# *Emerging Automotive Technologies and Technicians*

October 4, 2019

**Michigan Automotive Teachers Association (MATA)**

Macomb Community College


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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 a book chapter on electrolytic hydrogen.

# The Center for Advanced Automotive Technology (CAAT)

- Located at Macomb Community College, South Campus in Warren, MI
- Became an Advanced Technological Education Center in 2010 funded by the National Science Foundation (NSF)
- Mission
  - Develop and disseminate advanced automotive technology curricula
  - Provide outreach activities to middle and high school students (STEAM)

# CAAT is one of the about 40 ATE Centers Across the United States


https://atecenters.org/

# Today’s Main Questions

1. What are the emerging technologies in automotive technology?
2. How do those technologies work?
3. What are the remaining challenges?
4. What new educational materials are needed for automotive technician education? How has CAAT responded to this need?

# 1. Emerging automotive technologies

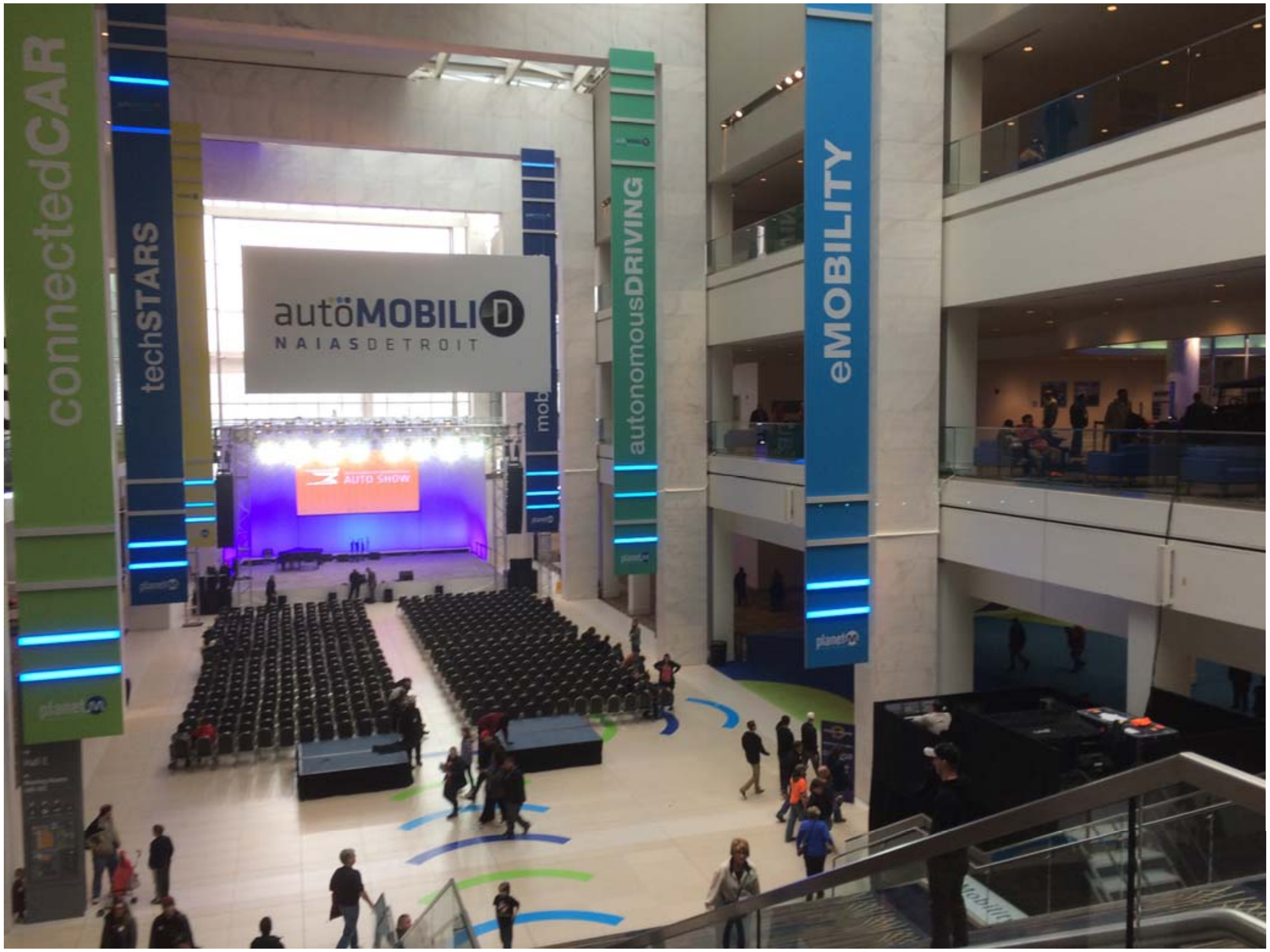
- Electrification of the powertrain
- Electromechanical control of throttle, steering, and braking
  - Advanced Driver Assistance Systems (ADAS)
  - Automated driving
- Automated and connected vehicles
  - ACES acronym (automated, connected, electrified, shared)
- Use of lightweight materials

# Mary Barra, GM CEO, as quoted during the introduction of the Chevy Bolt at the 2016 Consumer Electronics Show

“I have no doubt that the automotive industry will change more in the next five to 10 years than it has in the last 50,” she said. “The convergence of connectivity, vehicle electrification, and evolving customer needs demand new solutions.”

She noted that broader “societal trends” such as urbanization and sustainability are going to drive a lot of this change, as well as new technological developments at improving safety, fuel economy, and creating autonomous vehicles.

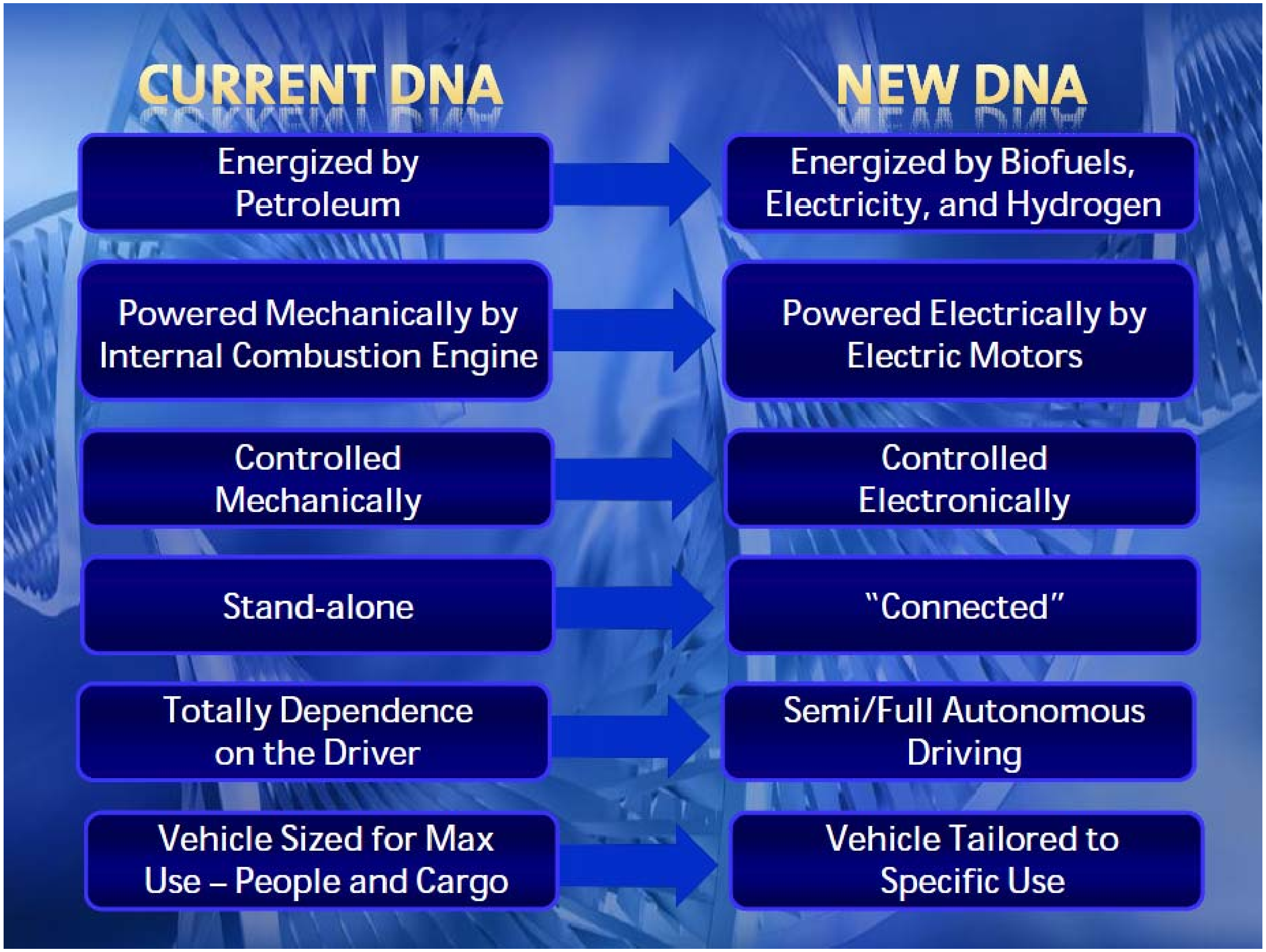
Latest statement of goals: zero crashes, zero emissions, zero congestion


connectedCAR
techSTARS
autoMOBILI D
NAIASDETROIT
AUTO SHOW
autonomousDRIVING
eMOBILITY

# Automotive Technicians Must Understand New Systems
# The New DNA of Vehicles

- High voltage batteries, power conversion, electric motors
- Advanced Driver Assistance Systems (ADAS)
- Lightweight materials and advanced joining and fasteners
- New educational materials are needed to train technicians to work on vehicles with these technology advances
- CAAT has developed some of the new educational materials through seed funding
  - and they can be downloaded and used for free

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

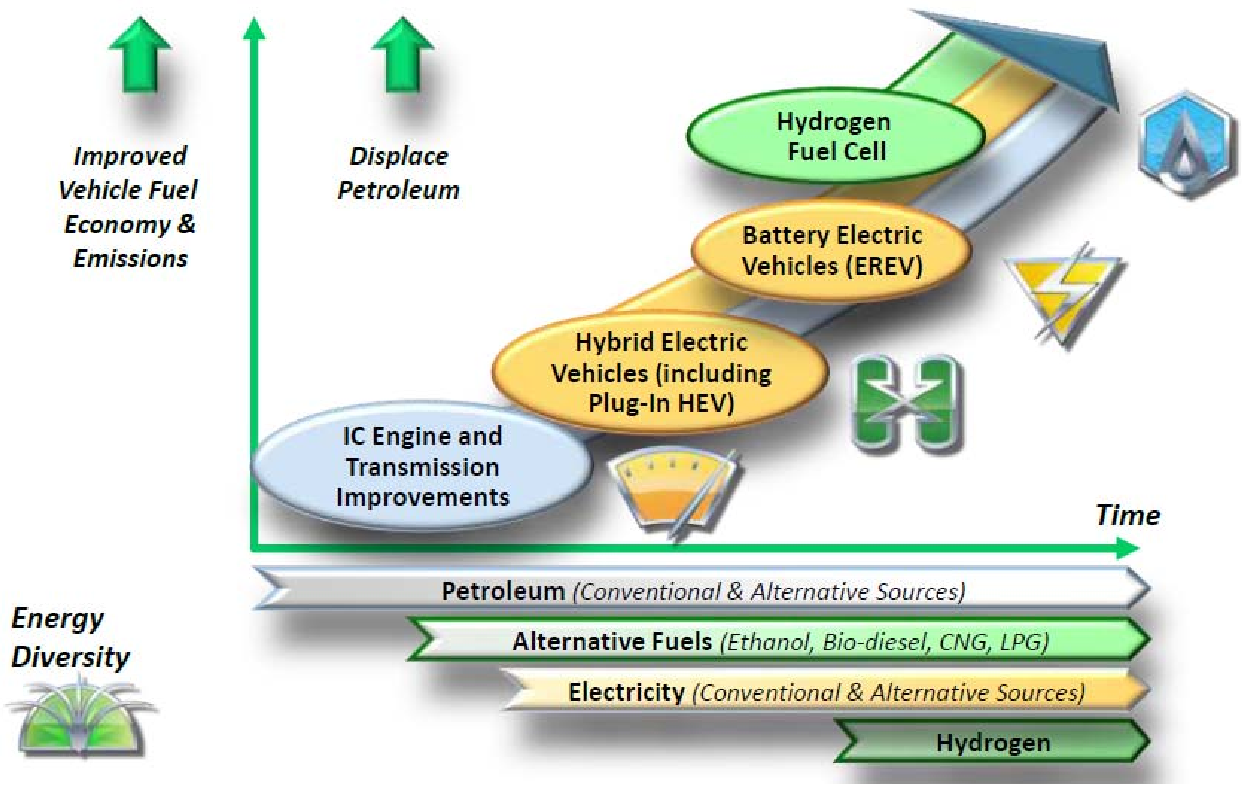

CURRENT DNA
NEW DNA
Energized by Petroleum
Energized by Biofuels, Electricity, and Hydrogen
Powered Mechanically by Internal Combustion Engine
Powered Electrically by Electric Motors
Controlled Mechanically
Controlled Electronically
Stand-alone
"Connected"
Totally Dependence on the Driver
Semi/Full Autonomous Driving
Vehicle Sized for Max Use – People and Cargo
Vehicle Tailored to Specific Use

# Why do we need these new technologies?

- Electrification and lightweighting
  - Reduce emissions of air pollutants
  - Reduce the emissions of greenhouse gases (mainly carbon dioxide)
  - Reduce the usage of fossil fuels; sustainability

- Advanced driver assistance systems and connectivity
  - Safety – reduce traffic deaths and injuries
  - Convenience

# Advanced Propulsion Technology Strategy
## No single silver bullet exists




Source: Charles Freese, GM Executive Director, Global Fuel Cell Activities

# Why Must Automakers Build Electric Vehicles?

- EPA and CARB can set pollutant emission standards to protect public health (hydrocarbons, CO, NOx, $SO_2$, lead, particulate matter)
  - NHTSA can set mpg standards (CAFE)
  - $CO_2$ can also be regulated – a greenhouse gas (GHG)
- Increasingly difficult for internal combustion engines (ICE) to meet fuel economy standards (mpg and $CO_2$ emission) standards
  - 54.5 mpg by 2025 (163 g $CO_2$/mile)
- Impossible for ICE to meet California zero-emission vehicle (ZEV) standards

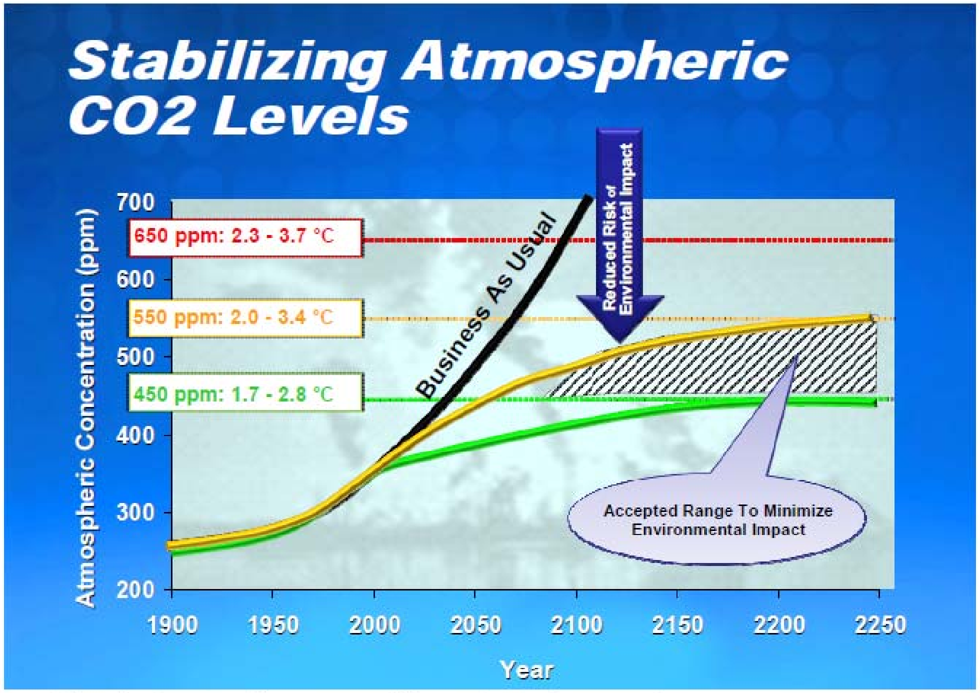
# Different Objectives With Similar Outcomes

NHTSA — petroleum reduction

United States Environmental Protection Agency — greenhouse gas reduction

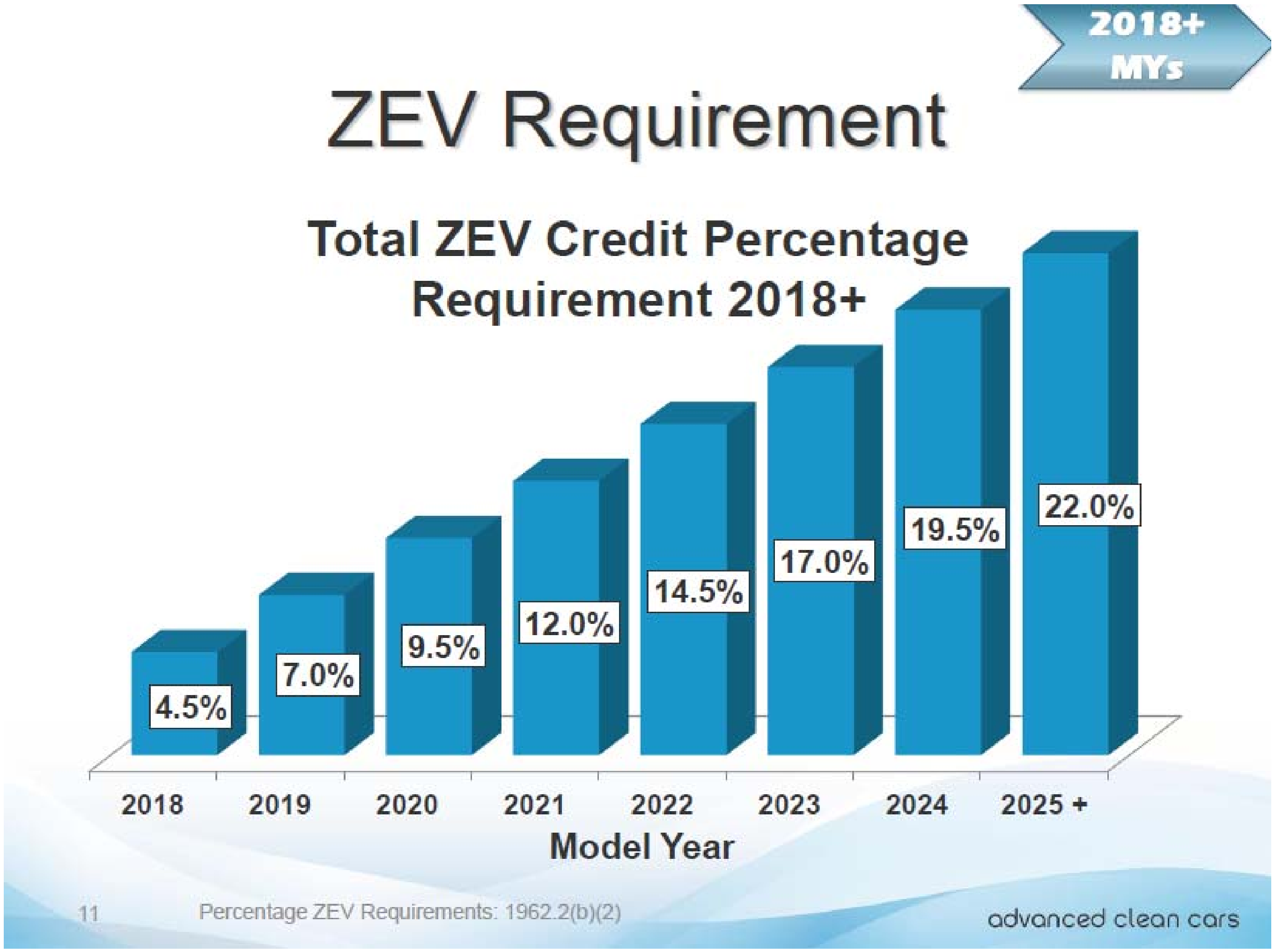
California Environmental Protection Agency Air Resources Board — greenhouse gas reduction

# What's Driving Us?




- Simply "not getting worse" is not good enough
- $CO_2$ reduction is required on a global basis going forward
- This is a long term commitment for a sustainable future

# California


2018+
MYs
ZEV Requirement
Total ZEV Credit Percentage
Requirement 2018+
4.5%
7.0%
9.5%
12.0%
14.5%
17.0%
19.5%
22.0%
2018
2019
2020
2021
2022
2023
2024
2025 +
Model Year
11
Percentage ZEV Requirements: 1962.2(b)(2)
advanced clean cars

# Why Must Automakers Reduce Vehicle Mass?

## VEHICLE WEIGHT AND FUEL ECONOMY

¶ 6% improvement in fuel economy for 10% mass reduction

– 0.4 mpg improvement per 100 lbs., for 3,500-lb. vehicle

– 0.5 km/L improvement per 100kg weight reduction, for 1500kg vehicle

# Why Must Automakers Add Safety and Convenience Features?

- Safety – Traffic Deaths are Increasing
  - 40,000 deaths per year in U.S. -- like a 747 crashing every week
  - Over 6000 pedestrians
  - 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 do the new technologies work

- Electrification of the powertrain

- Use of lightweight materials

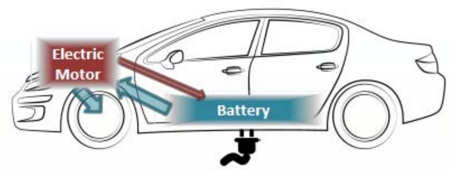
- Electromechanical control of throttle, steering, and braking
  - Advanced Driver Assistance Systems (ADAS)
  - Automated driving systems (SAE/NHTSA level 2)

- Automated and connected vehicles (SAE/NHTSA levels 3 to 5)

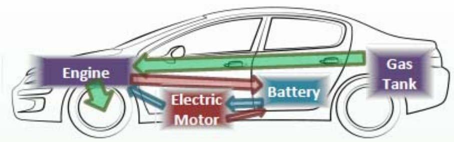
# Electrification of the Powertrain

## EV Types

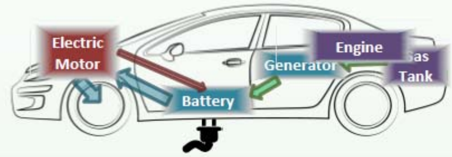
- Battery electric vehicle (BEV):



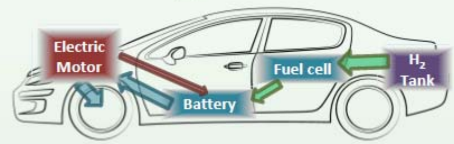

- Hybrid electric vehicle (HEV):




- Plug-in hybrid vehicle (PHEV):




- Fuel cell electric vehicle (FCEV):



# Examples of Each Type of xEV

<u>HEV</u>

Toyota Prius

<u>PHEV</u>

Chevy Volt

<u>EREV</u>

Very common

<u>BEV</u>

Tesla Model S, X, 3

Nissan Leaf

Becoming common

<u>FCEV</u>

Toyota Mirai

Honda Clarity

California only

# Energy Conversion in an ICE versus an Electric Vehicle

- **ICE**

  **Fuel + $O_2$ → $CO_2$ + $H_2O$ + pollutants + heat**

  **1st law of thermodynamics, limited efficiency (Carnot)**

- **Electric vehicles**

  **Electrochemistry: direct conversion of chemical energy to electricity**

  **Electric motor: high conversion of electricity to mechanical energy**

# Energy Storage for a BEV or FCEV

## Chemistry is the key

Electrochemistry

Oxidation/Reduction Reactions

Anode/Cathode/Electrolyte

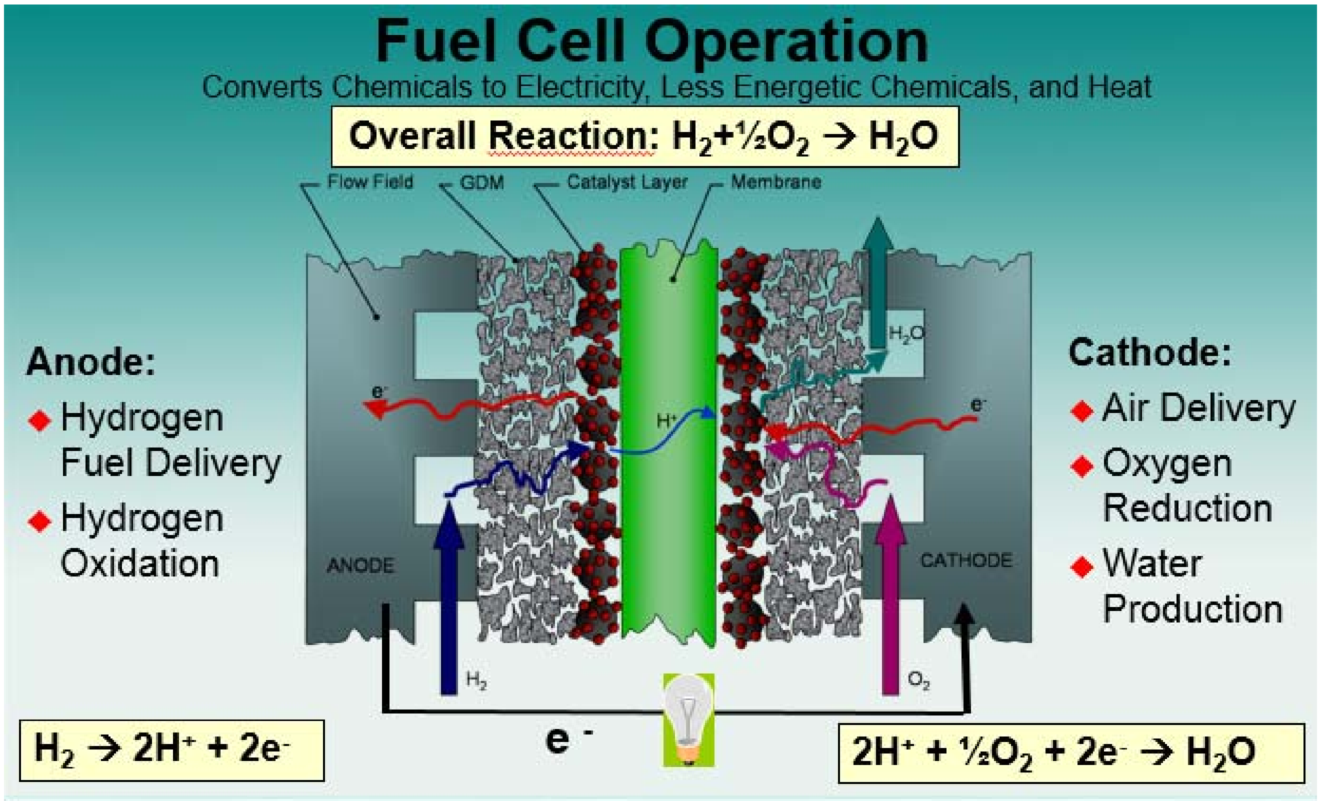
Ion and Electron Flow

The Electromotive Series, Half-Reactions

Standard Potential, $E^0$

Overvoltage

# A Proton Exchange Membrane (PEM) Fuel Cell



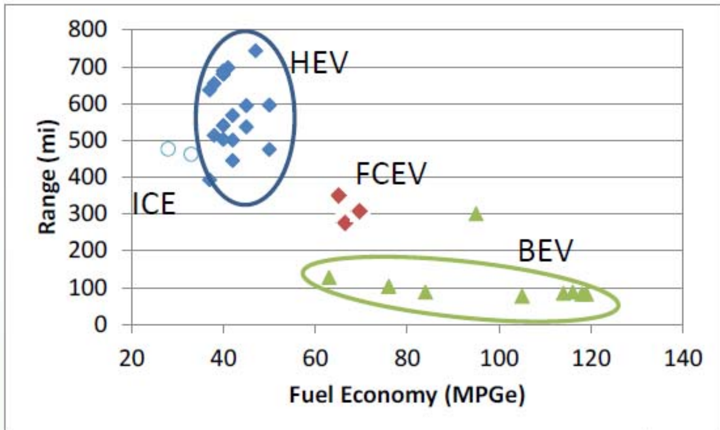
# PEM Fuel Cell Chemistry

| | | |
|---|---|---|
| Oxidation | $2\ H_2 \rightarrow 4\ H^+ + 4\ e^-$ | 0.0 V |
| Reduction | $O_2 + 4\ H^+ + 4\ e^- \rightarrow 2\ H_2O$ | 1.23 V |
| Overall reaction | $2\ H_2 + O_2 \rightarrow 2\ H_2O$ | 1.23 V |

- Real world voltage under load is 0.6 to 0.7 V
  - Due to sluggish reaction for oxygen reduction
  - So efficiency is about 50%
- For comparison, Li-ion batteries have efficiencies of 80 to 90% (energy out/energy in)
  - depends on charging and discharging rate

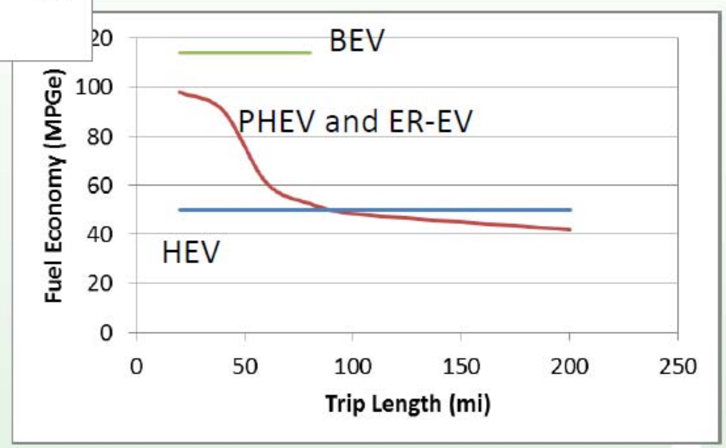
# Toyota Mirai FCEV

# Fuel Economy and Range of EVs

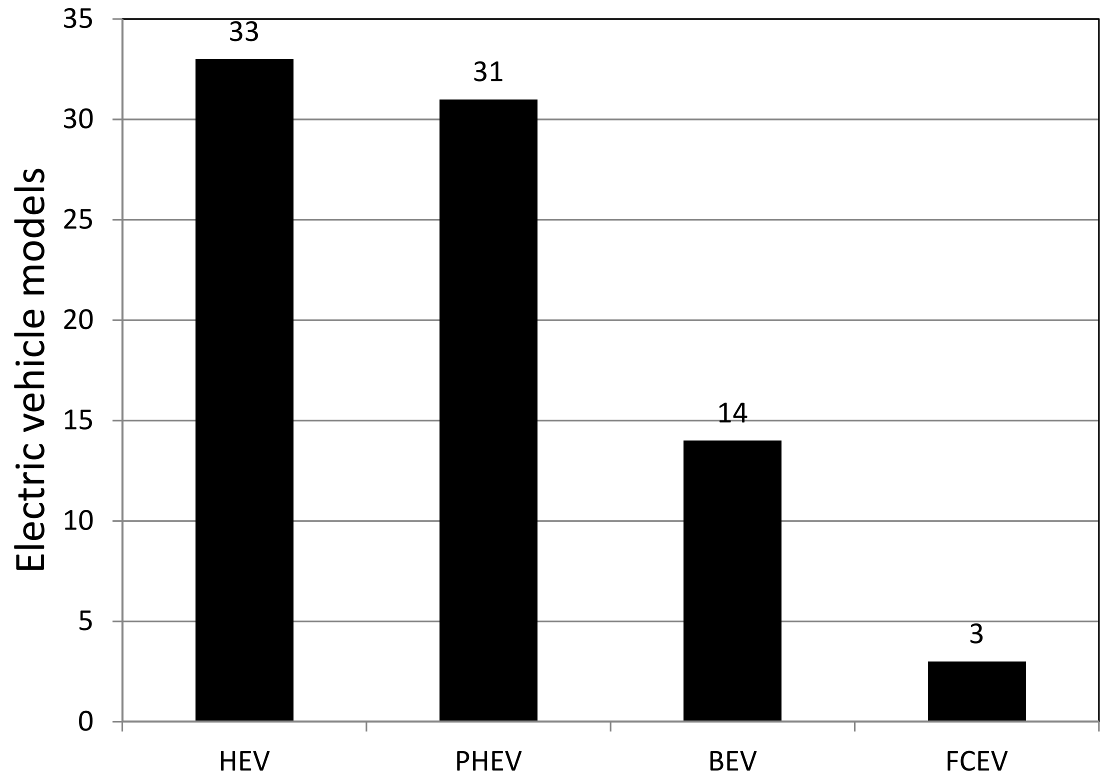



- BEV > FCEV > HEV > ICE

- The fuel economy of PHEV and ER-EV highly depends on driving behavior.



# 81 Models of Electric Vehicles for Sale in 2018



# 3. xEV Remaining Challenges

- Cost
  - Tesla Model 3, from $42,900
  - Chevy Bolt, from $36,600, getting closer
- Infrastructure
  - Fast BEV charging stations
  - Hydrogen fueling
- Other
  - BEV range and "refueling" time (getting much better)
  - FCEV $H_2$ cost

# Reducing Mass Using Lightweight Materials

## ADVANCED MATERIALS FOR LIGHTWEIGHT VEHICLES

| Material | Weight Reduction vs. Low-Carbon Steel |
|---|---|
| High-strength steel | 15-25% |
| Glass-fiber composite | 25-35% |
| Aluminum | 40-50% |
| Magnesium | 55-60% |
| Carbon-fiber composite | 55-60% |

# Lightweighting

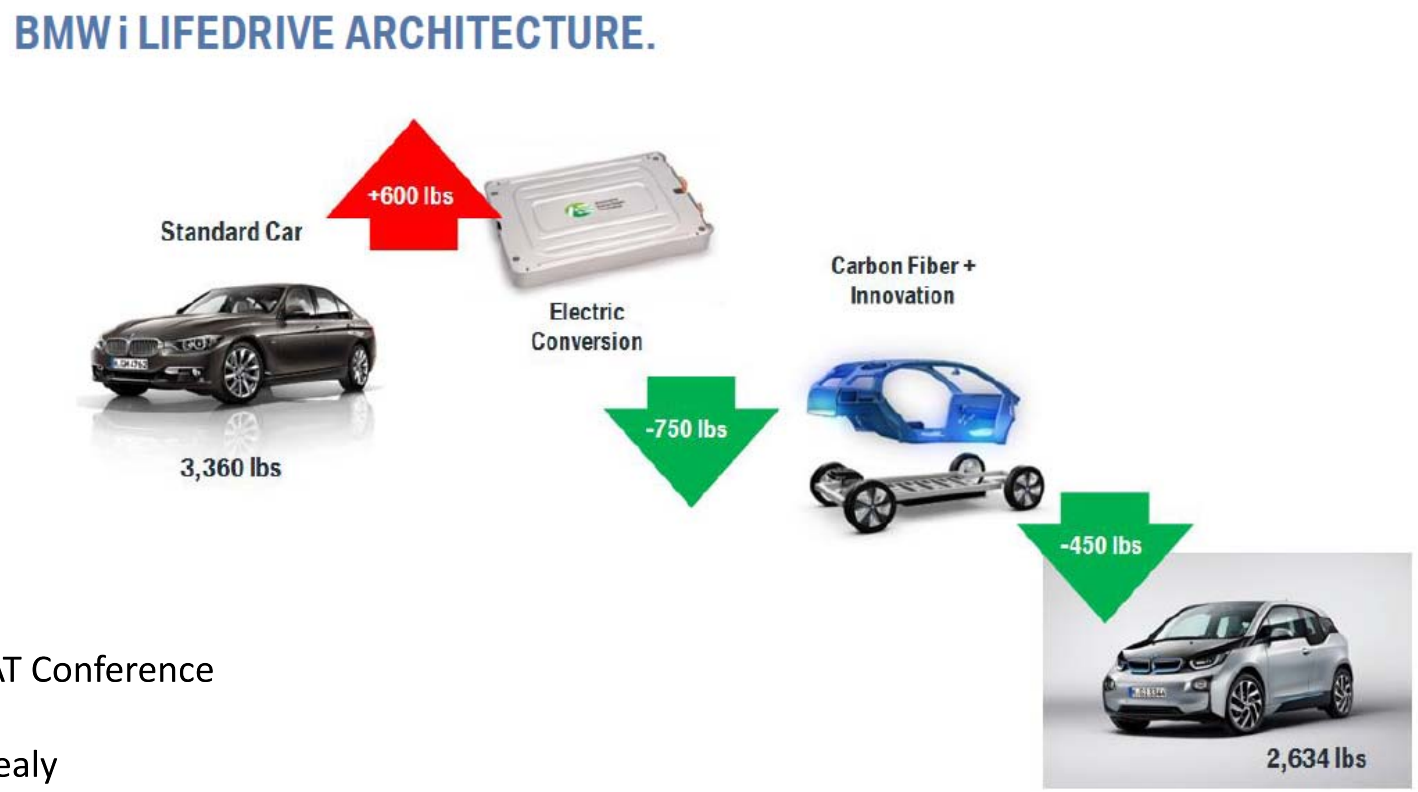
## VEHICLE WEIGHT AND FUEL ECONOMY

- 6% improvement in fuel economy for 10% mass reduction
  - 0.4 mpg improvement per 100 lbs., for 3,500-lb. vehicle
  - 0.5 km/L improvement per 100kg weight reduction, for 1500kg vehicle

GM

# 2015 Ford Aluminum Body F-150 Reduces Mass by 700 lbs.

# Use of Lightweight Materials and Electrification




2016 CAAT Conference

Robert Healy
Head of EV Infrastructure, BMW

# Automated and Connected Vehicles

- 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

# Electronic and Electromechanical Controls Controls

- 1980s Microprocessors for electronic powertrain control, CAN and other busses, sensors (MAF, $O_2$, rpm), stoichiometric A/F ratio control, spark timing, algorithms and engine maps
- 1990s OBD-II, cylinder deactivation, electromechanical systems for throttle, steering
- 2000s Adaptive cruise control, parking systems
- 2010s Sensors: ultrasonic, radar, cameras, connectivity, advanced driver assistance systems, fully automated systems under test and "teaser" that they will be released

# 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 | 🤖 | 🤖 | 🤖 |

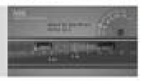
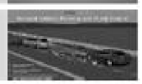
Source: Adapted from NHTSA and SAE J3016

# 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 |
| **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 |

# 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

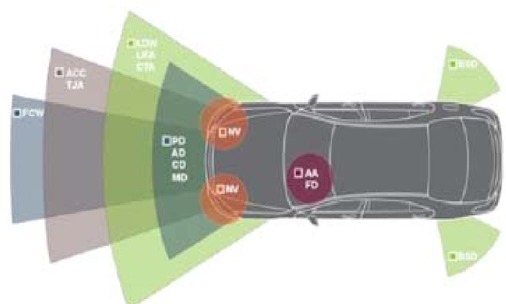
**ACC**: Adaptive Cruise Control
**TJA**: Traffic Jam Assist
**RSR**: Road Sign Recognition
**ISA**: Intelligent Speed Assistance
**AP**: Active Parking
**HBA**: High Beam Assist
**AH**: Adaptive Headlights

### Driver Monitoring

**FD**: Fatigue Detection
**AA**: Attention Assist

### Vision

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



RICARDO

WIND 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)

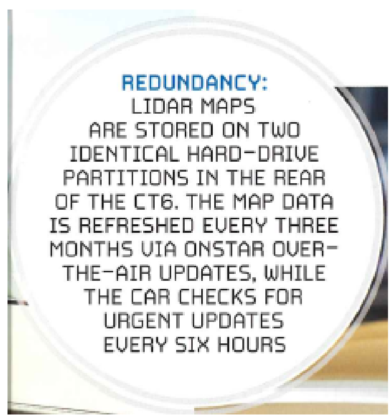
# Hands-Free for 700 Miles

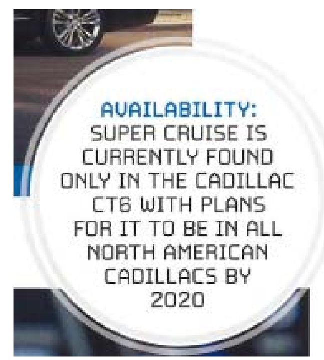

Automotive Engineering, November 2017

# GM Super Cruise







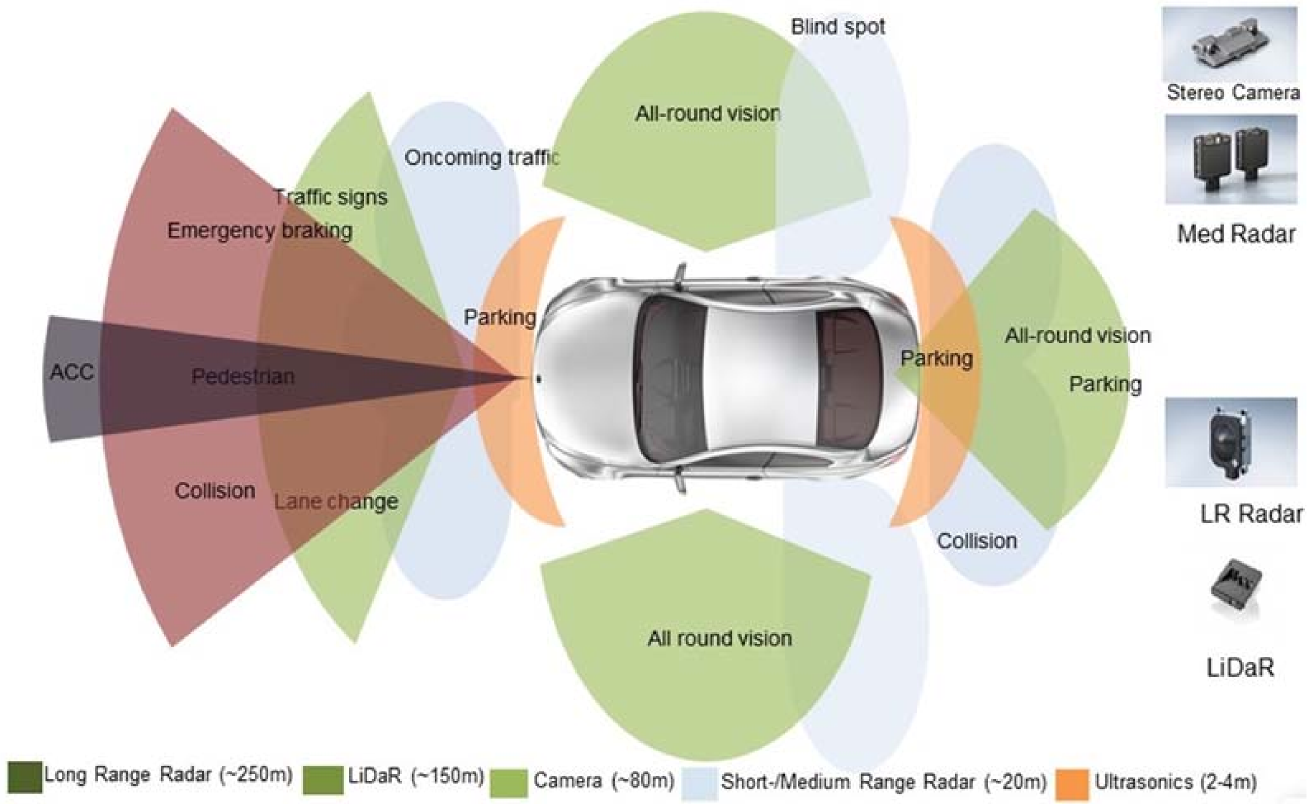



# Comparison of Tesla Autopilot and Cadillac Super Cruise

- 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

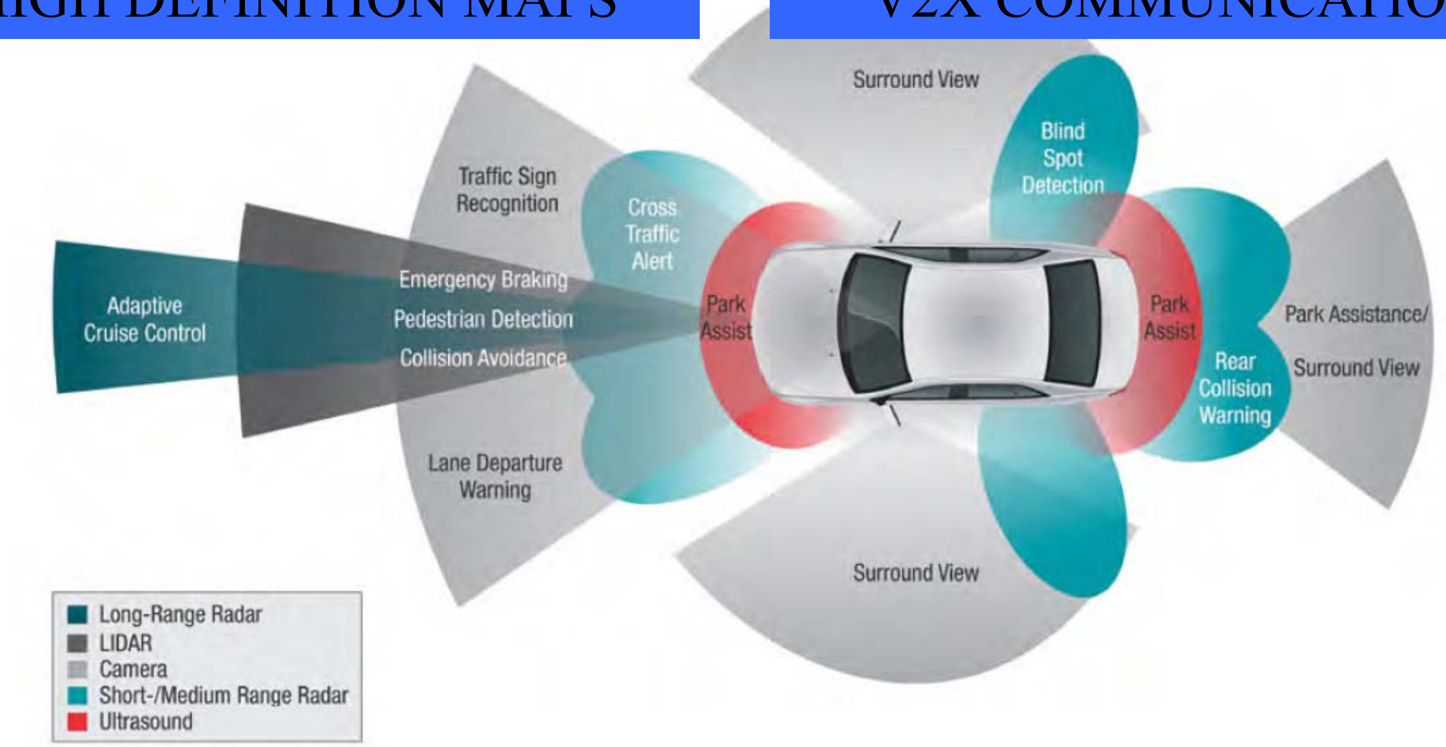
F
R
O
N
T



# Automated Driving:
# Enabling and *Supporting* Technology

HIGH DEFINITION MAPS

V2X COMMUNICATIONS

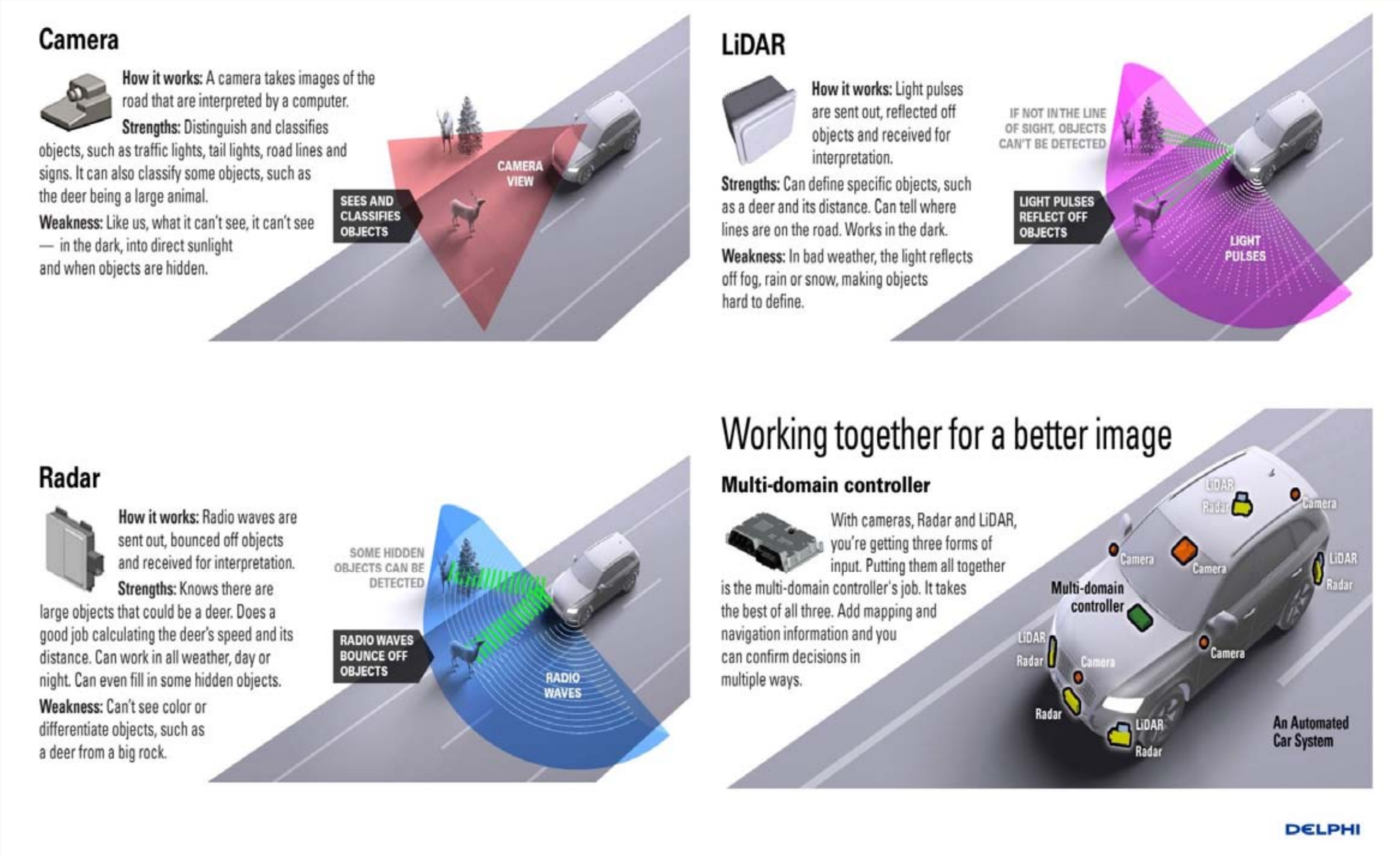



Source: Texas Instruments ADAS Solutions Guide

# 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

# Camera/Radar/Lidar Operation and Sensor Fusion



# 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

# 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

# The Multi-Domain Controller for Sensor Fusion, Data Analysis, and System Control

# 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

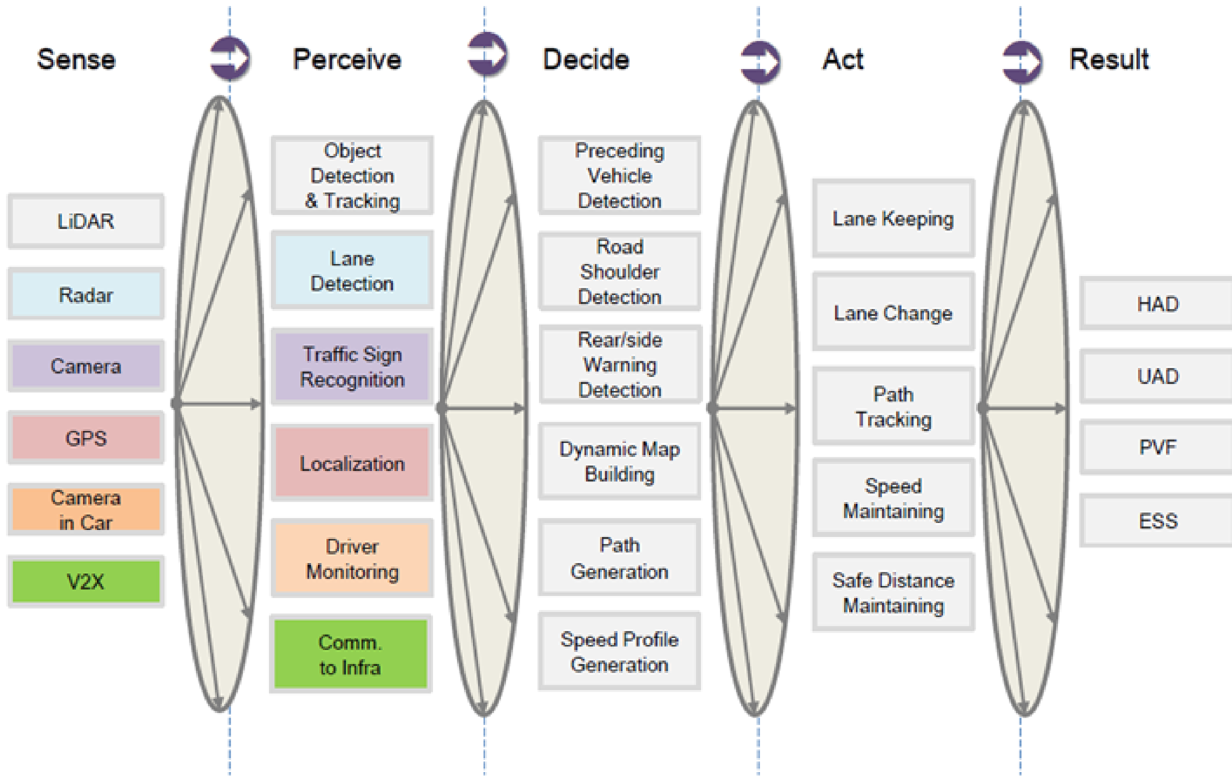
**24 million lines of code**
F-35 fighter jet

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

**61 million lines of code**
Facebook

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

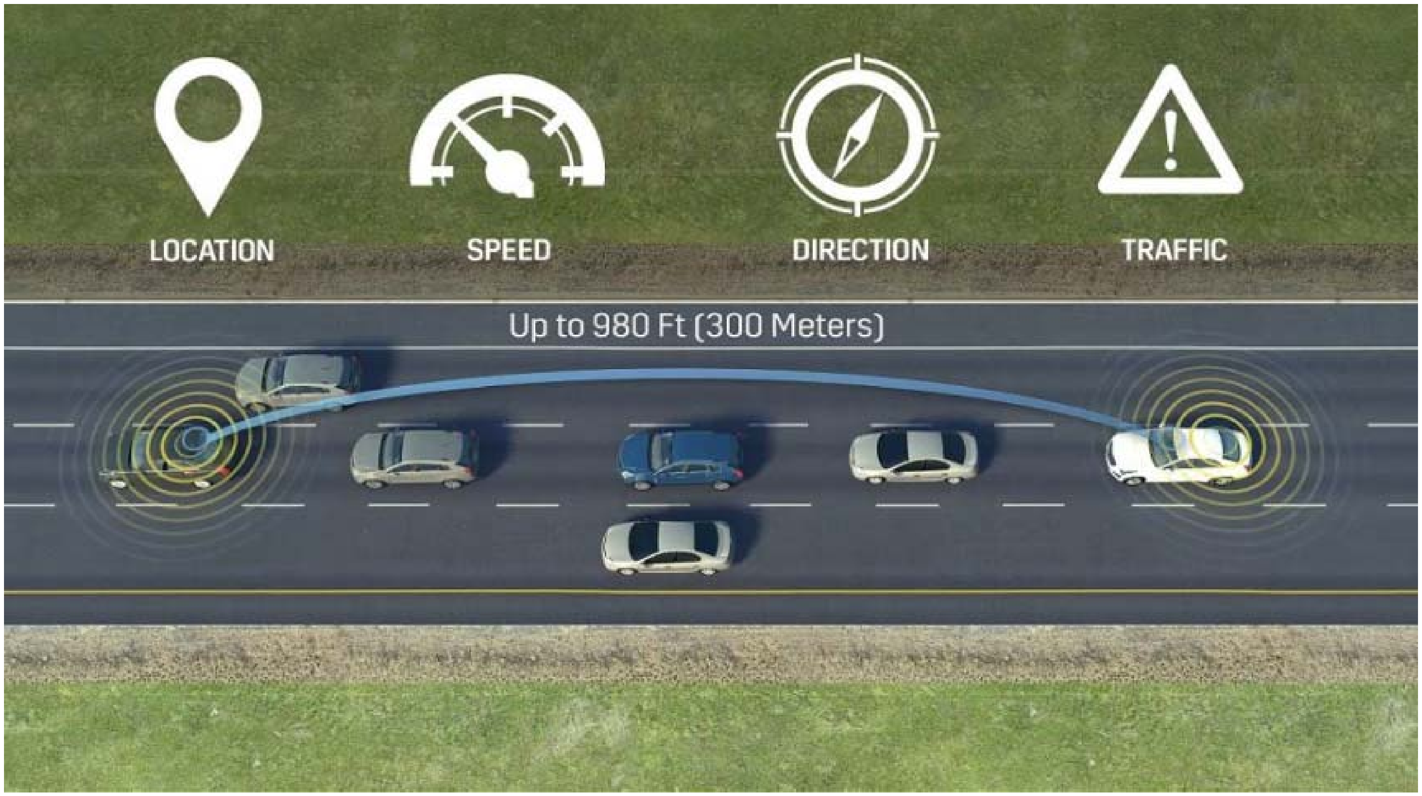
# System Flow




The Power to Surprise

# V2X Systems – What is X?

# 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

# What we have here is a failure to communicate

- DSRC
  - Was supposed to be implemented, NHTSA
  - No mandate, only Cadillac CTS got DSRC
- C-V2X
  - 5G will probably make this a winner
  - Ford and others have signed on
  - Big players in wireless technology are behind it

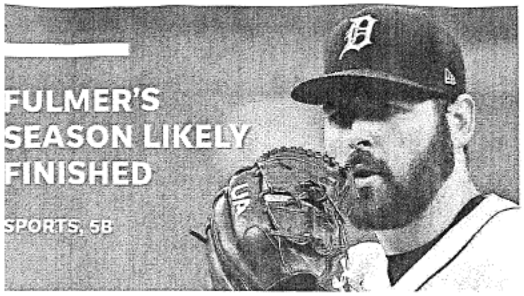
## Expected Improvements Resulting from the Development of Connected/Automated Vehicles

- 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
- Communication standards (DSRC versus C-V2X)
- Added electrical load
- Cybersecurity
- Loss of privacy
- Managing the transition from automated control to driver control (re-engagement of the driver)
- Cost
- Technician education

# 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.

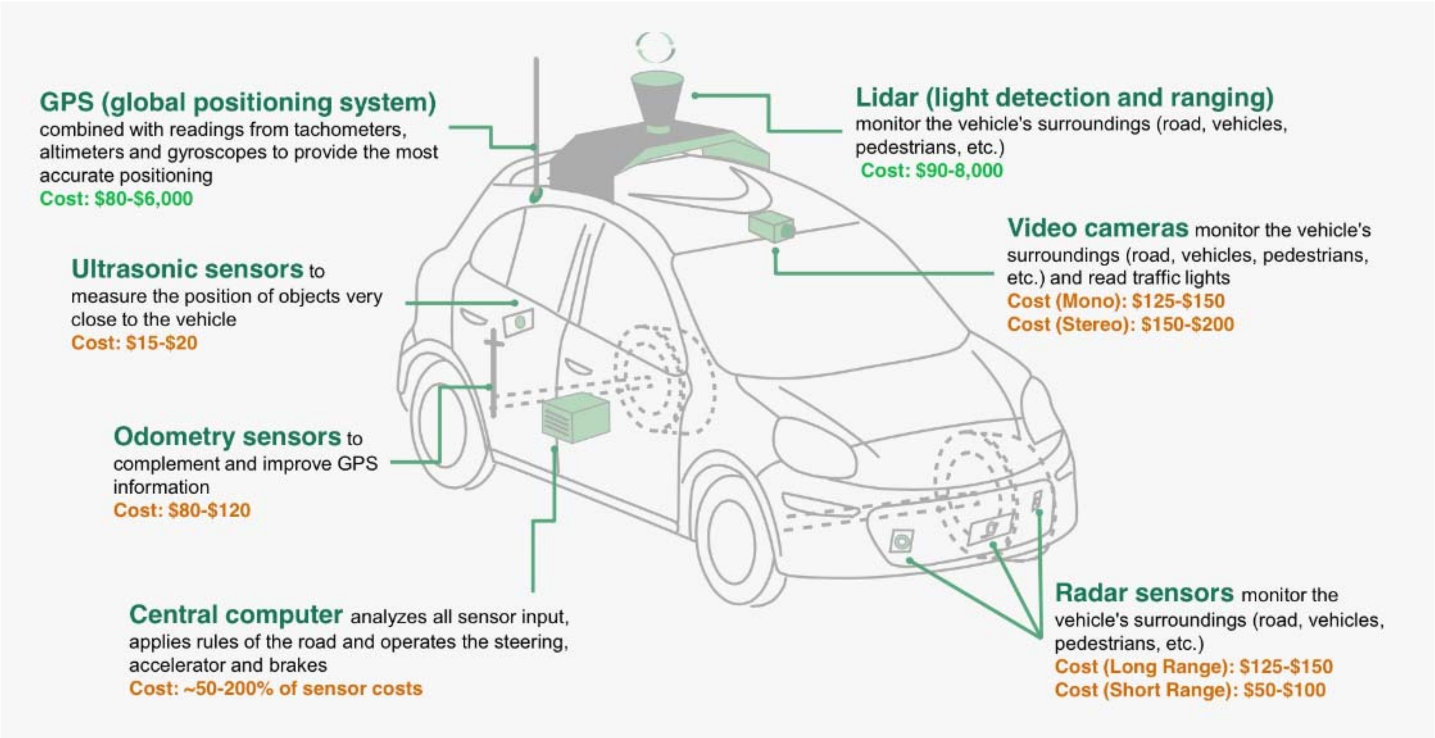
But what happens when these ever-more technologically advanced vehicles crash? Experts say the cost to repair all that technology could be hefty.

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




"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. What new educational materials are needed for automotive technician education? How has CAAT responded to this need?

- CAAT seed funding: our mechanism for new advanced automotive technology course development
- Funding available on a first come, first serve basis for educational institutions to develop or adapt materials for secondary and post-secondary education on advanced automotive technologies:
    - From modules and artifacts to courses and complete curricula
    - Requested funds must be less than $25,000
    - Equipment not to exceed 20% of funding request
- 18 seed funding contracts completed
    - Hybrid and battery electric vehicles (originally this was the main focus)
    - STEM
    - Connected and automated vehicles
    - Light-weighting and new materials/joining
    - Vehicle experimental testing
    - Latest contract on automotive cybersecurity

# CAAT's 18 Seed Funding Partners and their Contributions to New Course Materials

| | 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 | | | Experimental Testing | 2017 |
| 18 | Kettering University | | | Cybersecurity | 2019 |

# CAAT Seed Funding Courses and Modules on Hybrid or Electric Vehicles

| Partner # | Institution | Date | Modules | Courses |
|---|---|---|---|---|
| 1 | Lawrence Technological University | 2011 | 4 | 1 |
| 2 | Lewis and Clark Community College | 2011 | | 1 |
| 3 | Grand Rapids Community College | 2012 | 1 | |
| 4 | Lansing Community College | 2012 | 3 | |
| 5 | Grand Valley State University | 2013 | 1 | |
| 6 | Ivy Tech Community College | 2014 | 1 | |
| 9 | Wayne State University | 2015 | | |
| 10 | University of Alabama, Birmingham | 2015 | 1 | 1 |
| **Totals** | | | **11** | **3** |

# CAAT Seed Funding Courses and Modules on STEM

| Partner # | Institution | Date | Modules | Courses |
|---|---|---|---|---|
| 7 | Kent Intermediate School District | 2014 | 1 | |
| 8 | Utica Community Schools | 2014 | | 1 |
| **Totals** | | | **1** | **1** |

# STEM is Still the Foundation

- Physics
  - Newton’s Laws
  - Distance, velocity, acceleration, vectors
  - thermodynamics, energy, work, heat
  - electricity and magnetism
- Chemistry
  - the periodic table, chemical bonding
  - chemical reactions, energy, entropy
- Mathematics
  - algebra, trigonometry, pre-calculus

# CAAT Seed Funding Courses and Modules on Lightweighting

| Partner # | Institution | Date | Modules | Courses |
|---|---|---|---|---|
| 12 | Kettering University | 2016 | | 1 |
| 13 | Roane State Community College | 2017 | | 4 |
| 14 | Kettering University | 2016 | | 1 |
| 16 | Kettering University | 2016 | | 1 |
| **Totals** | | | **0** | **7** |

# Creation of an Automotive Lightweighting Course at Macomb Community College

- Used three CAAT Seed Funding, Kettering-Developed modules
- New Course: PRDE 2918 – Advanced Materials, 48 contact hours
- Taught as part of Michigan Advanced Technician Training ($MAT^2$) Program
- Good student success
  - 4 $A^-$, 3 $B^+$, 2 B, 1 $B^-$

# CAAT Seed Funding Courses and Modules on Connected/Automated Vehicles

| Partner # | Institution | Date | Modules | Courses |
|---|---|---|---|---|
| 11 | Jackson State University | 2016 | 1 | 2 |
| 15 | Springfield Technical Community College | 2017 | | 1 |
| 18 | Kettering University | 2019 | | 1 |
| **Totals** | | | **1** | **4** |

# Let's Look at an Example of the Results of a Seed Funded Course on Connected/Automated Vehicles

- Connected, Automated, and Intelligent Vehicles
- Created by Prof. Gary Mullett of Springfield Technical Community College
  - CAAT paid $20,000
- The course materials are available for free to anyone at the CAAT web site
  - Comprehensive syllabus with learning outcomes, course outline, and course map
  - 15 PowerPoint lectures
  - Quizzes and Projects

http://autocaat.org/webforms/ResourceDetail.aspx?id=4551

# All CAAT Seed Funding Materials are Avaliable on the CAAT web Site for Free!!!

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

| Topic | Modules | Courses |
| --- | --- | --- |
| Hybrid and/or Electric Vehicles | 11 | 3 |
| STEM | 1 | 1 |
| Connected, Automated Vehicles | 1 | 3 |
| Lightweighting | | 7 |
| Experimental Testing | | 1 |
| **Total** | **13** | **15** |

# Auto Industry Message to CAAT

- We need technicians
- We won't hire traditional service technicians
- We will hire your electronics technicians, but…. we have to train them on automotive skills
- We want you to educate a new type of automotive technician that we (OEMs and suppliers) can hire directly out of college
  - Vehicle Development Technician (VDT)

# Collaborating with Industry CAAT Created A New Associate of Applied Science Degree in Automotive Technology

- VDT needs to learn additional skills in addition to traditional service technician mechanical skills
  - Electronic
  - Computer
  - Experimental testing
- Combine courses from Automotive Technology, Engineering Technology, and Information Technology
- Two new courses are also needed
  - Connected/Automated Vehicles
  - Vehicle Experimental Testing

# CAAT Seed Funding Process was used to Develop Two New Courses Needed for the VDT Degree

- Connected, Automated Vehicles, and Intelligent Vehicles
  - Based on Springfield Technical Community College, #15 (became AUTO 2000 at Macomb Community College)
- Vehicle Experimental Testing
  - Based on University of Alabama, Birmingham, #17 (became ELEC 2310 at Macomb Community College)

# Vehicle Development Technician (VDT)

- 2-year Associate of Applied Science Degree in Automotive Technology
- Will work with engineers at an OEM or supplier
- Will work on test and prototype systems – no service manual
- In addition to mechanical skills, has skills in
  - Electronics
  - Information technology
  - Experimental testing
- Began Fall 2018 at Macomb Community College
  - http://ecatalog.macomb.edu/?_ga=2.206542995.1092588604.1552394959-311990549.1547492829

# Automotive Technology-Vehicle Development Technician Associates Degree

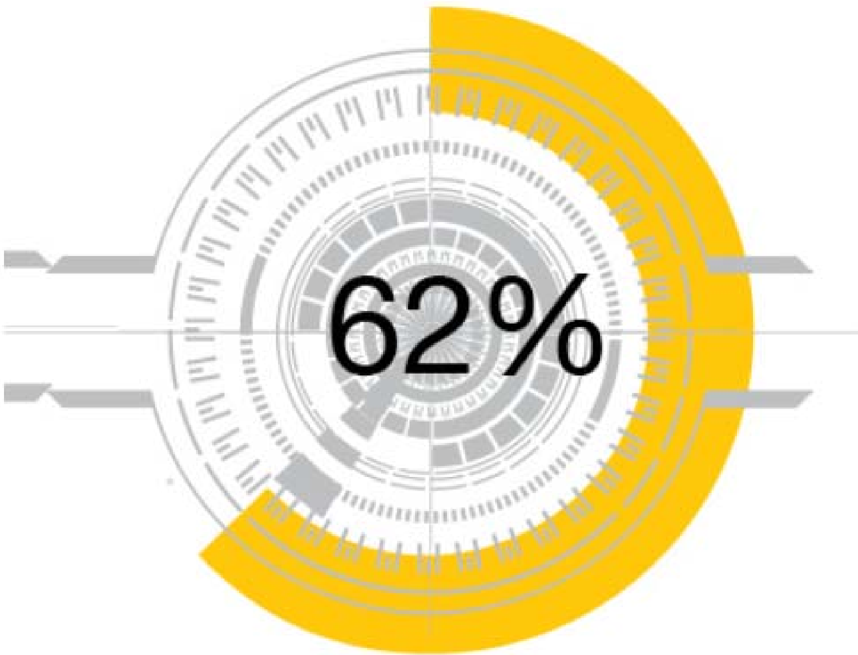
| Course and Sequence | Course Title | Semester 1 | Semester 2 | Semester 3 | Semester 4 | Credits |
|---|---|---|---|---|---|---|
| AUTO-1000 | Automotive Systems | 3 | | | | 3 |
| AUTO-1040 | Automotive Electrical I | | 3 | | | 3 |
| AUTO-1050 | Automotive Electrical II | | | 3 | | 3 |
| AUTO-1100 | 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 |

# CAAT Identified the Need for an Automotive Cybersecurity Course

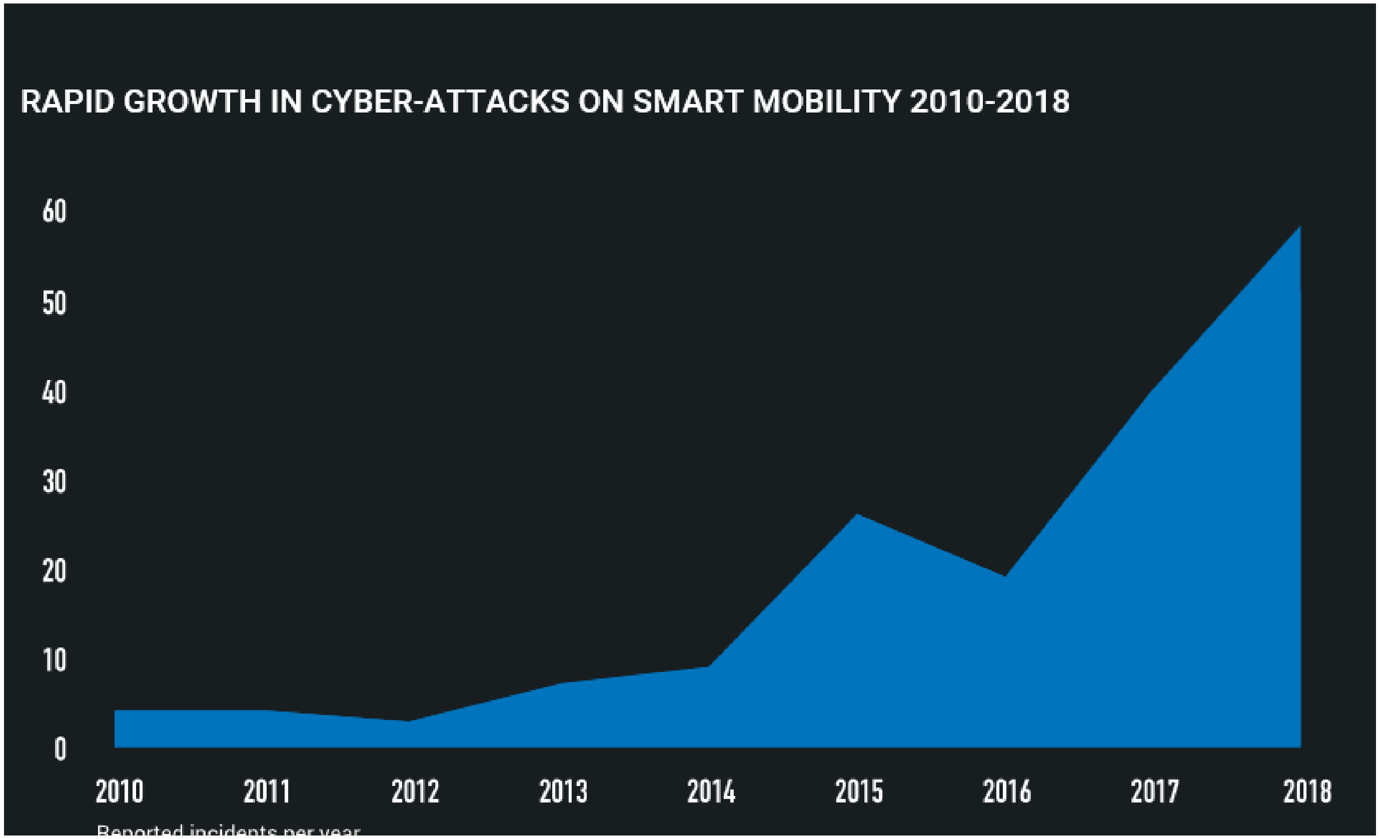
- Connected Vehicles: vehicles are becoming nodes on the Internet of Things
  - GPS, wireless, OTA, DLC attack surfaces
- Vehicle software is not keeping pace with automotive technology
  - Cybersecurity needs to be considered in the initial design, not added in afterwards

https://www.sae.org/binaries/content/assets/cm/content/topics/cybersecurity/securing_the_modern_vehicle.pdf

**More Data and Connectivity of Vehicles Increases the Risk of Cyber-Attacks**




of respondents think it is likely or very likely that malicious attacks on their software or components will occur within the next 12 months



RAPID GROWTH IN CYBER-ATTACKS ON SMART MOBILITY 2010-2018
60
50
40
30
20
10
0
2010
2011
2012
2013
2014
2015
2016
2017
2018

# Keeping Vehicles out of Bad Headlines

- HACKERS REMOTELY KILL A JEEP ON THE HIGHWAY—WITH ME IN IT
- **Report warns of possible mass casualties from automotive cyberattacks**
- GM TOOK 5 YEARS TO FIX A FULL-TAKEOVER HACK IN MILLIONS OF ONSTAR CARS
- **Vehicle Cyber Attacks Rise Six-Fold, Exposing Digital Weakness**

# Automotive Cybersecurity

- NHTSA
  - Cybersecurity, within the context of road vehicles, is the protection of automotive electronic systems, communication networks, control algorithms, software, users, and underlying data from malicious attacks, damage, unauthorized access, or manipulation.

**ADDITIONAL RESOURCES**

- NHTSA AND VEHICLE CYBERSECURITY PDF, 196.08 KB
- AUTOMATED VEHICLES SYMPOSIUM 2016
- CYBERSECURITY BEST PRACTICES FOR MODERN VEHICLES PDF, 2.69 MB
- FEDERAL REGISTER NOTICE ON AUTOMOTIVE CONTROL SYSTEMS
- AUTOMOTIVE CYBERSECURITY TOPICS & PUBLICATIONS
- CRASH AVOIDANCE TECHNICAL PUBLICATIONS
- ELECTRONIC SYSTEMS PERFORMANCE IN PASSENGER MOTOR VEHICLES
- VEHICLE CYBERSECURITY ROUNDTABLE

https://www.nhtsa.gov/crash-avoidance/automotive-cybersecurity

# CAAT Development of Automotive Cybersecurity Course Using Seed Funding

- Re-vamp CAAT seed funding model
- 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
  - 8 proposals received
- Step 3: Choose best proposal
- Step 4: Contract issued, March 4, 2019
  - Kettering University
- Step 5: Review course materials, approve, and post for free use on CAAT web site on August 7, 2019

Kettering University Proposal was Funded by CAAT

Prof. Mehrdad Zadeh, Electrical and Computer Systems Department

Prof. Craig Hoff, Dean, Mechanical Engineering

# Course Outline

1. Understanding Threat Models
   - Identify areas with the highest risk components
   - Threat modeling & identification
   - Threat rating systems
2. Bus Protocols & Vehicle Communication
   - CAN bus and diagnostic link connector (DLC) - OBD-II
   - CAN Bus Packet Layout
   - Media Oriented Systems Transport (MOST)
   - SocketCAN interface
   - Diagnostics/Logging, CAN Security, ISO-TP protocol
   - SAE J1698 Standard
3. Automotive Electronics and ECUs
   - Introduction to ECUs, software, and firmware
   - ECU Hacking
4. Attacking Vehicles
   - Classes of attack vectors
   - SAE J2534 & tools
   - In-vehicle infotainment (IVI) system & remote attacking
5. Defining Frameworks for Cybersecurity in Vehicles
   - J3061
   - ISO 21434
6. Attacking Connected/automated vehicles
   - V2V and V2I communication
   - IEEE 1609 & Wireless Access in Vehicular Environments (WAVE)
   - Attacking Wireless Systems
   - Potential attacks on automated vehicles
7. Protecting Vehicles from Attacks
   - Cybersecurity protection methods
   - Penetration testing
   - Security Credentials Management System (SCMS)

# Learning Outcomes

- Understand potential cybersecurity threats for automotive systems;
- Identify areas in cars with the highest risk components;
- Understand threat modeling and identification in the automotive industry;
- Understand the basics of threat rating systems for the cybersecurity of cars;
- Become familiar with the various types of bus protocols and communications in vehicles;
- Understand the concept of diagnostics/logging with security considerations;
- Become familiar with important ISO and SAE standards from cybersecurity point of view and the roll of various organizations in the development and evolution of these standards;
- Understand the basic concepts of automotive electronics and ECU from cybersecurity point of view;
- Become familiar with ECU hacking and the roles of software and firmware in the hacking process;
- Understand various methods of attacking vehicles;

# Learning Outcomes

- Be familiar with classes of attack vectors in the current automotive industry;
- Understand the fundamental principles of protocols and standards related to attacking vehicles;
- Understand the In-vehicle infotainment (IVI) system
- Become familiar with several remote attacking methods;
- Become familiar with the concepts and standards for defining frameworks regarding cybersecurity of vehicles;
- Understand the fundamentals of attacking connected/automated vehicles;
- Become familiar with basics of V2V and V2I communication technology;
- Become familiar with important standards and protocols regarding wireless access in vehicles;
- Understand the potential for attacks on automated vehicles;
- Become familiar with cybersecurity protection methods;
- Understand penetration testing and related methods;

# Course Materials

- Comprehensive syllabus
- Seven Lectures
- Homework for each topic
- Quizzes for each topic
- Experiments
- Projects

# To Download CAAT Course Materials for Free

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

# 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
- 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)

# The Automotive Future

- Electrified
- Uses sophisticated sensors
- Electronically controlled (automated)
- Connected
- Environmentally friendly, sustainable, safe, and secure
- Coming fast

## 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/

**Come to the free CAAT Conference on May 8, 2020**

We can **evade reality**, but we cannot evade the consequences of evading reality.

-- Ayn Rand

May you live in interesting times.

-- Purported Chinese Curse

# Contact Information

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www.autocaat.org

# Thank You!

# Questions?

# Backup Slides

# 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<br>AUTO 1050 Automotive Electrical II | 3<br>3 |
| Other | AUTO 2000 Connected, Automated, Intelligent Vehicles (NEW COURSE) | 3 |
| **Engineering Technology/Electronics** | | |
| Fundamentals | TMTH 1150 RCL Analysis<br>ELEC 1161 Electronic Technology 1<br>ELEC 1171 Electronic Technology 2 | 4<br>3<br>3 |
| Applications | ELEC 1211 Digital Electronics Basics<br>ELEC 2150 LabVIEW Basics 1 | 3<br>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 |

# National Automotive Service Task Force (NASTF)

- Formed to connect OEMs and independent techs
- Vehicle Security Professional (VSP) and Service Data Release Model (SDRM)
  - aftermarket access to security sensitive information related to automobiles, including key codes, PIN numbers, immobilizer reset information and similar types of information
  - Locksmiths and service technicians qualified in vehicle security system repairs need a subscription to the NASTF VSP
- Example: J2534, re-flashing
- Note: this is not what is meant by Vehicle Cybersecurity