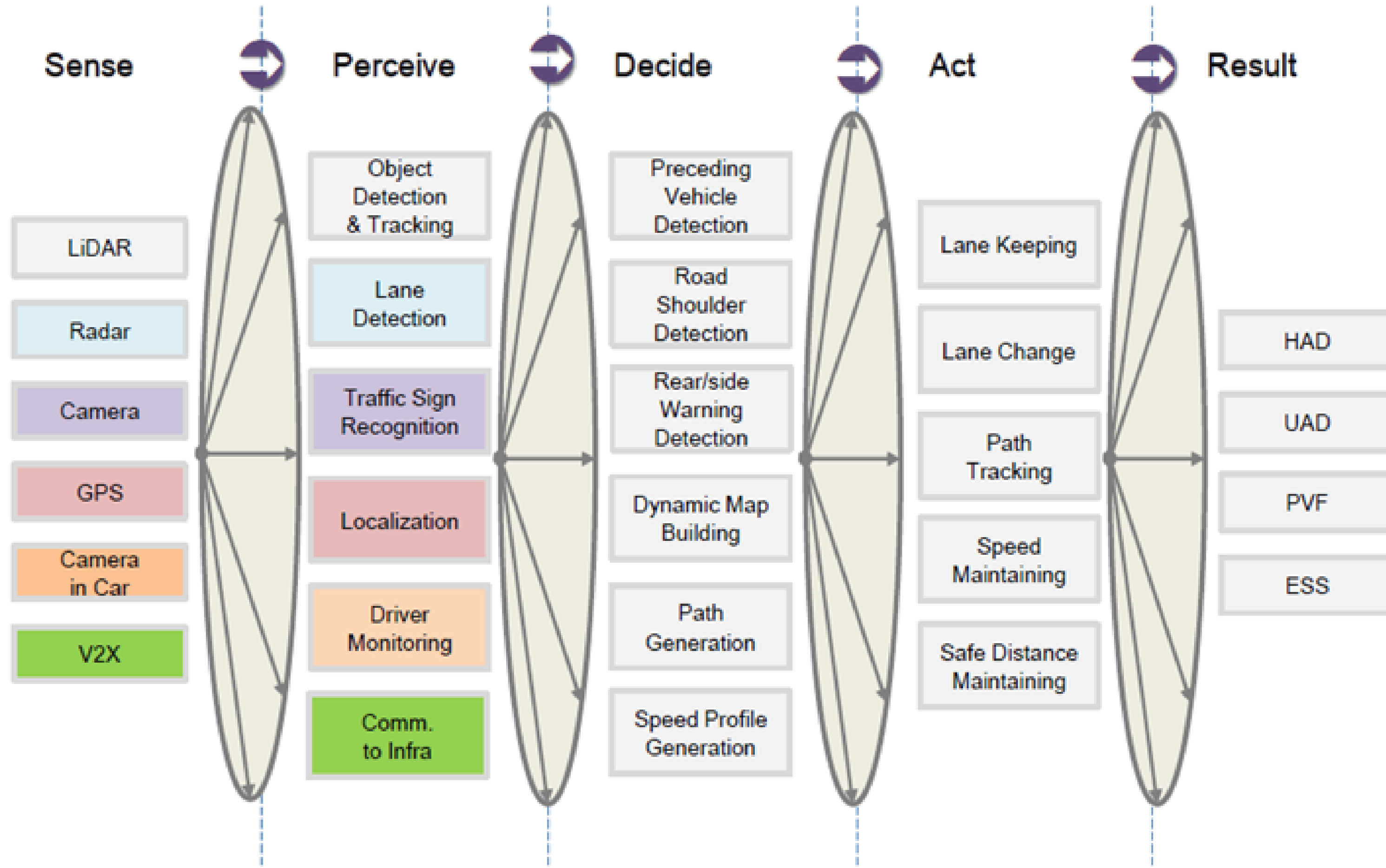


Larry Burns, Babcock Ranch talk, June 2016

“This is an animation of how it works. First they take a very detailed digital map of three dimensions … They categorize everything that’s moving. They put sensors on the car, a laser on the roof, radars on each corner and a camera. And then they take all of that data from the sensors, bounce it against the map as a reference, and they make the exact same two decisions you’re making when you’re driving: You’re making them over and over again: How fast should I go and which way should I steer? That’s it, so you might ask, ‘Why Google?’ Well this is about speed to insight. A massive amount of information is coming in and then the insight is how fast should I go and which way should I steer. What’s Google do for a living? Search. It’s all about speed to insight so this is right smack in the middle of Google’s sweet spot of what they’re capable of doing. It’s very sophisticated analytics, large databases, deep artificial intelligence, simulation models and then 1.5 million miles (that Google driverless cars have already gone). They have discovered pretty much everything they have needed to discover and solve that challenge using computer algorithms. So it’s not a fairy tale. I ride in their cars. The last ride I had I was in Mountain View, Calif. I rode for an hour in the middle of the day. Mountain View is a very busy community and I never had to take control of the car. So that’s how close we are. So now if a car can drive itself you can start to think about tailoring the design of the car.”

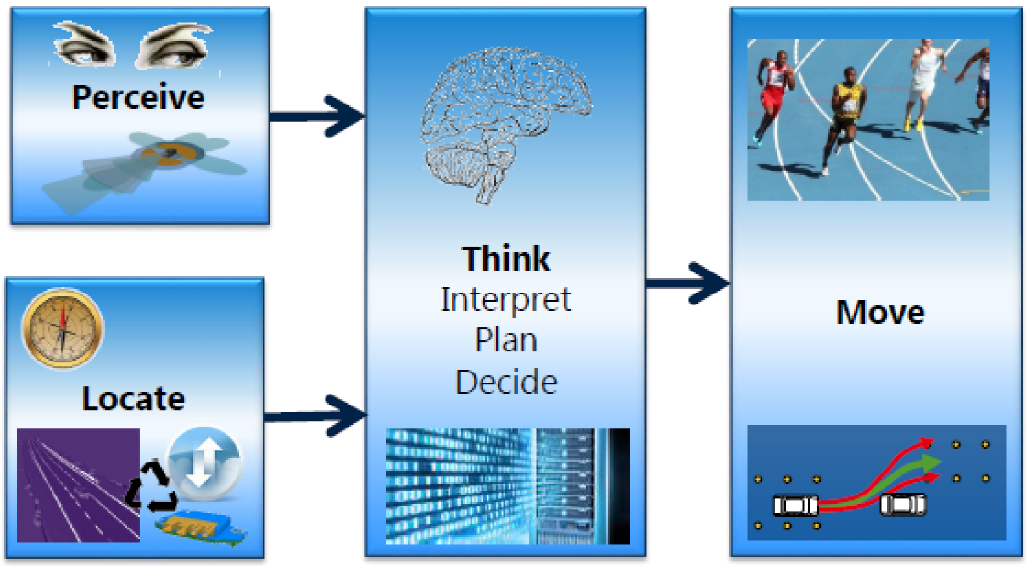
https://www.babcockranchtelegraph.com/articles/what-is-the-future-of-the-car-larry-burns-explains/

System Flow

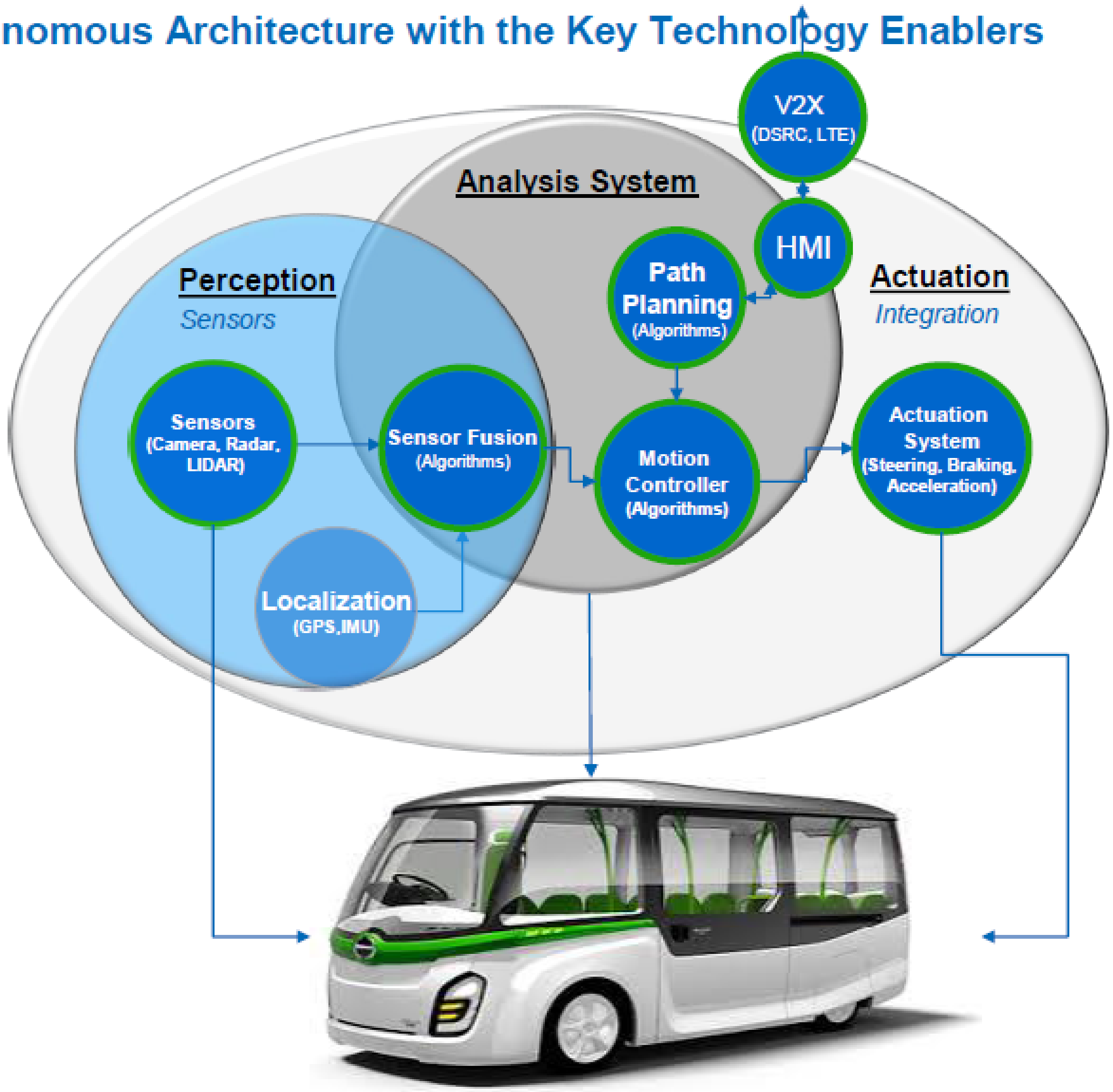


The Power to Surprise

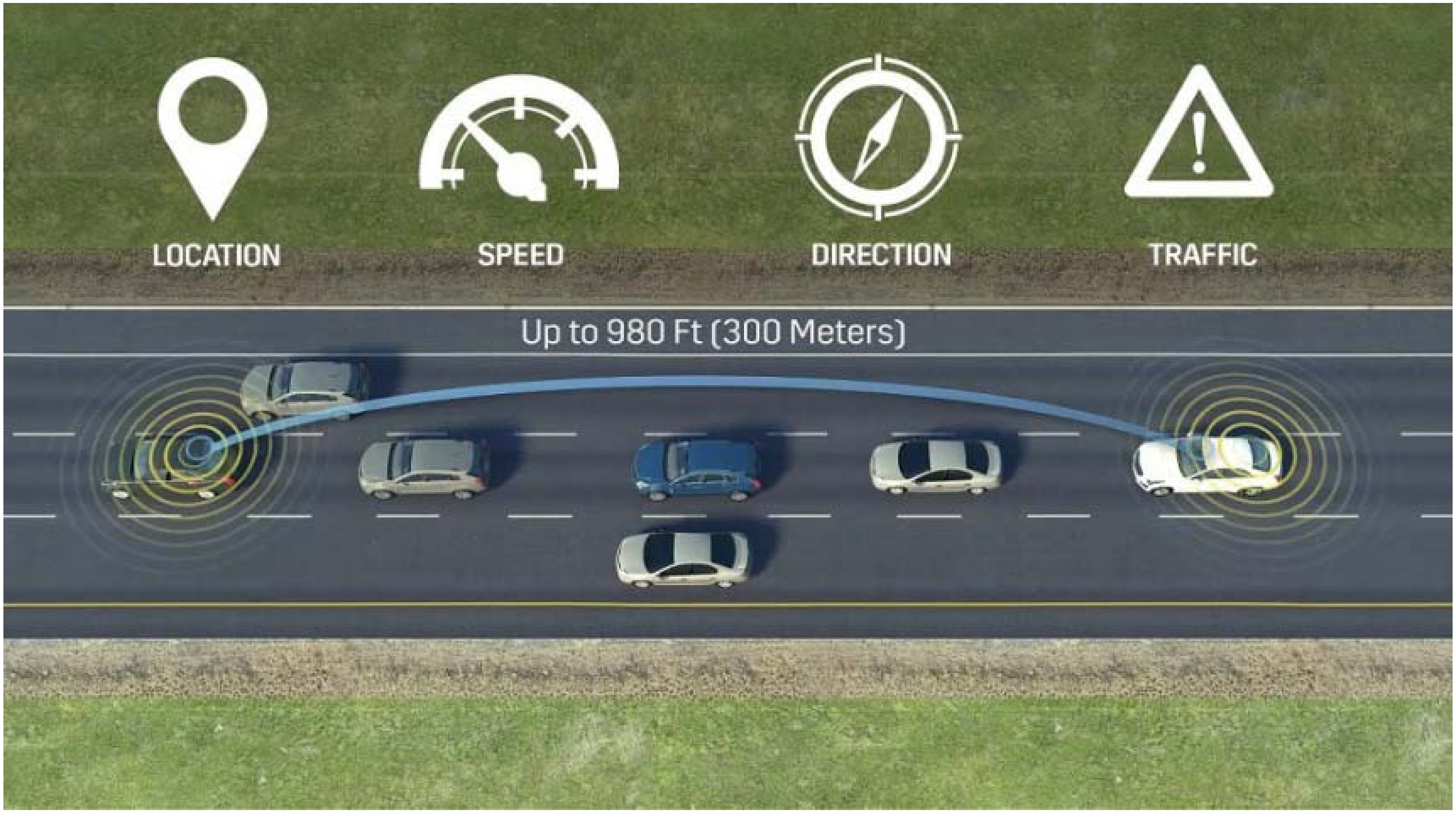
2017 CAR MBS
Effort to mirror the human ability to reason and decide



The Autonomous Architecture with the Key Technology Enablers



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

V2V/DSRC/5.9 GHz Safety Spectrum

- ITS America strongly urges the Federal government to protect the 5.9 GHz safety spectrum band that was allocated by the FCC for development of Dedicated Short Range Communications (DSRC)-enabled vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) technology.
- NHTSA, which proposed V2V standards last year, estimates DSRC potentially could reduce 80% of unimpaired crash scenarios, saving thousands of lives per year.
- DSRC-enabled vehicles effectively can "see" around corners and achieve greater 360-degree situational awareness to inform/warn a driver of an impending crash.
- ITS America is neutral on technology but not neutral on safety. DSRC is the only technology that exists today that has been tested and proven to support safety critical vehicle applications.

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V2X Systems – What is X?

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

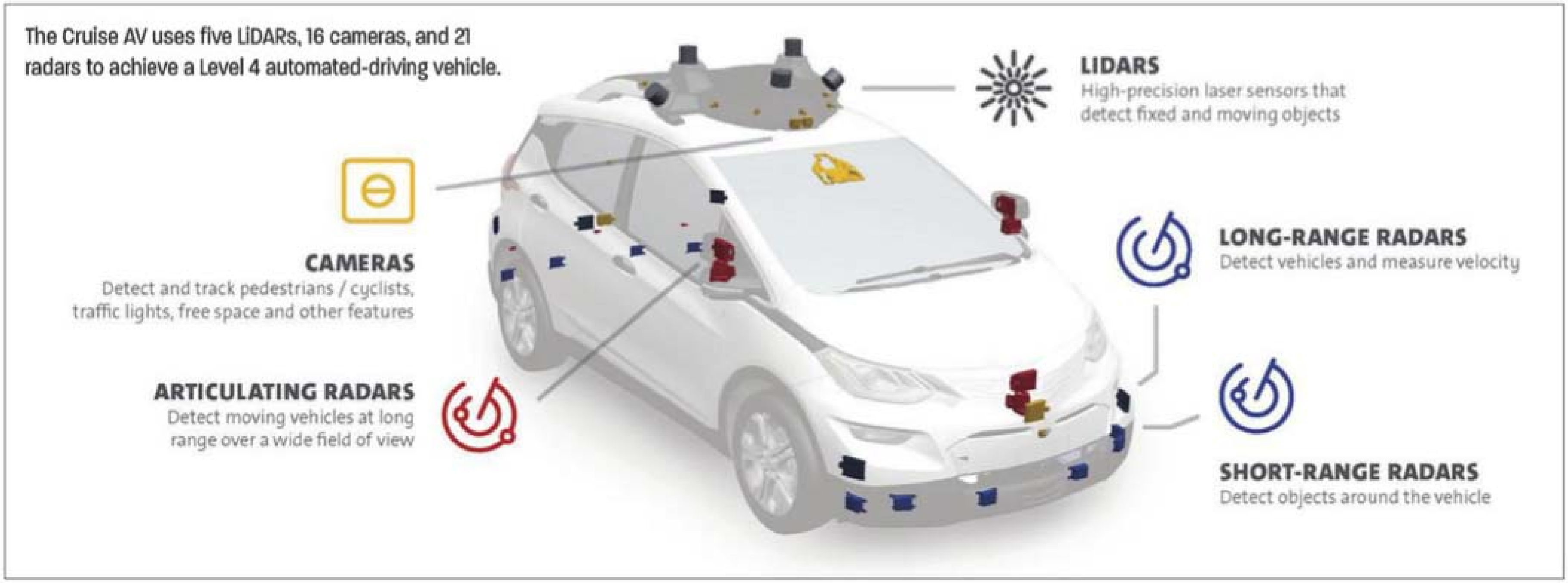
This information is fused with the local sensors and processed to drive the car, autonomously.

The Autonomous Car IS Connected!

Development and Testing of 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

Cruise-GM: Test Vehicles from the Factory



Developing Automated Vehicles

- Simulation
  - dSpace
  - ANSYS
  - rFpro
- Test course
  - M-City
  - ACM
  - Nine other DOT sites, like ACM
- On-road testing
  - Congress (House and Senate)
  - DOT, NHTSA
  - MI Public Act 335 and many others

2018 CAAT Conference
"Testing Tomorrow's Vehicles Today"

April 20, 2018

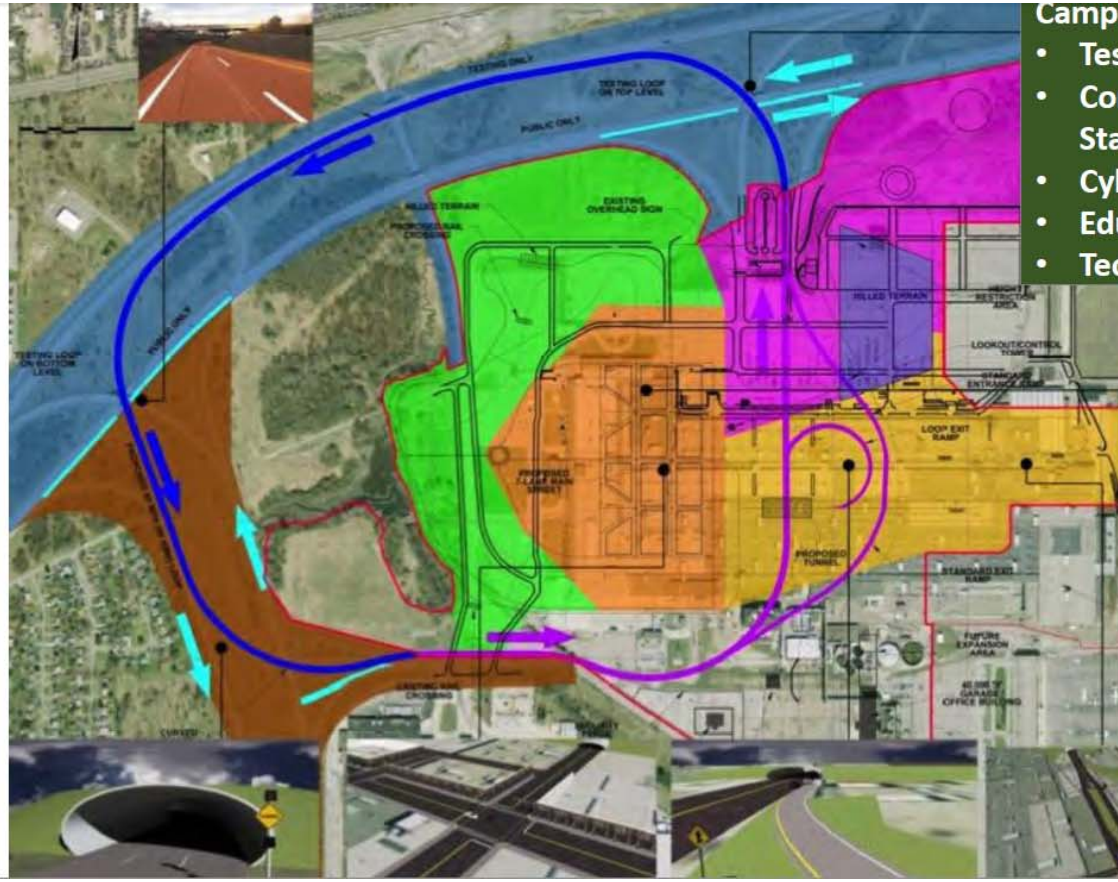
- **Keynote Speaker, Carla Bailo, Center for Automotive Research (CAR)**
  - The Future of Mobility
- **Featured Speakers**
  - **Mark Chaput, American Center for Mobility (ACM)**
    - Testing Autonomous Vehicles
  - **Jace Allen, dSpace Inc.**
    - Autonomous Automation: How Do We Get to a Million Miles of Testing
  - **Michele Economou Ureste, Workforce Intelligence Network (WIN)**
    - Impact on the Workforce
  - **Robert Feldmaier, Center for Advanced Automotive Technology (CAAT)**
    - STEM Activities in Southeast Michigan

Slides are available at:
http://autocaat.org/webforms/ResourceDetail.aspx?id=4949

American Center for Mobility

Phase 1 Highway Environment:

- 2.4 mile loop
- Re-use of west bound US12
- 65-70mph
- On and off-ramps
- Triple overpasses
- 2/3/4/5 lanes
- 700’ tunnel on bend



Campus-Operations:

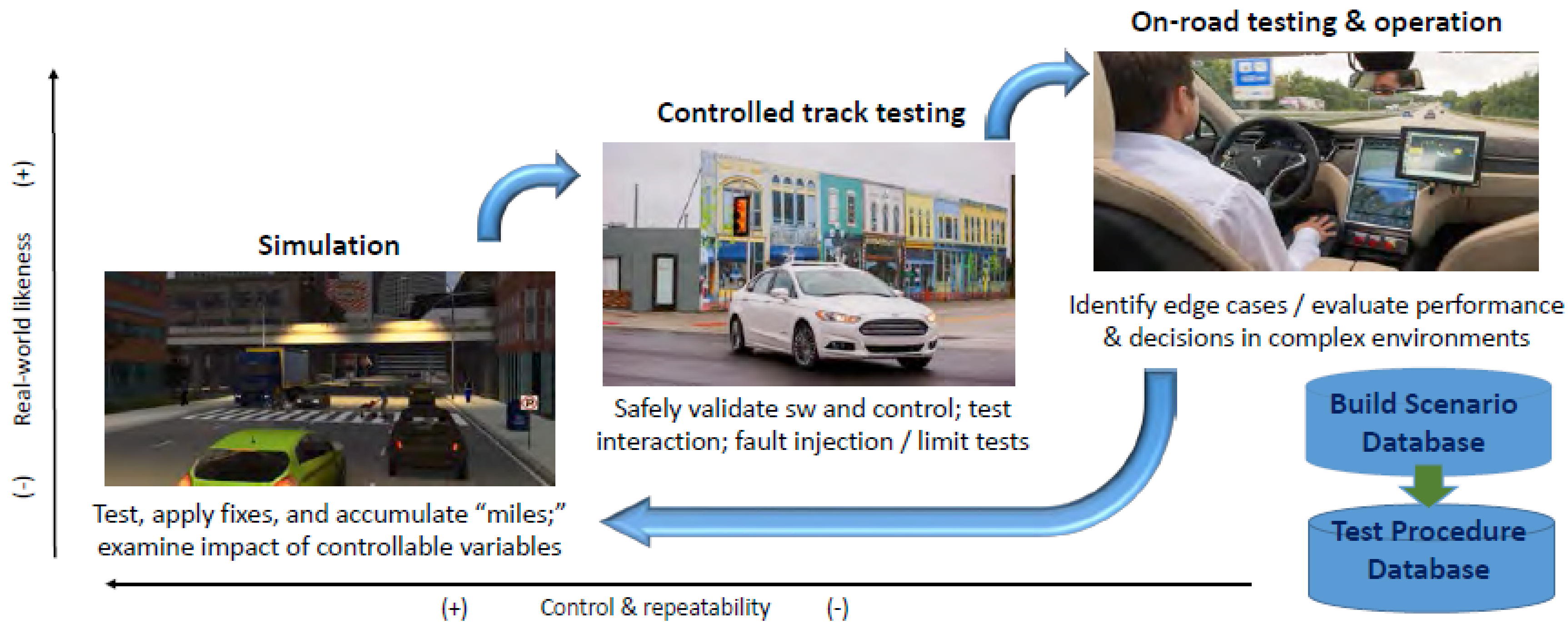
- Testing Support
- Convening for Standards
- Cybersecurity Lab
- Education
- Technology Park

REPRESENTATIVE REAL WORLD CONNECTED AND AUTOMATED VEHICLE TEST ENVIRONMENTS:
- HIGHWAY
- URBAN
- RURAL
- OFF-ROAD
- COMMERCIAL
- RESIDENTIAL
- CELLULAR
- CYBER

Network:

- DSRC
- 4G LTE
- 5G
- Cloud
- Traffic control

Product development & validation: Structured combination of three methodologies



Need for simulation:
Billions of miles of testing needed for autonomous vehicle safety . . .

Driving to Safety

How Many Miles of Driving Would It Take to Demonstrate Autonomous Vehicle Reliability?

- Autonomous vehicles would have to be driven hundreds of millions of miles and sometimes hundreds of billions of miles to demonstrate their reliability in terms of fatalities and injuries.

TECH

Google's Self-Driving Car Program Odometer Reaches 2 Million Miles

Alphabet Inc.'s car program had nearly 60 self-driving vehicles on roads in four states in August

By TIM HIGGINS

Updated Oct. 5, 2016 3:24 p.m. ET

Akio Toyoda, President of Toyota @ 2016 Paris Auto Show

"It is estimated that some 8.8 billion miles of testing, including simulation, are required"

. . . an impossible task without simulation

Reference: http://www.rand.org/pubs/research_reports/RR1478.html

Reference: http://www.forbes.com/sites/alanohnsman/2016/10/03/toyotas-robot-car-line-in-the-sand-8-8-billion-test-miles-to-ensure-safety/#188f073235b7

Reference: https://www.wsj.com/articles/googles-self-driving-car-program-odometer-reaches-2-million-miles-1475683321

ANSYS

Expected Improvements Resulting from the Development of Connected/Automated Vehicles

- 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

3. What are the remaining challenges?

- Assignment of liability for errors
- Resistance to loss of vehicle control
- Hardware function in bad weather
- Software decision protocols
- Software reliability
- Added electrical load
- Cybersecurity
- Loss of privacy
- Managing the transition from automated control to driver control (re-engagement of the driver)
- Cost
- Technician education

With Connectivity, Data Becomes "Bigger"

OEMs & Dealerships

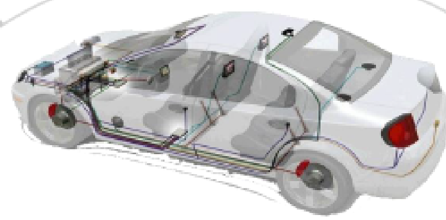
- Vehicle diagnostics, location,
- In-car consumption of services
- Aggregated cross-OEM reference

Insurance Companies

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

Smart Cities

- Real Time traffic flow
- Incident alert
- Parking



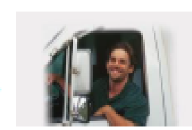
Data Source

- 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 Surroundings Sensors Data Becomes “Bigger”

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

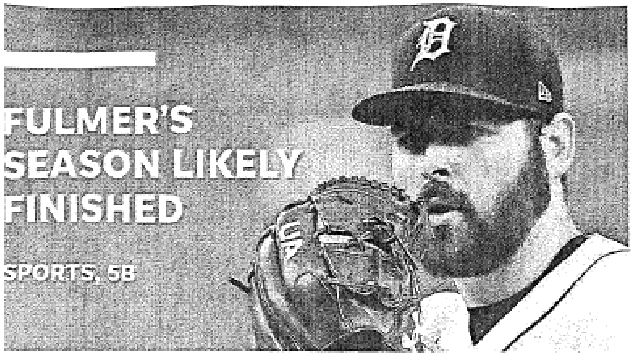
Challenges: Sense

Weather can blind sensors

Challenges: Sense

Challenges: Plan

Challenges: Cost

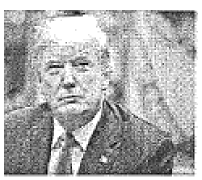


ON GUARD FOR 187 YEARS

Detroit Free Press

TUESDAY, SEPTEMBER 18, 2018 | FREEP.COM

PART OF THE USA TODAY NETWORK



SINESS, 10A

ump ramps trade war

U.S. will impose tariffs 200 billion more of ese imports.

Cost of a fender bender: $34K?

Eric D. Lawrence
Detroit Free Press
USA TODAY NETWORK

Tech in new vehicles means high repair bills

Many new vehicles these days come loaded with all kinds of extras, including safety features that should help you avoid a crash.

Automatic emergency braking, blind-spot detection, forward-collision warning — the list goes on.

Advanced safety features have helped reduce fatalities for those behind the wheel and their passengers, and features that help vehicles avoid pedestrians have the potential to cut into the dramatic increase in pedestrian fatalities in recent years.

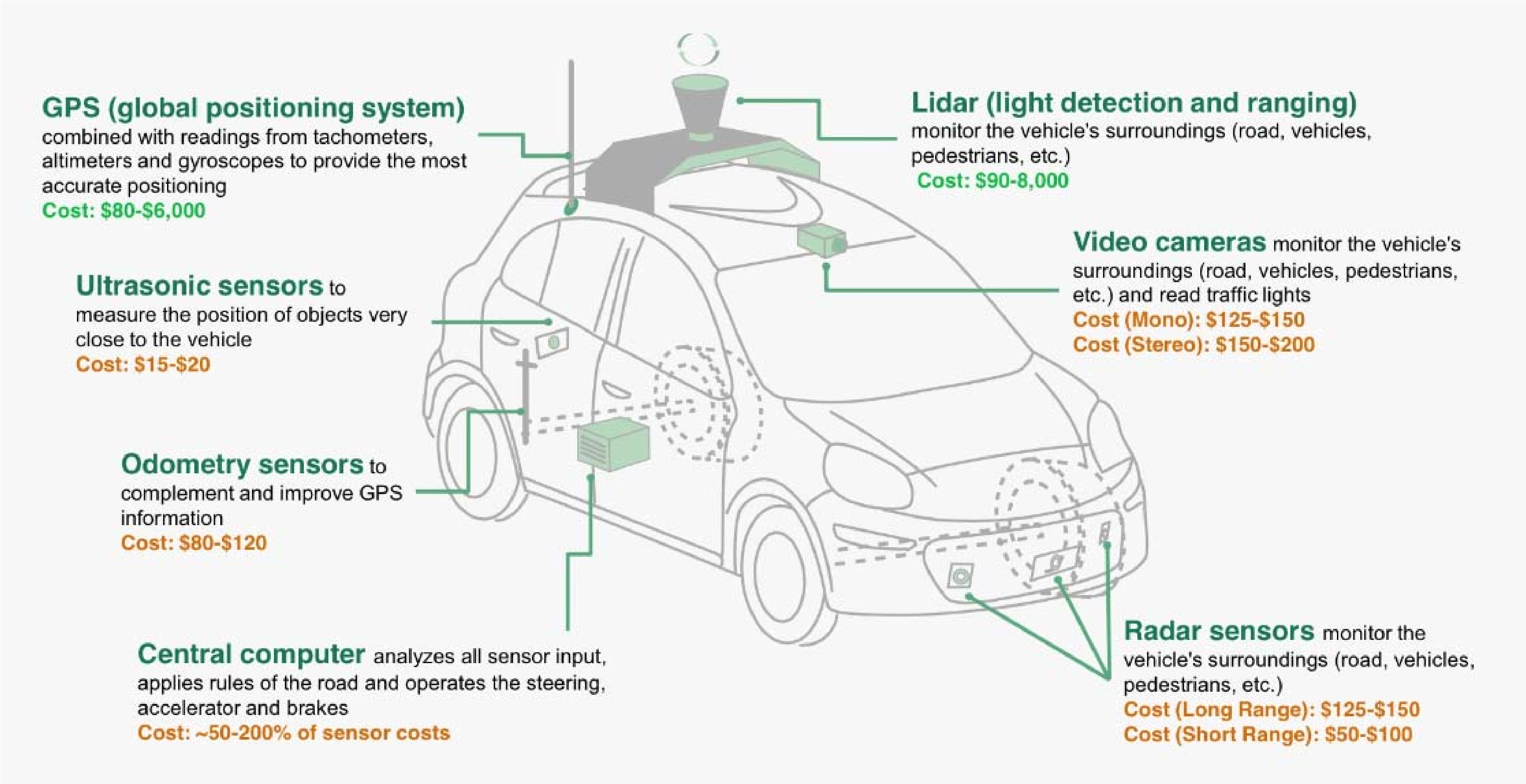
But what happens when these ever-more technologically advanced vehicles crash? Experts say the cost to repair all that technology could be hefty.

John Van Alstyne, CEO and president of I-Car, a nonprofit focused on vehicle repair education, recently provided a jaw-dropping figure during an appearance on Autoline, an industry-focused program, to repair a "left front corner hit" on a Kia K900: $34,000.

"The Kia K900, for example, has a ton of technology around the front and the corners of that vehicle," Van Alstyne told host John McElroy, who sounded, not surprisingly, stunned by the figure to repair a luxury sedan,

See REPAIRS, Page 7A

Challenges: Cost



When

Sooner

- Connected Vehicles
- Coordinated Vehicles
- Shared Vehicles
- Self-Driving Features
- Lower Mass Vehicles
- Significant Hybrid Share
- Platooned Trucks
- Smart Parking Systems
- Real-Time Traffic Control
- Improved Safety

Later

- Internet of "Things"
- Integrated Intermodal System
- Driverless-Shared Fleets
- Driverless Vehicles
- Tailored Vehicles
- Significant Electric Vehicle Share
- Driverless Trucks
- Significantly Less Parking
- Real-Time Situation Awareness
- > 90% Fewer Crashes

Larry Burns, 2015

Will the Challenges be Met and When?

- Larry Burns
  - Yes, possibly by 2018
- Bob Lutz
  - Yes
  - In about 25 years cars drivers will be met with an incredulous “look, that car has a driver” -- like seeing a horse on the road now
  - Cars will be modules with no distinction
- Elon Musk
  - Make Autopilot level 5 in a couple of years (2019)

“Mobility Moonshot”

This nation should commit to achieving the goal, before 2025, of safely enabling the full potential of connected and autonomous vehicles for all people individually and together

Larry Burns, 2015

4. How Does this Affect Education? 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, 5G and LTE/cellular, WiFi, DSRC, Bluetooth)
- Lab testing, data acquisition and analysis

Vehicles are Becoming Computer Controlled Electromechanical Devices

- Technician needs to learn additional skills in addition to mechanical skills
  - Electronic
  - Computer
  - Experimental testing
- Service technicians will work on increasingly complicated semi-autonomous vehicles and autonomous vehicles

Repair Technician Skills

- Associates Degree
- Experience with maintenance & repair
- Experience with standard vehicle communications, e.g., OBDII
- Basic software & electronics skills
- Understand ADAS sensor integration, alignment, and calibration
  - Camera, RADAR, LIDAR (coming)
- Good problem solving skills

Knowledge Gap

What's going on with the workforce?

Employers need talent… | **Workforce needs training…**

2015 CAR Industry Report

* Applicants with the desired skills are hard to find.
80% of respondents have difficulty finding talent in the region.

Higher Education Institutions

* Higher education are challenged to prepare students for jobs that may not even exist yet.

Converging industry

Professionals in the automotive industry may not be trained in mobile technologies. Software and telecommunication carries may not be trained in the business of automotive. Transportation professionals may not be trained in connected technologies. What about interoperability?

1 CAR 2015: http://www.cargroup.org/assets/files/bb/2_kristin_dziczek_am.pdf
2 Higher Education: https://youtu.be/uqZiIO0YI7Y

The Challenge to Find Talent

- Plenty of applicants; but applicants with the desired skills are hard to find
- Difficulty filling positions
  - Only 40% of positions filled in the last 12 months
  - 80 day average per position—about 20-35 days "too long"
- 80% of respondents have difficulty finding talent in the region
  - 50% say talent is hard to find anywhere
  - So, moving the job to another location is not always a solution
- Suppliers are competing with their customers for talent

8

mobile comply

Mobil Comply, CVTA meeting, October, 2015

Working on ADAS Equipped Vehicles

- ADAS sensor testing
  - Radar and LiDAR generate complex data sets
- Troubleshooting V2X
  - New skills for automotive technician
- System re-calibration and alignment
  - JN Phillips calibration for windshield repairers
- Wireless networking tools
  - WireShark (an RF sniffer)
- V2X system troubleshooting
  - NHTSA operational standards
  - Spectrum analyzers, power meters are expensive

Examples of ADAS Troubleshooting

- For ADAS troubleshooting the diagnostic test equipment needed has become more complex and sophisticated
- Much of the diagnostics are done with a PC or a specialized tester under program control with Windows based test programs
- Automotive students should be exposed to several of the Wabco ADAS maintenance manuals - the Meritor OnGuard™ Collision Mitigation System and the Meritor OnLane™ LDW system are useful

ADAS Troubleshooting Software - TOOLBOX™

- The TOOLBOX™ software (available on the web site for purchase) interface looks like this:

ADAS Troubleshooting Software - TOOLBOX™

- The software allows one to connect to the ODBII port through various adapters
- This is the future workspace of the vehicle/ automotive technician when one deals with advanced ADAS systems and eventually autonomous vehicles! IT/PC skills become extremely necessary and important!

The challenge is cross-disciplinary

Connected & Automated Vehicles

- Mechanical engineering
- Electrical engineering
- Software engineering
- HMI
- Cybersecurity
- Wireless & Telecomms
- Infrastructure/ civil engineering
- Optics
- Big Data management
- Urban planning
- Behavioral sciences
- Other…

Traditional Proving Ground → AV Proving Ground

CAAT Developed CAV Curriculum

- Three free courses are available in the CAAT website Resource Library
- Springfield Technical Community College
  - Automated, Connected, and Intelligent Vehicles
  - Comprehensive syllabus, 15 lectures, quizzes, projects for 16 week, 3-credit course
  - Basis of new course, AUTO 2000 at Macomb Community College
- Jackson State (2 courses)
  1. Sensors used in connected and automated vehicles
  2. Navigation techniques used in connected and automated vehicles

http://autocaat.org/Educators/Seed_Funding/Funded_Programs/

Automated, Connected, and Intelligent Vehicles, AUTO 2000

- 3-credit, 16-week course will cover the technologies and systems that will enable automated vehicles
- Operation, maintenance and repair of safety and self-driving systems
- Will be taught for the first time at Macomb Community College as part of a new Automotive Technology-Vehicle Development Technician degree program

Auto 2000, Course Outcomes and Objectives

- Outcome 1: Student will be able to explain the benefits of computer controlled electro-mechanical systems on vehicles

  Objectives:

  1. Identify which automotive systems have been replaced by electronic control systems
  2. Apply the fundamental theory of operation of electronic control systems
  3. Apply the basics of how automotive electronic control units (ECUs) function in conjunction with the vehicle data bus networks and sensors
  4. Identify the various types of advanced driver assistance systems (ADAS)
  5. Apply and their application to collision avoidance and autonomous vehicles
  6. Identify the advantages of fully automated vehicles with regard to impaired driver technology

- Outcome 2: Student will be able to explain the six different levels of automation

  Objectives:

  1. Analyze modern display/cluster technology in semi-automated vehicles
  2. Compare the responsibility for the vehicle action: human driver versus the cyber-physical control systems
  3. Analyze differences in the human-machine interface in semi-automated vehicles

- Outcome 3: Student will compare the types of sensor technology needed to implement remote sensing of objects

  Objectives:

  1. Analyze the operation of radar systems and data
  2. Analyze the operation of camera systems and data
  3. Analyze the operation of Lidar systems
  4. Analyze the operation of ultra-sonic sensors
  5. Identify the strengths and weaknesses of each of the above systems

Auto 2000, Course Outcomes and Objectives, continued

- Outcome 4: Student will be able to explain the concept of a connected vehicle

  Objectives:

  1. Apply the basic concepts of wireless communications and wireless data networks
  1. Interpret the role of various organizations in the development and evolution of vehicle to vehicle and vehicle to infrastructure standards
  2. Give real-world examples of data networking and its roll in advanced driver assistance systems (ADAS) and future autonomous vehicles
  3. Identify protocols, and IP addressing, and on-board vehicle networks

- Outcome 5: Student will analyze the concept and advantages of sensor data fusion

  Objectives:

  1. Identify the reasons for redundancy in sensors
  2. Interpret the importance of signal to noise ratio
  3. Use sensor inputs to control system response
  4. Analyze new skill sets needed by technicians to work on intelligent vehicles

Course syllabus:
http://ecatalog.macomb.edu/content.php?catoid=33&navoid=3127

Vehicle Development Technician (VDT)

- 2-year Associates Degree in Automotive Technology
- Will work with engineers at an OEM or supplier
- Will work on test and prototype systems – no service manual
- Needs to learn additional skills in addition to mechanical skills
  - Electronic
  - Computer
  - Experimental testing
- Began Fall 2018 at Macomb Community College

Automotive Technology-Vehicle Development Technician Associates Degree

Course and Sequence	Course Title	Semester 1	Semester 2	Semester 3	Semester 4	Credits
AUTO-1000	Automotive Systems	3				3
AUTO-1040	Automotive Electrical I		3			3
AUTO-1050	Automotive Electrical II			3		3
AUTO-1100	Automotive Brake Systems			3		3
AUTO-1130	Automotive Steering and Suspension			3		3
AUTO-1200	Automotive Engines		3			3
TMTH-1150	RCL Analysis	4				4
ELEC-1161	Electronic Technology 1	3				3
ELEC-1171	Electronic Technology 2	3				3
ELEC-1211	Digital Electronics Basics		3			3
ELEC-2150	LabVIEW Basics 1			3		3
ITCS-1140	Intro. to Programing Design & Development		4			4
ITNT-1500	Principles of Networking			4		4
PRDE-1250	Basic Blueprint Reading				2	2
ELEC-2310 NEW	Vehicle Experimental Testing				4	4
AUTO-2000 NEW	Connected, Automated & Intelligent Vehicles				3	3
Core Hours Total		13	13	16	9	51
Gen Ed, Group I	ENGL 1180 (4) or ENGL 1210 (3)	3				3
Gen Ed, Group II	PHYS 1180 (recommended)		4			4
Gen Ed, Group III	ECON 1160 (recommended)				3	3
Gen Ed, Group IV	ENGL 2410 (recommended)				3	3
Gen Ed, elective	Gen Ed elective of 2 or more credits				2	2
General Ed Total		3	4	0	8	15
Grand Total		16	17	16	17	66

Vehicle Development Technician Degree Combines Automotive Technology, Engineering Technology, and Information Technology Courses

Automotive Systems	Course	Credits
Introduction	AUTO 1000 Automotive Systems	3
Transmissions	(drop)	
Engines	AUTO 1200 Automotive Engines	3
Brakes	AUTO 1100 Automotive Brake Systems	3
Chassis	AUTO 1130 Automotive Steering and Suspension	3
Electrical-Electronics	AUTO 1040 Automotive Electrical I AUTO 1050 Automotive Electrical II	3 3
Other	AUTO 2000 Connected, Automated, Intelligent Vehicles (NEW COURSE)	3
Engineering Technology/Electronics		
Fundamentals	TMTH 1150 RCL Analysis ELEC 1161 Electronic Technology 1 ELEC 1171 Electronic Technology 2	4 3 3
Applications	ELEC 1211 Digital Electronics Basics ELEC 2150 Labview Basics 1	3 3
Software	ITCS 1140 Intro. to Program Design & Development	4
Networking	ITNT 1500 Principles of Networking	4
Testing	ELEC 2310 Vehicle Experimental Testing (NEW COURSE)	4
Product Design	PRDE 1250 Basic Blueprint Reading	2
Science Elective	PHYS 1180 Physics (recommended)	4

New Automotive Cybersecurity Course

- Use CAAT seed funding model
  - Proposal, review, revision, contract with deliverables and dates, approval of resources, payment, free posting of materials in CAAT Resource Library)
- Step 1: CAAT prepares course outline
  - Research, webinars, meetings, books, journal articles
  - identify and solicit input from experts
- Step 2: Issue RFP on CAAT web site with instructions
- Step 3: Choose best proposal, solicit experts comments
- Step 4:Revise proposal and issue a contract
  - Deliverables and dates
- Step 5: Review materials, approve, and post for free use on CAAT web site

Cybersecurity Course Content

(first pass)

- Automotive electronics, ECUs, and CAN
  - Software and firmware
- Attacking (hacking) vehicles and connected/automated vehicles
  - History, Miller and Valesek Jeep hack, cybersecurity awareness
  - Attack vectors; types of threats and attacks
- SAE and ISO standards
  - J3061, ISO 21434
  - Safety <u>and</u> security from start to finish
- Textbooks and reports
  - Cybersecurity for Commercial Vehicles (2019), The Car Hackers Handbook (2016)
  - SAE Journal, Transportation Cybersecurity and Privacy (2018)
  - SAE , Cybersecurity for Commercial Vehicles, Gloria D'Anna (2019)
- Protecting vehicles from attacks
  - Penetration testing

Review Existing or Currently Planned Automotive Cybersecurity Courses

- SAE
  - Short courses, J 3061, etc.
  - SAE CyberAuto Challenge (5-day hands-on)
- MAGMA (short course from SAE)
  - "Cybersecurity: An Introduction for the Automotive Sector"
- Walsh College
  - B.S. in Information Technology with a concentration in Automotive Cybersecurity
- Square One (short courses and 12-week program)
  - "Masters of Mobility"
- Pinckney Cyber Training Institute (some automotive)
  - Hub on Michigan Cyber range

Summary

- Vehicles are becoming electro-mechanical devices controlled by computers
- Automotive service technicians will need enhanced electronic, software, and troubleshooting skills to maintain and repair future vehicles
  - The step to level 3 autonomy is very near (it may be here already)
- Vehicle development technicians (VDTs), with enhanced electronic, software, and laboratory testing skills is needed by OEMs and suppliers to assist engineers in the development of highly automated and highly electrified vehicles
  - The step to level 4 and 5 autonomy is coming soon
- Macomb Community College in collaboration with CAAT has begun an **Automotive Technology-Vehicle Development Technician** degree program
  - It has a connected/automated vehicle course, AUTO 2000
  - It has an automotive testing course, ELEC 2310
- Foundational STEAM skills are important foundational skills needed by both vehicle service and development technicians as vehicles become computerized robotic devices
  - We need to get this message out to youngsters (and parents)

USDOT CENTER FOR CONNECTED AUTOMATED TRANSPORTATION

The Future

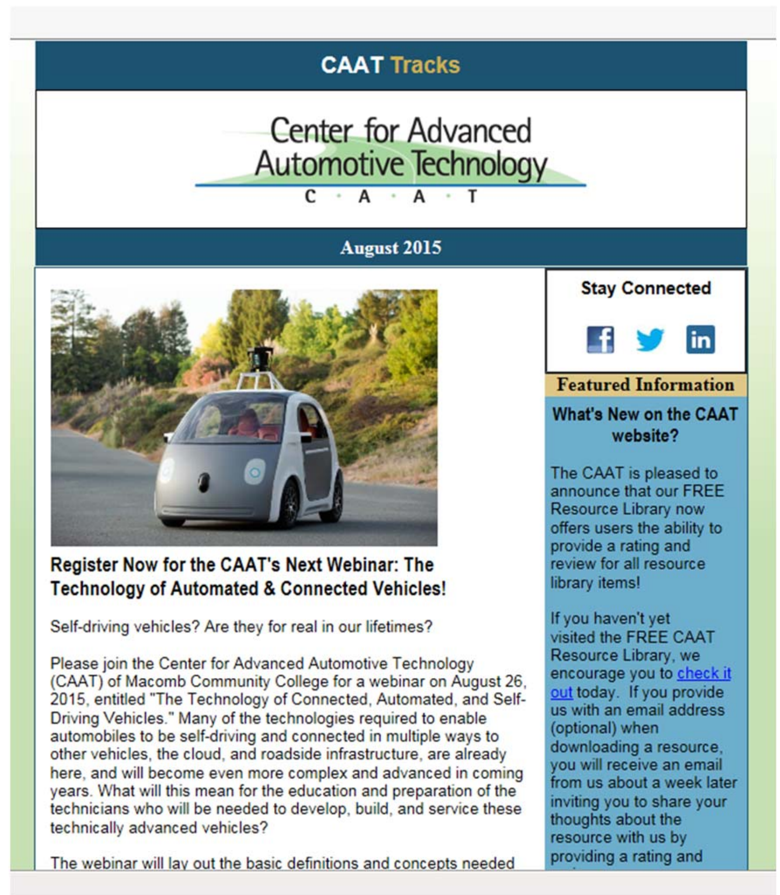
- Is *Connected*
- Is *Automated*
- Is **Here!**

UMTRI TRANSPORTATION RESEARCH INSTITUTE UNIVERSITY OF MICHIGAN

Stay Connected with CAAT

- Visit our website at www.autocaat.org
- Sign up for our monthly newsletter
- Follow us on social media
- Utilize our free course resources
  – Connected/Automated Vehicles
  – Lightweighting
  – Testing
  – Electric Vehicles and Alternative Fuels

http://autocaat.org/Educators/Seed_Funding/



CAAT Tracks

Center for Advanced Automotive Technology
C · A · A · T

August 2015

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

Stay Connected

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

Thank You!

Questions?

Backup Slides

Auto 2000 Course Outline by Week

1. Introduction to Automated, Connected, and Intelligent Vehicles

    Introduction to the Concept of Automotive Electronics; Automotive Electronics Overview, History & Evolution; Infotainment, Body, Chassis, and Powertrain Electronics; Advanced Driver Assistance Electronic Systems

2. Connected and Autonomous Vehicle Technology

    Basic Control System Theory applied to Automobiles; Overview of the Operation of ECUs; Basic Cyber-Physical Systems,   Theory and Autonomous Vehicles; Role of Surroundings Sensing Systems and Autonomy; Role of Wireless Data Networks and Autonomy

3. Sensor Technology for Advanced Driver Assistance Systems

    Basics of Radar Technology and Systems; Ultrasonic Sonar Systems; Lidar Sensor Technology and Systems; Camera Technology; Night Vision Technology; Other Sensors,;Use of Sensor Data Fusion; Integration of Sensor Data to On-Board Control Systems

4. Overview of Wireless Technology

    Wireless System Block Diagram and Overview of Components; Transmission Systems - Modulation/Encoding; Receiver System Concepts - Demodulation/Decoding; Signal Propagation Physics; Basic Transmission Line and Antenna Theory

5. Wireless System Standards and Standards Organizations

    Role of Standards; Standards Organizations; Present Standards for Autonomous Applications

6. Wireless Networking and Applications to Vehicle Autonomy

    Basics of Computer Networking - the Internet of Things; Wireless Networking Fundamentals; Integration of Wireless Networking and On-Board Vehicle Networks; Review of On-Board Networks - Use & Function

7. Connected Car Technology

    Connectivity Fundamentals; Navigation and Other Applications; Vehicle-to-Vehicle Technology and Applications; Vehicle-to-Roadside and Vehicle-to-Infrastructure Applications; Wireless Security Overview

Auto 2000 Course Outline by Week

8. Advanced Driver Assistance System Technology
   Basics of Theory of Operation; Applications - Legacy; Applications - New, Applications - Future; Integration of ADAS Technology into Vehicle Electronics; System Examples; Role of Sensor Data Fusion
9. Connected Car Display Technology
   Center Console Technology; Gauge Cluster Technology; Heads-Up Display Technology; Warning Technology - Driver Notification
10. Impaired Driver Technology
    Driver Impairment Sensor Technology; Sensor Technology for Driver Impairment Detection; Transfer of Control Technology
11. Vehicle Prognostics Technology
    Monitoring of Vehicle Components; Basic Maintenance; End-of-Life Predictions; Advanced Driver Assistance System Sensor Alignment and Calibration
12. Autonomous Vehicles
    Driverless Car Technology; Moral, Legal, Roadblock Issues; Technical Issues; Security Issues
13. Present Advanced Driver Assistance System Technology Examples
    Toyota, Nissan, Honda, Hyundai; Volkswagen, BMW, Daimler; Fiat Chrysler Automobiles; Ford, General Motors
14. Troubleshooting and Maintenance of Advanced Driver Assistance Systems
    Failure Modes - Self Calibration; Sensor Testing and Calibration; Redundant Systems; Standard Manufacturing Principles
15. Non-Passenger Car Advanced Driver Assistance Systems and Autonomous Operation
    Uber/Lyft - Disruptive Technology; Trucking; Farming; Mining; Shipping & Rail; Military
16. Course review and final exam