# Autonomous Vehicles

Minnesota House Committee on Transportation
**March 8, 2018**

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# Today’s objectives

- How did we get here?
- Why did we come here?
- Where are we going?
- When will we get there?
- What should policymakers do?

# How did we get here?

# “New” Vehicle Technology

From the labs...

POPULAR SCIENCE Monthly

## The Car That Drives Itself

***The car in your future will be run by black boxes while you watch. Here's a peek at what's coming***

**By Martin Mann**

I DROVE a car no hands. It steered itself safely down the center of the lane, up the straightaway and around a hairpin, automatically following an electronic track.

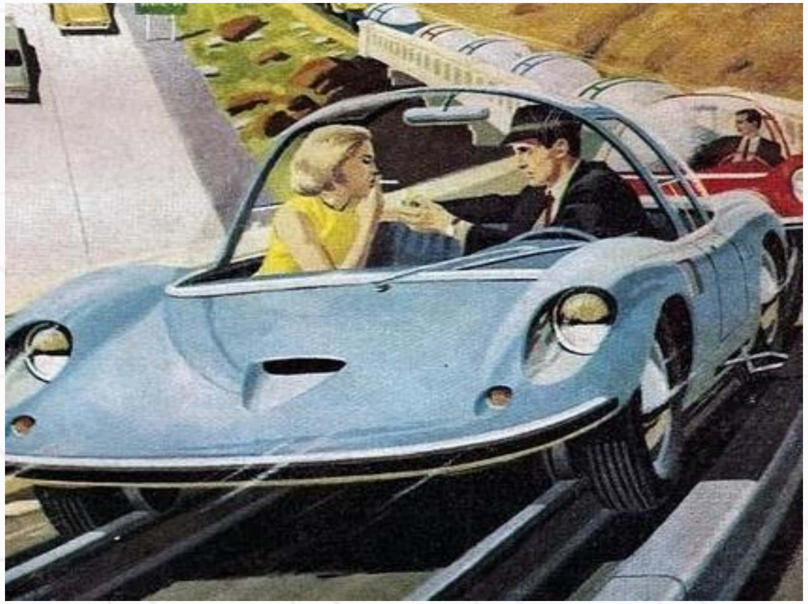
Sure, the job I rode was experimental—strictly a breadboard rig cobbled into a green Chevy. It automates steering alone, and that only on a one-mile-long GM test road and a 300-foot stretch of Nebraska Highway 2, which are the two places in the world equipped with the electronic guiding track that is needed.

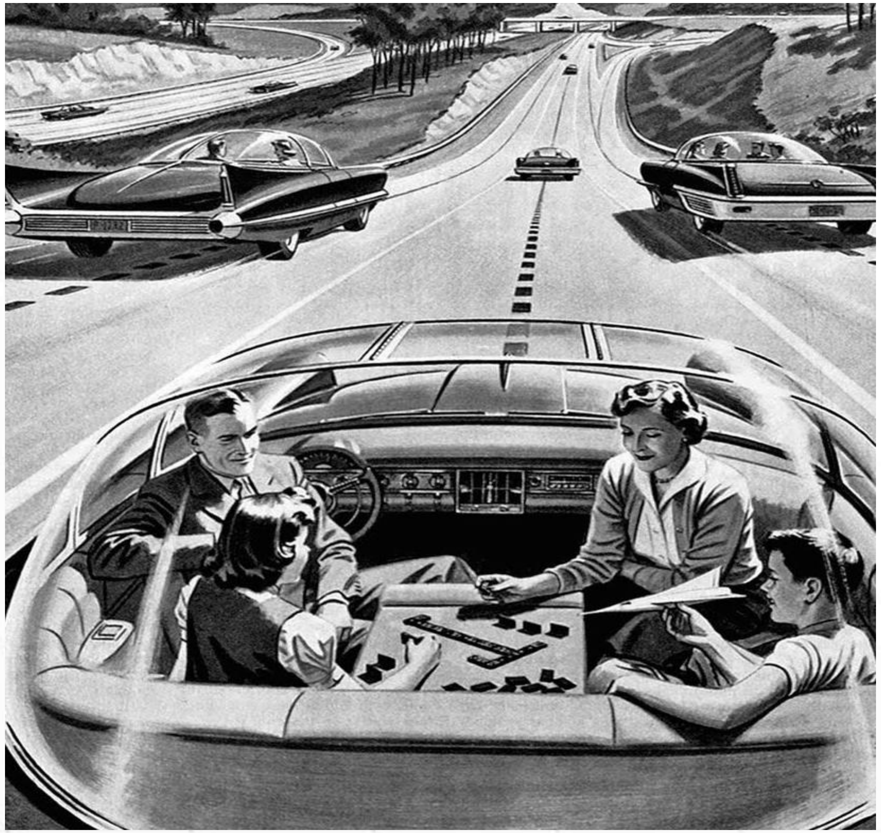
Yet it is significant because it is one of several steps leading straight to the car that drives itself. And that, a tour of Detroit research palaces convinced me, is definitely coming. Not this year, probably not next, but still soon.

Idea men at Ford, General Motors and Chrysler are noodling over a problem you know well: Broad expressways crisscross the country for high-speed, no-stop trips betweeen cities. Powerful, roomy cars make such travel convenient. But . . .

Beguiling roads and cars invite heavy

MAY 1958 75





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# Existing Vehicle Technologies

## Not a "computer on wheels"

AIR-FUEL RATIO SENSOR, AIR-TEMPERATURE SENSOR, BAROMETRIC PRESSURE SENSOR, COOLANT LEVEL SENSOR, COOLANT TEMPERATURE SENSOR, CRANKSHAFT POSITION SENSOR, ELECTRONIC FOOT PEDAL SENSOR, FUEL RESTRICTION SENSOR, FUEL TEMPERATURE SENSOR, HALL EFFECT SENSOR, KNOCK SENSOR, MANIFOLD ABSOLUTE PRESSURE SENSOR, MANIFOLD AIR TEMPERATURE SENSOR, MASS AIRFLOW SENSOR, OIL LEVEL SENSOR, OIL PRESSURE SENSOR, OIL TEMPERATURE SENSOR, OXYGEN SENSOR, SPEED SENSOR, STARTER LOCKOUT SENSOR, SYNCHRONOUS REFERENCE SENSOR, THROTTLE POSITION SENSOR, TIMING REFERENCE SENSOR, TIRE-PRESSURE SENSOR, TORQUE TRANSDUCER SENSOR, TRANSMISSION FLUID TEMPERATURE SENSOR, TURBINE SPEED SENSOR, TURBOCHARGER BOOST SENSOR, VANE AIRFLOW SENSOR, VEHICLE SPEED SENSOR…

## …but dozens of computers on wheels!

# Automated Vehicle Technology

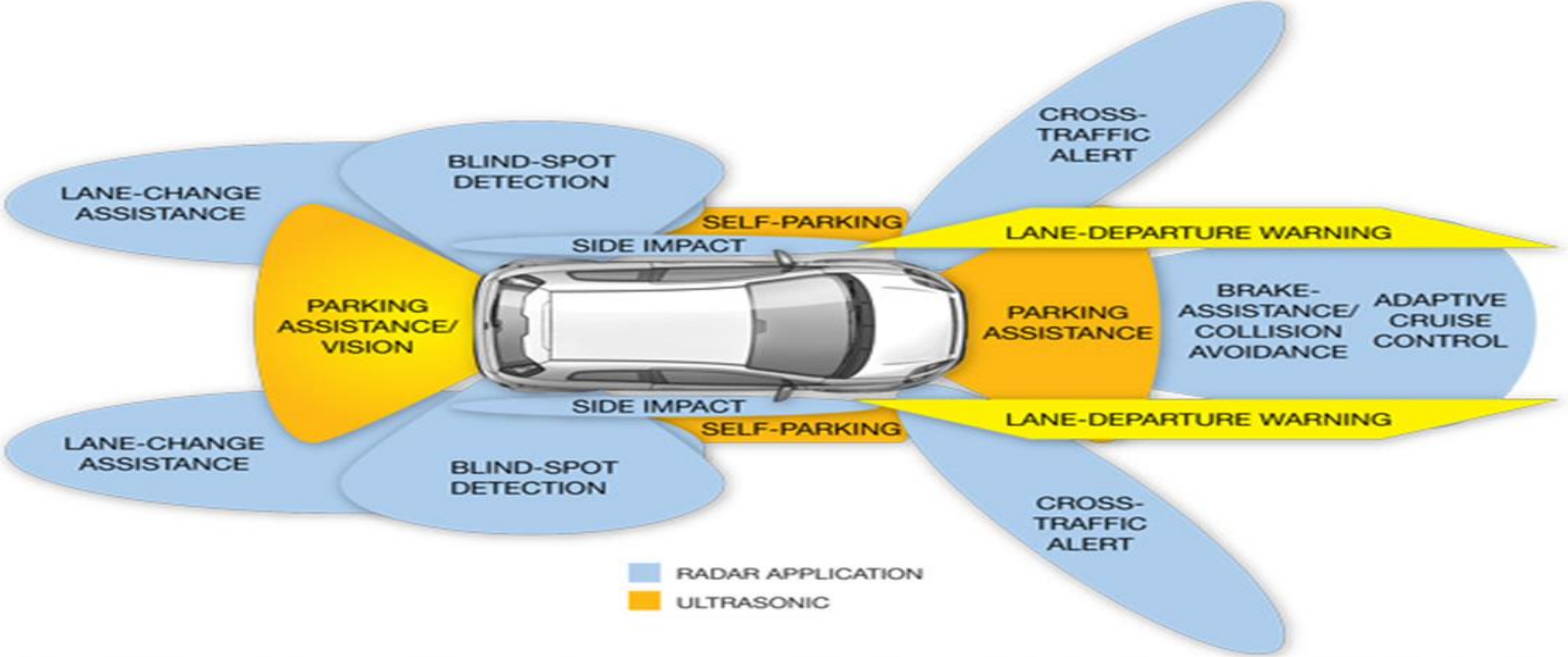
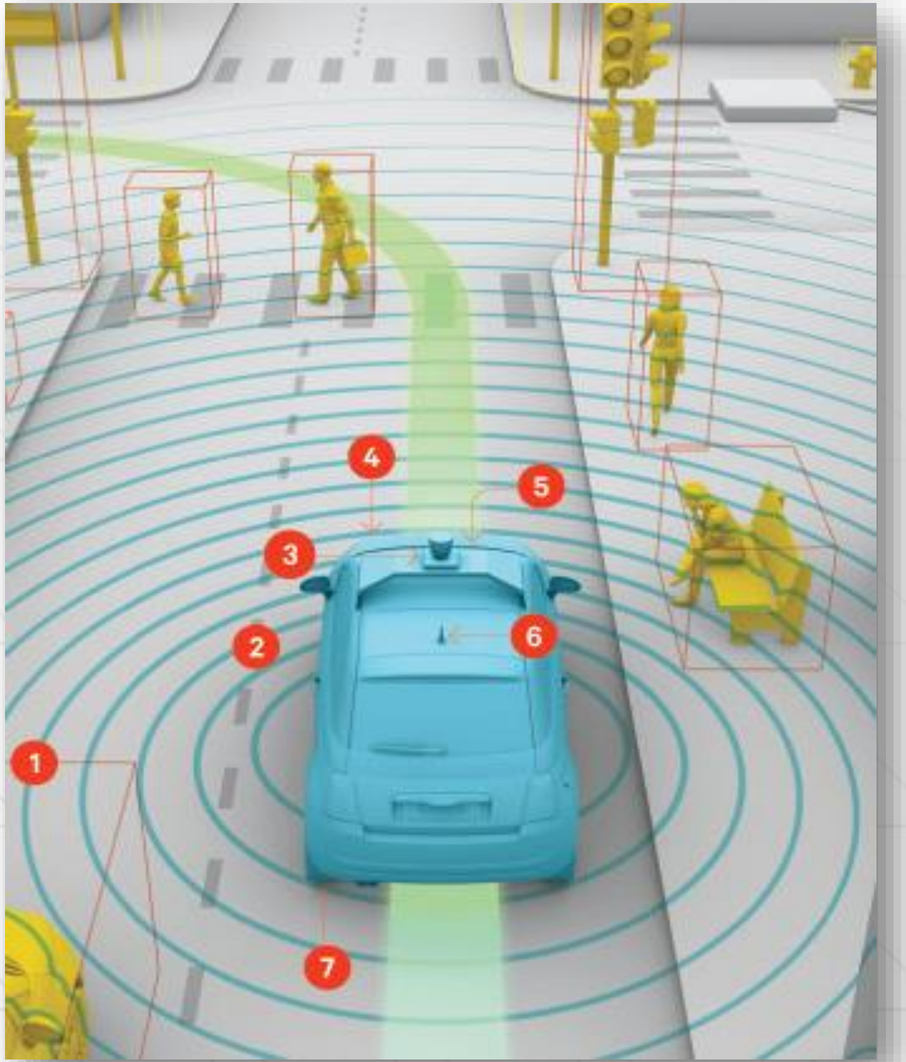



Figure 2 Several driver-assistance systems are currently using radar technology to provide blind-spot detection, parking assistance, collision avoidance, and other driver aids (courtesy Analog Devices).

# Automated Vehicle Technology




1. **Radar:** Detects objects nearby & in “blind zones”
2. **Lane–keeping Cameras:** Measures contrast between road and lines
3. **LIDAR:** Spinning lasers make a 360º real–time “map” around vehicle
4. **Infrared Camera:** Detects objects ahead in the day & night
5. **Visible Light Camera**: Detects & predicts movement of objects
6. **GPS Navigation:** Advanced mapping tells the vehicle where to go
7. **Wheel–mounted Sensors:** Measures velocity relative to close objects

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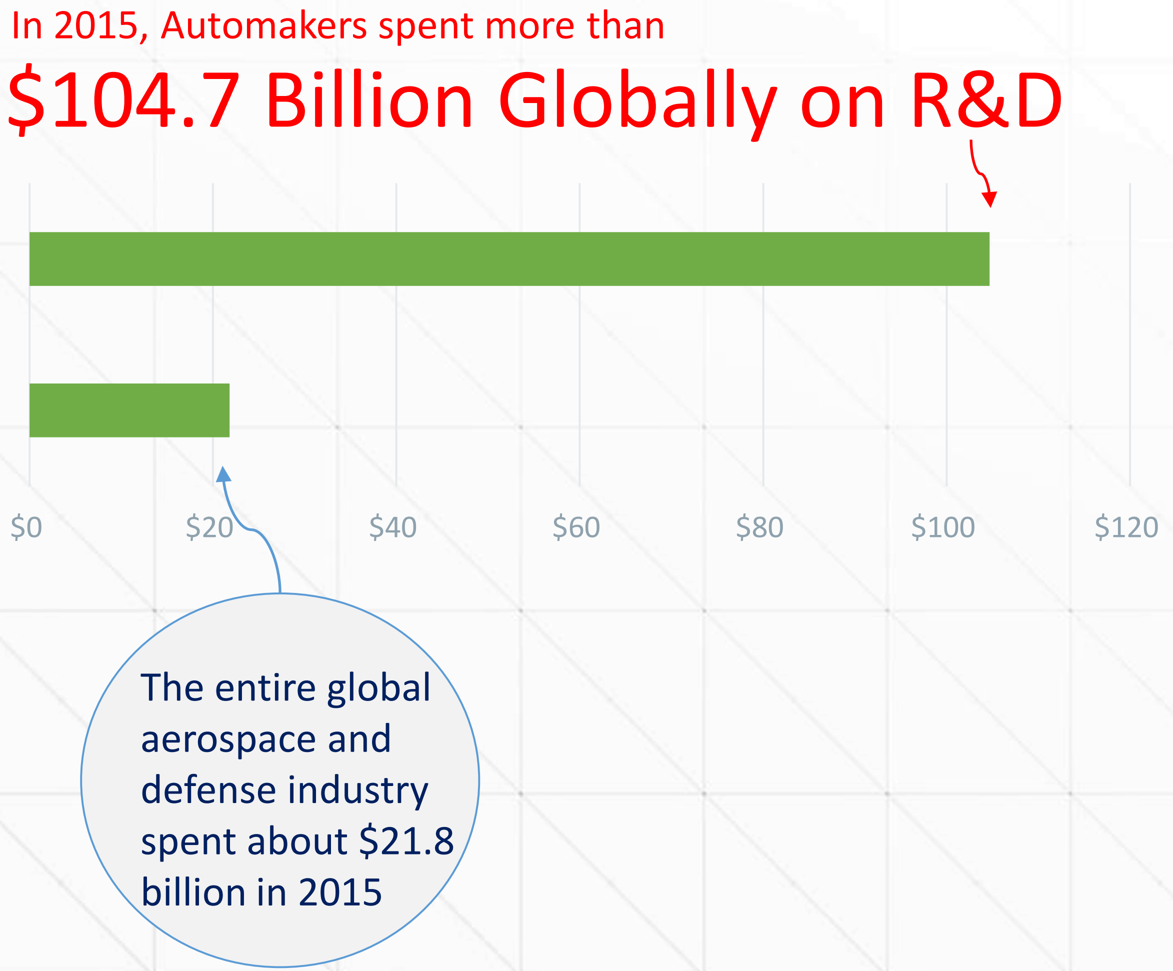
# Investment Leads to Change




- Billions and billions invested in R&D on automated vehicle technologies.
- Many believe auto industry will change more in next 10 years than it has in last 50 years.

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# Why did we come here?

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# Benefits are Many

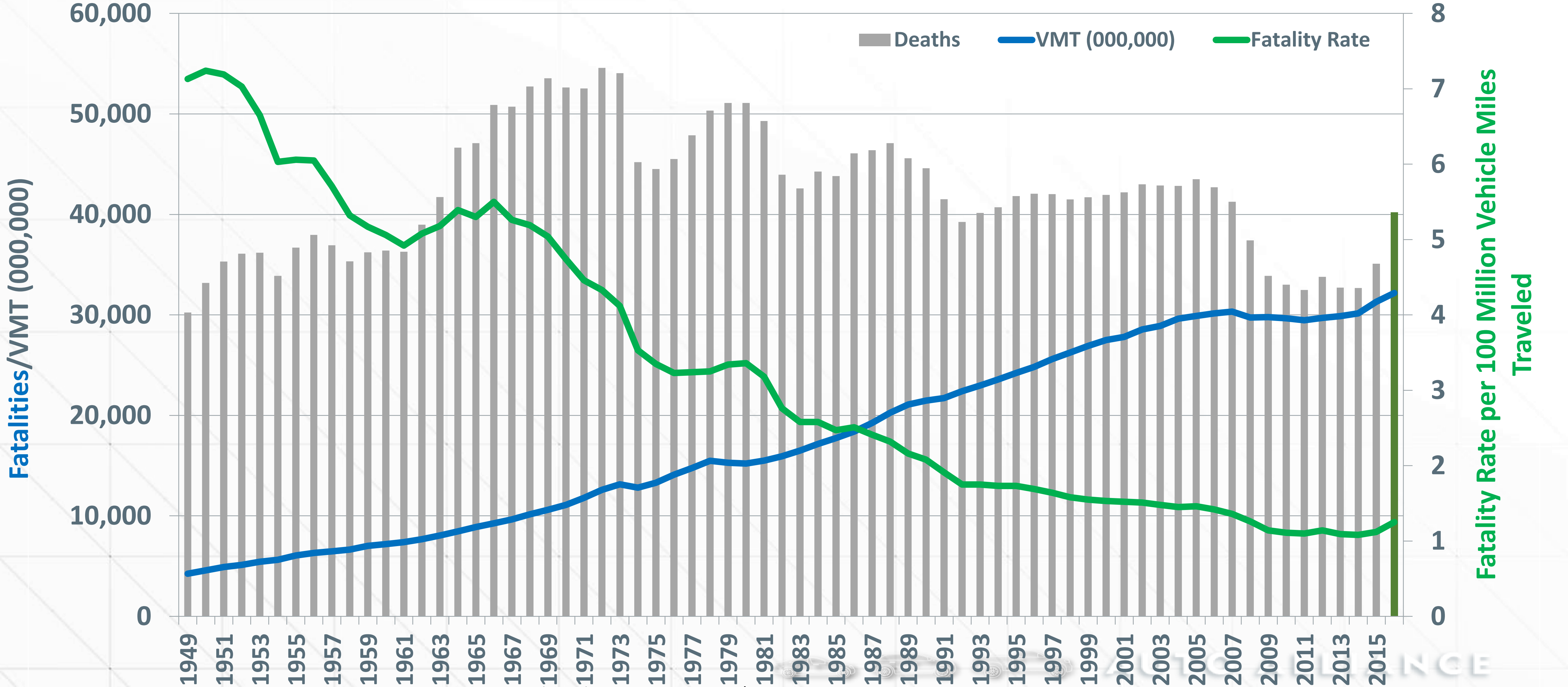
Automation =

- Increased Safety
- Reduced Environmental Impact
- Expanded Roadway Capacity
- Enhanced Mobility
- More Efficient Land Use

# Safety

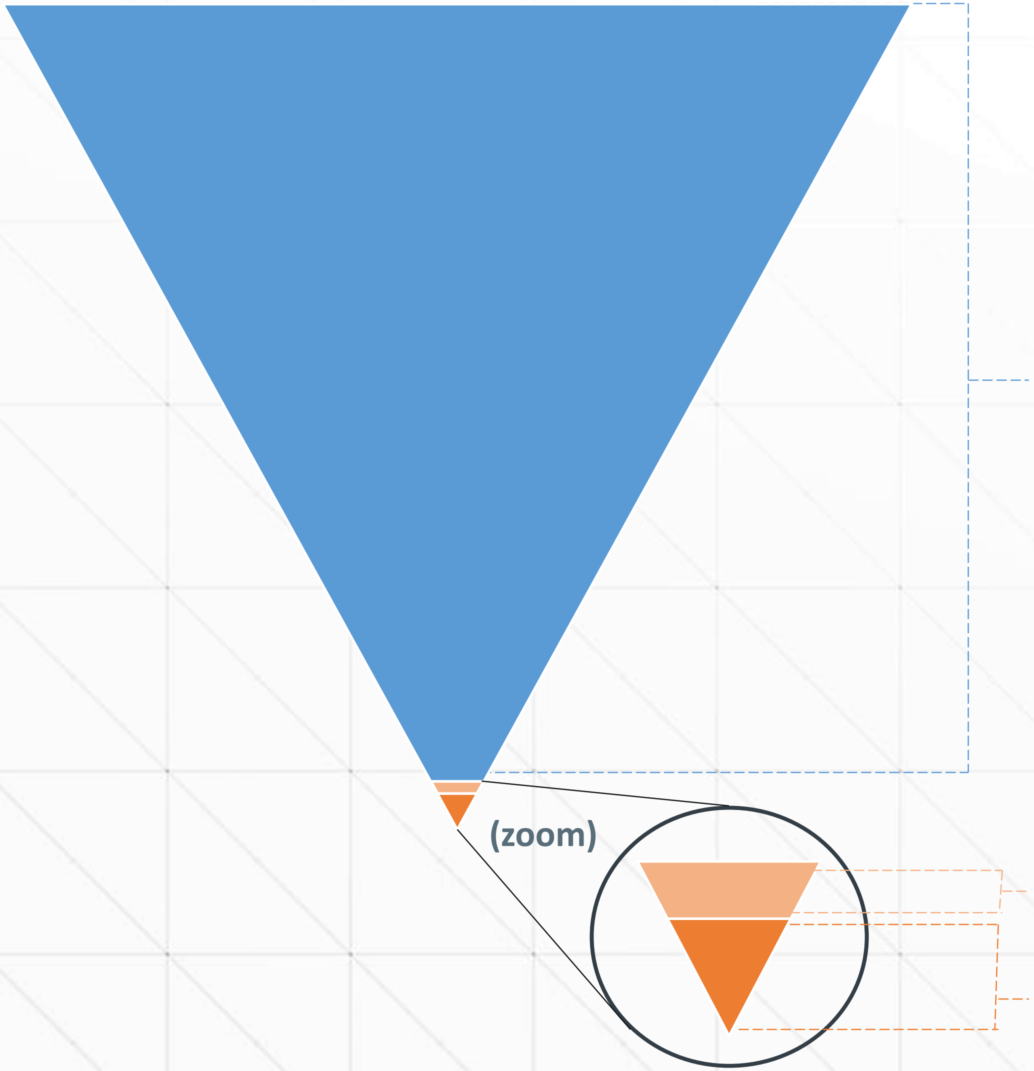

- 1.25 million people died globally in 2015
- 35,092 people died on U.S roadways in 2015

# Vehicles Safer, More to Do




Figures compiled from 2015 Fatality Analysis Reporting System (FARS) at www.nhtsa.gov/FARS

# Human vs. Car




## 37,491: 2016 Total Fatalities from Motor Vehicle Traffic Crashes

### 94% Fatalities Related to Human Error

- While 87% of Americans now buckle up, about half of all of all vehicle occupant fatalities in 2015 were not wearing safety belts.

- Alcohol-impaired drivers make just 0.25% of trips taken in the U.S., but that fraction of a percent results in nearly 1/3 of this country's motor vehicle fatalities.

**1% (374) Fatalities Related to Possible Defects or Maintenance with Motorcycles, Medium-Heavy Duty Trucks and Misc. Vehicles**

**2.46% (922) Fatalities Related to Possible Defects or Maintenance in Light Duty Vehicles**

Source: 2016, National Highway Traffic Safety Administration's (NHTSA) Fatality Analysis Reporting System (FARS).


Environmental
• Fewer accidents means less congestion
• Less congestion means increased fuel efficiency and lower emissions

# Infrastructure Demands

- AV can travel more closely expanding roadway capacity
- AV can augment public transit efficiently

# Mobility

- Automated technology gives freedom of mobility to those who otherwise might not be able to get around easily
- Disabled, young, old – all now liberated to move about safely

# Efficient Land Use

- AV can change traditional use practices
- AV can easily be shared, increasing utility

Exports

High-Tech Materials

Innovation

Technology

Auto Jobs

Safety

Automotive Recycling

Design & Testing

# Where are we going?

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# Change is Coming

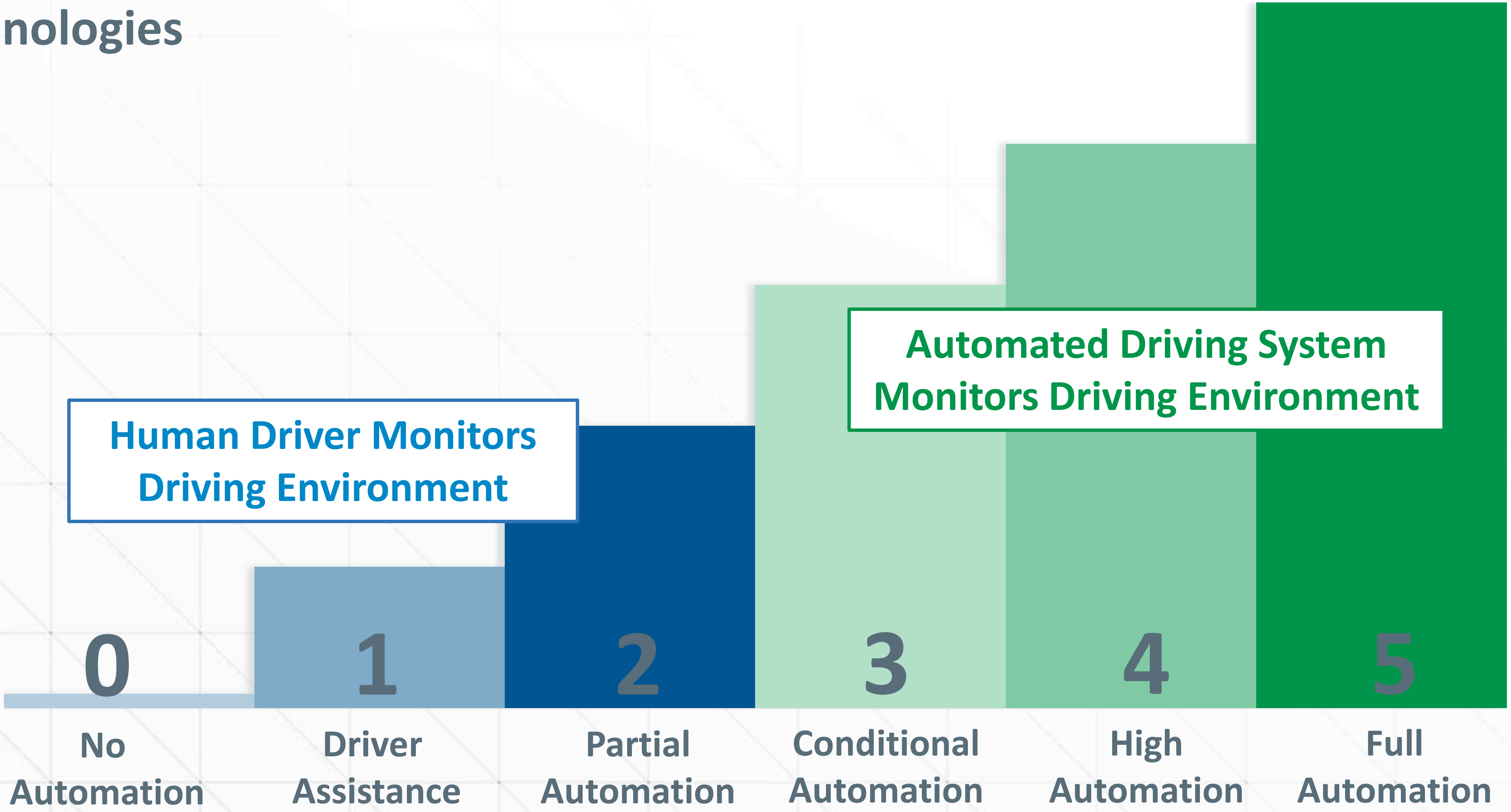
“We are on the cusp of a new era in automotive technology with enormous potential to save lives, reduce greenhouse gas emissions, and transform mobility for the American people,”

-Former U.S. Transportation Secretary Anthony Foxx.

# SAE Levels of Autonomy

**Common Language** - To help policymakers and engineers begin to speak the same language, the Society of Automobile Engineers developed categories of automation to delineate between technologies

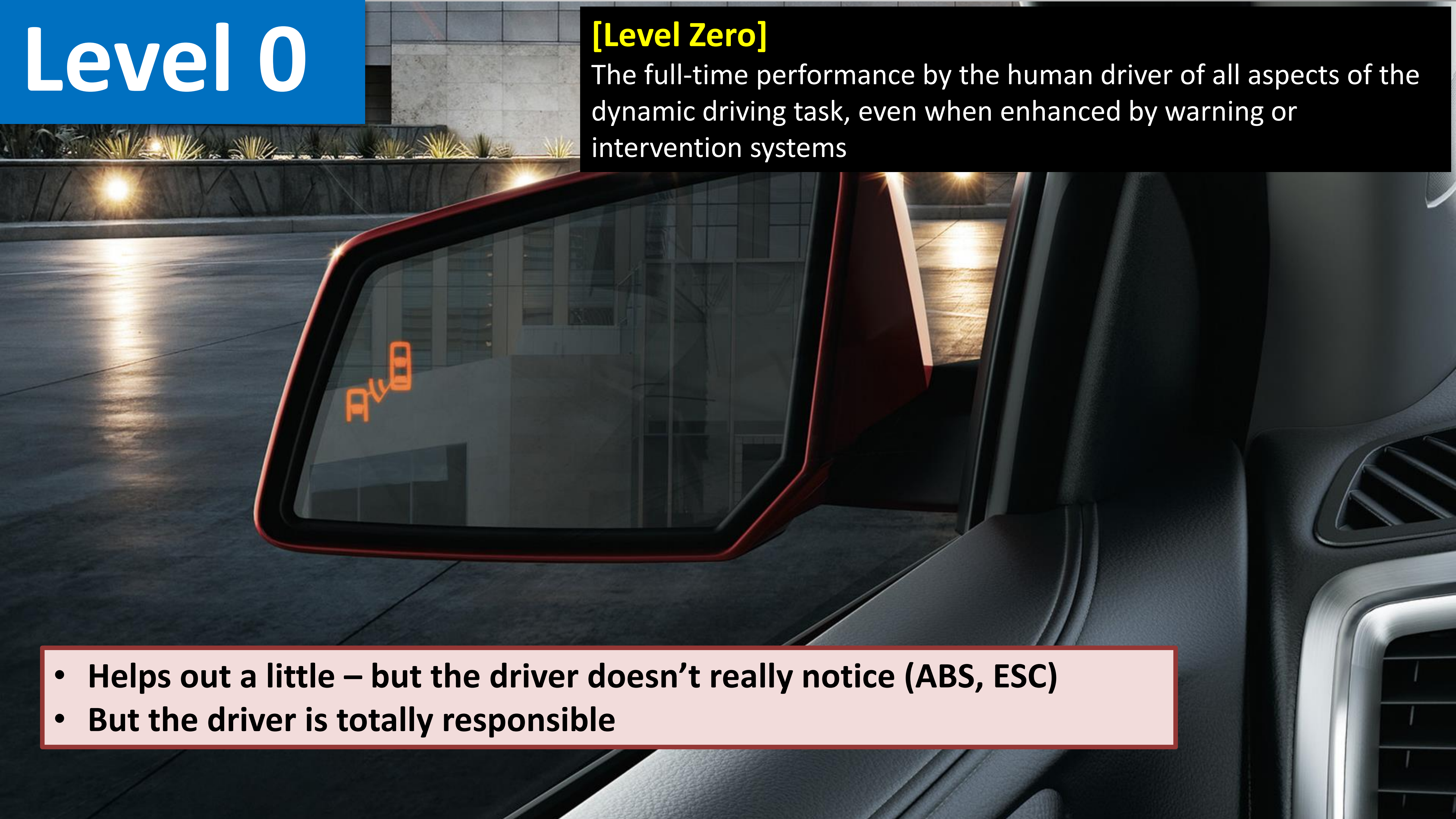
SAE INTERNATIONAL
Levels of Driving Automation



# Level 0

**[Level Zero]**

The full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems

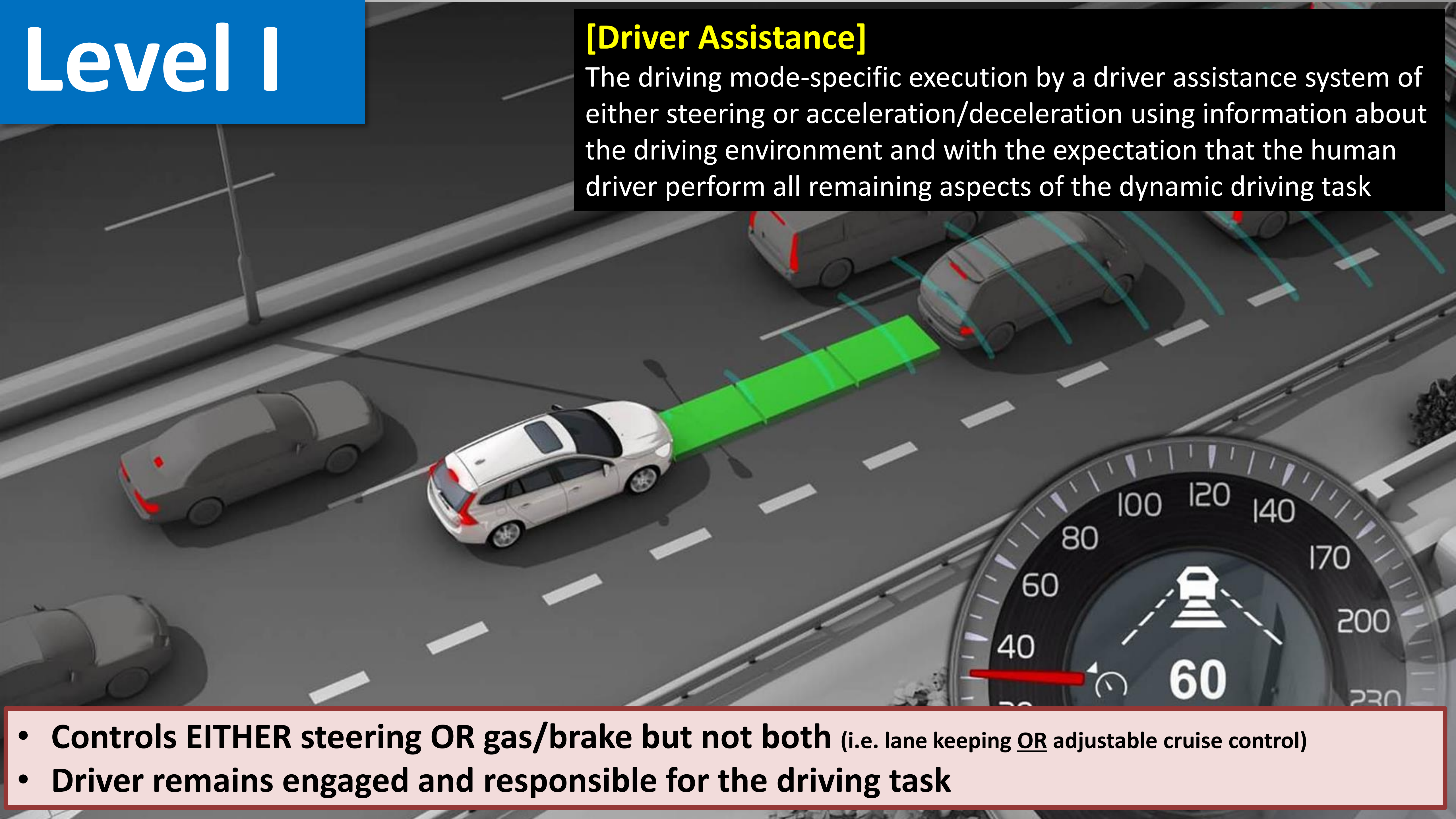


- **Helps out a little – but the driver doesn't really notice (ABS, ESC)**
- **But the driver is totally responsible**

# Level I

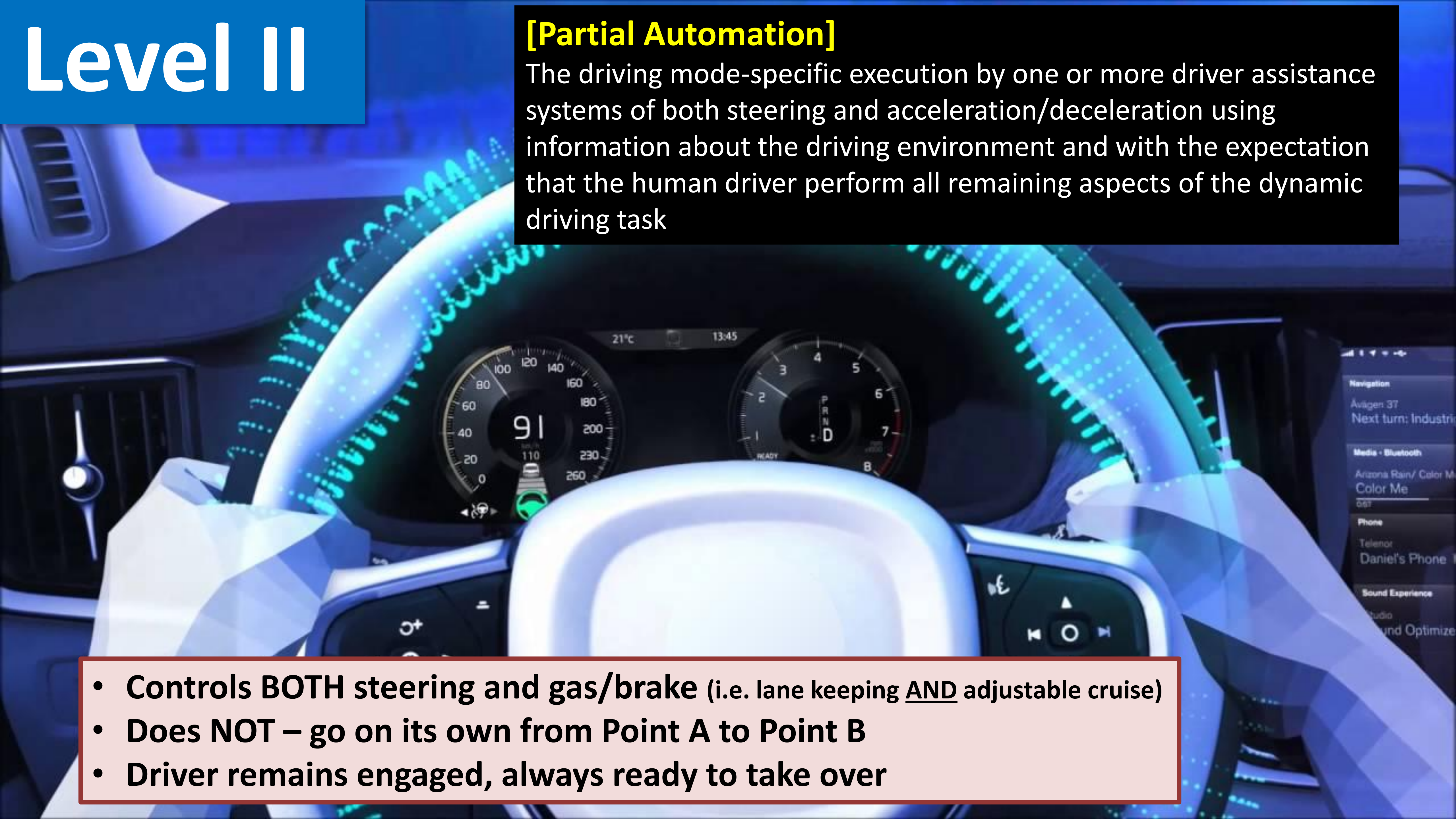
**[Driver Assistance]**

The driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task




- **Controls EITHER steering OR gas/brake but not both** (i.e. lane keeping <u>OR</u> adjustable cruise control)
- **Driver remains engaged and responsible for the driving task**

# Level II




**[Partial Automation]**

The driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task

- **Controls BOTH steering and gas/brake** (i.e. lane keeping AND adjustable cruise)
- **Does NOT – go on its own from Point A to Point B**
- **Driver remains engaged, always ready to take over**

# Level III

**[Conditional Automation]**

The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene


- **In full control within limits – but not anywhere or anytime**
- **Driver remains prepared to take over**

# Level IV

**[High Automation]**
The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene

- **Able to drive entirely on its own in designated areas**
- **No human driver is necessary (ADS is the fallback)**
- **Can travel from Point A to Point B**

# Level V

**[Full Automation]**

The full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver

- **Free to go anywhere at any time – no curfew and no radius**
- **Steering wheel and brakes unnecessary**

# So, WHEN are they coming?

# The Future is Coming

- Timing is difficult to predict

- Many experts expect Level 3 and Level 4 technologies to be on the road in 3 to 5 years

- First deployment likely not privately-owned automobiles

The first deployment of AV may be in more controlled, commercial settings such as:

- Ride Sharing
- Geo-fenced campuses
- Fleets

# Timetable

| Year | Vehicle Sales | Fleet Share |
| --- | --- | --- |
| 2020 | 2-3% | 1-2% |
| 2030 | 20-40% | 10-20% |
| 2040 | 40-60% | 20-40% |
| 2050 | 80-100% | 40-60% |

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# What should policymakers do?

Auto Jobs

Exports

Safety

High-Tech Materials

Innovation

Technology

Automotive Recycling

Design & Testing

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# Challenge for Legislators

Initial, limited deployments likely coming soon, yet broad acceptance will take many years.

Insurance Institute of Highway Safety stated that if Level 4 and Level 5 technologies were mandated today, it would take **25 years** for 95% of the U.S. fleet to roll over.

How to juggle both realities?

# Challenges to Successful Deployment

| | |
|---|---|
| Transition | How quickly will human drivers learn to share road with AVs? |
| Laws | How will manufacturers navigate conflicting federal & state requirements? |
| Costs | How will consumers respond to initially higher costs of AV technology? |
| AV Safety | Will AVs analyze and react to risky situations the same way a human driver would? |
| Human Driver Safety | Will human drivers learn to interact with AVs in a consistently safe manner? |
| System Failures | What happens if an AV's computer system fails while in operation? |
| Ethics | How would an AV choose between alternatives that risk occupants and those outside vehicle? |
| Liability | Who is liable for a crash when an AV is at least partially at fault? |
| Security | Can an AV's data system be protected against hackers? |
| Data Privacy | How will consumer privacy be protected when using an AV? |
| Travel | How will policymakers manage rise in VMT resulting from less burdensome driving task? |
| Infrastructure Issues | What street and highway technology will be needed? How will it be funded? |

# Federal Guidance

## Clear Delineation of Responsibilities

- States should NOT codify the FAVP
- FAVP maintained traditional roles

Federal government (DOT, NHTSA):

- Controls design, construction, and performance of vehicle
- Federal government regulates *the vehicle*

State governments:

- Control insurance, licensing, registration, and law enforcement
- State governments regulate *the driver*

# Where to Start?

**States should first focus on removing impediments to testing and deployment**

- Review of existing laws and definitions
- Review rules of road
- Standardize infrastructure
- Convene stakeholder groups
- Identify lead agency

# Where has Minnesota Started?

Governor Dayton Executive Order on Connected and Automated Vehicles

Successful Super Bowl LII Autonomous Shuttle Testing/Deployment

# Ready, Aim, Fire!

Auto Industry wants to be partners in effort

Everyone benefits from policy done right

No one benefits from policy done wrong

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