An Introduction to Connected Automated Vehicles

2017 Advanced Technologies in Transportation Symposium
May 9, 2017
National Transportation Research Center
The Scale of the Problem

Safety
- 35,092 highway deaths in 2015
- 6.3 million crashes in 2015
- A leading cause of death for ages 1-44

Mobility
- 6.9 billion hours of travel delay
- $160 billion cost of urban congestion

Environment
- 3.1 billion gallons of wasted fuel
- 60 billion lbs of additional CO₂

Data Sources:
2 10 Leading Causes of Death by Age Group, United States – 2014, Centers for Disease Control and Prevention
3 2015 Urban Mobility Scorecard, Texas A&M Transportation Institute and INRIX (August 2015)
The Opportunity
Why Now?

Image Source: http://www.computerhistory.org

Image Source: http://images.thecarconnection.com
The Challenge

- Intelligent vehicles cannot achieve human levels of performance until machine vision systems achieve human levels of performance (James Albus, 2009)
- Measure of human performance in 2015, in the U.S.:
  - 500,000 miles driven between crashes (approximately 1.9 years)
  - 1.8 million miles driven between injury crashes
  - 98 million miles driven between fatal crashes (approximately 370 years of operation between extreme failures)
Topics

1. What are Connected Vehicles?
2. What are Automated Vehicles?
3. What are State & Local Agencies Doing?
4. What is USDOT Doing?
5. How Does this Impact YOU?
What are Connected Vehicles?
Connected Vehicle Technology

5.9GHz DSRC (Dedicated Short Range Communications) + GNSS

• 802.11p technology similar to 802.11a
• Low latency communication (<< 50ms)
• High data transfer rates (6 – 27 Mbps)
• Line-of-sight, point-point-point communication range of up to 1000m
• Coverage over 360°
• Multi-hopping possible for extended range
• 7 channels support a wide range of safety and non-safety applications
Connected vehicles includes...

**Drivers/Operators**

**Vehicles and Fleets**

**Infrastructure**

**Wireless Devices**
**Infrastructure Messages**
- Signal Phase and Timing
- Fog Ahead
- Train Coming
- Drive 35 mph
- 50 Parking Spaces Available

**Vehicle Data**
- latitude, longitude, time, heading angle, speed, lateral acceleration, longitudinal acceleration, yaw rate, throttle position, brake status, steering angle, headlight status, wiper status, external temperature, turn signal status, vehicle length, vehicle width, vehicle mass, bumper height
Curve Speed Warning

Alerts the driver if current speed is too fast for an approaching curve

- Target crashes approaching horizontal curves on segments or interchange ramps that are speed-related
- Alert cars and trucks they are entering a curve at too high a speed to negotiate it safely
- Improve:
  - Reduction in truck rollover and in road departure crashes
Red Light Violation Warning

Issues warning to the driver if he/she is about to run a red light

- Target crashes that result from signal violations
- Wireless exchange of critical safety and operational data
- Reduce the frequency and severity of safety-related incidents
- Improves:
  - Significant reduction in collisions, injuries, and fatalities at intersections
  - Non-recurring congestion resulting from incidents is reduced
Eco-Signal Operations Overview

Combined Modeling of Applications: Resulted in a 9.6% reduction in fuel consumption.

Use connected vehicle technologies to:
- reduce idling, number of stops, unnecessary accelerations/decelerations,
- and improve traffic flow to decrease fuel consumption and emissions.

Source: USDOT, July 2013
Mobility and the Environment

Photo source: Thinkstock

[Image of a busy highway]

[Image of a snowy mountain road with connected vehicles diagram]

Photo source: Thinkstock
What are Automated Vehicles?
What are Automated Vehicles?

- **Automated Vehicles (AVs)** are vehicles in which at least one element of vehicle control (e.g., steering, speed control) occurs without direct driver input.
- AVs work by gathering information from a suite of **sensors**:  
  - Cameras;  
  - Radar;  
  - Light detection and ranging (LiDAR);  
  - Ultrasonic; and  
  - Infrared.
- AVs may combine sensor data with other inputs, e.g. detailed map data & V2V/V2I data.
How do Automated Vehicles Work?

• AVs may combine sensor and map data, can detect and classify objects in their surroundings and may predict how they are likely to behave
  • Other moving vehicles
  • Pedestrians and cyclists
  • Stationary objects (e.g., signs, trees, traffic cones)

• Based on what an AV can “see” and what it predicts nearby objects are likely to do, it can make decisions about speed and steering inputs
## Varying Levels of Automation (SAE J3016)

<table>
<thead>
<tr>
<th>SAE Level</th>
<th>SAE Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Automation</td>
<td>Full-time performance by the human driver of all aspects of dynamic driving task</td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance</td>
<td>Driver assistance system controls either steering or speed while the human driver performs all remaining aspects of dynamic driving task</td>
</tr>
<tr>
<td>2</td>
<td>Partial Automation</td>
<td>Driver assistance system(s) controls both steering and speed while the human driver performs all remaining aspects of dynamic driving task</td>
</tr>
<tr>
<td>3</td>
<td>Conditional Automation</td>
<td>Automated driving system performs all aspects of dynamic driving task with the expectation that human driver will respond to a request to intervene</td>
</tr>
<tr>
<td>4</td>
<td>High Automation</td>
<td>Automated driving system performs all aspects of dynamic driving task, even if a human driver does not respond to a request to intervene</td>
</tr>
<tr>
<td>5</td>
<td>Full Automation</td>
<td>Automated driving system performs all aspects of dynamic driving task under all roadway and environmental conditions that can be managed by a human driver</td>
</tr>
</tbody>
</table>

*Full definition available at: www.sae.org/misc/pdfs/automated_driving.pdf*
Automated vehicles...on a road near you?

Here Today

Level 1

Level 2

In Testing

Level 3

Level 4

Someday(?)

Level 5

Image Sources (left to right): General Motors, Automobile Magazine, Tech Crunch, Newsweek/Google, Volkswagen/Dezeen
Automated vehicles are...here today

Most major manufacturers currently offer Level 1 systems (e.g., lane keep assist, adaptive cruise control); some offer Level 2 systems (e.g., Tesla Autopilot, Audi Traffic Jam Assistant).
Automated vehicles are...in testing

FHWA has been funding research into connected Level 1 applications, including cooperative adaptive cruise control (CACC), GlidePath, Connected/Automated Truck Platooning, and Lane Change/Merge.
Automated vehicles are...in testing

Dozens of manufacturers and technology companies are currently testing AVs. They are not only testing passenger vehicles, but also heavy duty commercial and small transit-like vehicles.
Automated vehicles are... coming soon

Many manufacturers are targeting 2020 (or potentially sooner) to introduce Level 3 and 4 automated vehicles...
Vehicle Fleet Turnover

Expected Survival Rate of Model Year 2017 Vehicles

AVs Could Introduce Significant Benefits

**Potential Benefits**
- Reduction in vehicle crashes
- Improved mobility for elderly, disabled and those unable to drive
- Improved convenience of travel

**Potential Challenges**
- Less efficient operations of the highway system
- Increases in VMT and congestion
- Land use implications, increased sprawl
Connectivity Could Enhance Automated Vehicle Benefits

**Vehicle-to-vehicle and vehicle-to-infrastructure** communications can enhance the safety and efficiency of AVs by providing greater situational awareness and efficiency.

**What is a Connected Vehicle?**

- An equipped vehicle sends basic safety messages (BSMs), transmitted 10 times per second
- Other nearby vehicles and roadside equipment receive the messages
- Drivers receive warnings and information to avoid potential crashes and improve mobility

**What is it?**

- Dedicated Short Range Communications (Wi-Fi adapted for moving vehicles)
- FCC 5.9 GHz spectrum allocation

Image Source: ITS JPO
Vision for CAV

**Autonomous Vehicle**
Operates in isolation from other vehicles using internal sensors.

**Connected Vehicle**
Communicates with nearby vehicles and infrastructure. Not automated (level 0)

**Connected Automated Vehicle**
Leverages automated and connected vehicle technologies.

Source: USDOT
What are State & Local Agencies Doing?
Connected Vehicle Pooled Fund Study

- Comprised of 18 State and local transportation agencies, FHWA, and Transport Canada.
- Play a leading role in advancing connected vehicle systems.
- Virginia DOT is the lead agency.
- Currently two active CV PFS projects:
  1. Development and testing of DSRC vehicle-based road weather condition application, and
  2. Development of a basic infrastructure message and corresponding standards support.
- A new project related to MMITSS Deployment Readiness is forthcoming
V2I Deployment Coalition

**Current Structure:**

AASHTO, ITS America and ITE collaborated to organize and manage the coalition

A single point of reference for stakeholders to meet and discuss V2I deployment related issues

**V2I Deployment Coalition**

- **CAV-ELT**
- **V2IDC Executive Committee**
- **TWG 1: Deployment Initiatives**
- **TWG 2: Deployment Research**
- **TWG 3: Infrastructure Operator, OEM, and Supplier Partnerships**
- **TWG 4: Deployment Guidance**
- **TWG 5: Deployment Standards**

**USDOT**
- ITS JPO
- FHWA
- FTA
- NHTSA
**V2I Deployment Coalition**

**Proposed Phase 2:**

AASHTO, ITS America and ITE will continue to manage the coalition.

Streamlined structure based on Phase 1 activities and lessons learned.
V2I Deployment Coalition

Proposed Phase 2:

CAV-ELT

V2IDC Executive Committee

USDOT - ITS JPO - FHWA

Will carry on activities previously performed by TWG 1 Initiatives For example:

- Continue SPaT Challenge Resource development;
- Look for new initiatives similar to SPaT Challenge
V2I Deployment Coalition

Proposed Phase 2:

- CAV-ELT
- V2IDC Executive Committee
- V2I DC Strategic Initiatives TWG
- V2I DC Guidance TWG
- V2I DC Peer Exchange / Outreach TWG
- USDOT - ITS JPO - FHWA

Will carry on activities previously performed by TWG 4 Guidance
For example:
- Review and provide feedback to USDOT on V2I Deployment Guidance and supporting products
V2I Deployment Coalition

Proposed Phase 2:

- CAV-ELT
- V2IDC Executive Committee
  - V2I DC Strategic Initiatives TWG
  - V2I DC Guidance TWG
  - V2I DC Peer Exchange / Outreach TWG

Large working group, meeting approximately quarterly, with well constructed agendas and invited speakers to allow peer exchange on key V2I topics, including:
- Pilot Deployment / Smart City Updates
- Connected Vehicle Standards
- Connected Vehicle Research
- Deployment Status
- AV Policy Updates
- Outcomes of IOO/OEM Forum Discussions

All members of V2I DC would be encouraged to participate in this TWG; group will carry on many functions of current TWG 2, 3, and 5
The SPaT Challenge

Challenge state and local public sector transportation Infrastructure Owners & Operators (IO&Os) to deploy DSRC infrastructure with SPaT broadcasts in at least one coordinated corridor or network (approximately 20 signalized intersections) in each state by January 2020.

Additional V2I Applications that build on SPaT are also encouraged!

20 Intersections in 50 states by 2020!
www.transportationops.org/spatchallenge
Arizona and Massachusetts governors signed executive orders supporting AV testing.

Virginia’s governor endorsed the Virginia Automated Corridors Initiative through a proclamation.

Texas has welcomed AV testing to Austin without specific legislative action.

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AV Legislation Passed Regarding Testing and/or Operation

Testing Occurring; No Legislation Passed*

*Testing on public roads publicly announced

What is USDOT Doing?
Recent NHTSA Activity

NHTSA issued initial Federal Automated Vehicles Policy in September 2016

• Discusses guidance on vehicle performance, model state policy and regulatory issues.

• Public comments requested and received

• More information: www.transportation.gov/AV
Recent NHTSA Activity

A Notice of Proposed Rulemaking (NPRM) that would establish Federal Motor Vehicle Safety Standard (FMVSS) No. 150 was issued on January 12, 2017

- Would mandate V2V communications using DSRC and GNSS on light vehicles

- Public comment period closed on April 12, 2017, with 450 comments received

- See: https://www.regulations.gov/docket?D=NHTSA-2016-0126
10 AV Proving Ground sites identified:

- City of Pittsburgh and the Thomas D. Larson Pennsylvania Transportation Institute
- Texas AV Proving Grounds Partnership
- U.S. Army Aberdeen Test Center
- American Center for Mobility (ACM) at Willow Run
- Contra Costa Transportation Authority (CCTA) & GoMentum Station
- San Diego Association of Governments
- Iowa City Area Development Group
- University of Wisconsin-Madison
- Central Florida Automated Vehicle Partners
- North Carolina Turnpike Authority
Other U.S. DOT AV Research

- Federal Motor Carrier Safety Administration
- Federal Transit Administration
- Intelligent Transportation Systems Joint Program Office
- MARAD
What is FHWA’s Role?

• How can FHWA facilitate integration of automated vehicles onto the nation’s roadways?

• How do automated vehicles impact FHWA’s areas of responsibility and programs?

• How can FHWA support the needs of its stakeholders, including State and local DOTs, planning agencies, and road users?
FHWA Automated Vehicle Research

FHWA conducts exploratory research to understand the impacts of automated vehicle technologies on the nation’s roadway system:

• Technical research on connected Level 1 automation applications (e.g., CACC, eco-glide)
• Exploratory research on truck platooning applications
• Evaluating the transportation planning process and policies
FHWA Automated Vehicle Vision Initiative

Established FHWA Automated Vehicle Working Group to Develop Vision Statement

Vision Purpose:

• Define FHWA’s role regarding Automated Vehicles
• Establish an agency-wide approach to addressing within FHWA’s programs and areas of responsibility & authority.
• Communicates the FHWA role across the agency and to its stakeholders
Key Tasks

- Develop unified vision on automated vehicles (AV) discussing FHWA’s role
- Conduct education and outreach on AVs for FHWA staff and stakeholders
- Explore technology deployment and adoption scenarios for AVs to inform FHWA program plans and research
Vision Goals

1. Prepare our roadway infrastructure for the future
2. Maximize potential benefits through connectivity
3. Serve as a resource for transportation agencies
4. Adapt programs and policies to meet emerging needs
Guiding Principles

- **Safety for All Road Users**: Foster the development and operation of AVs so as to ensure the safety of all road users, including AVs, non-automated vehicles, bicyclists, pedestrians, and other road users.

- **Equitable Access**: Support policies and practices that ensure mobility and equitable access to the benefits of AVs for underserved communities in rural and urban areas, as well as for individuals with disabilities.

- **Data-Driven**: Support the collection, analysis, sharing, and use of data on AV use, performance, and impacts to support effective transportation planning, policy, and investment decisions.

- **Technology Innovation**: Enable the availability of AV applications that significantly benefit the public and our State and local partners, through research, development, and testing that complements industry efforts.

- **Partnership Building**: Coordinate closely with partners in the public and private sectors to share knowledge, provide consistent guidance, and support the development and adoption of consistent and effective AV policies and practices.
How Does this Impact YOU?
Physical Infrastructure

- Unclear infrastructure requirements for AVs (signs, signals, markings)
- Possible need for adaptations to design standards, greater consistency
- Implications for maintenance and investment

Image Sources: Left (top to bottom): Streetsblog, Oregon State University, USDOT, Volpe Center; Right: Gallery of Flights (top), All County Asphalt (bottom)
Digital Infrastructure

- AVs as potential sources of roadway data
- Data updates on construction and road closures
- Maintenance of digital infrastructure
Roadway Operations

- Short-term challenges of managing a mixed traffic environment (AVs, CVs, non-AVs, C/AVs)
- New challenges in harmonizing traffic flow
- Potential travel demand changes
- Potential long-term efficiency, congestion benefits

Image Sources: Left (top to bottom): Streetsblog, Oregon State University, USDOT, Volpe Center; Right: FHWA (top), Oregon Live (bottom)
Programs and Practices

- Accounting for AVs and potential land use impacts and uncertainty in long range planning process
- Implications of shared vehicle fleets and new mobility models on travel demand modeling/forecasting
- Revenue and budget implications
Questions?
For More Information

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