Autonomous Vehicles: V2I and V2V

Tuesday, July 14, 2015
11 a.m. to 12 p.m.

Speakers:
Mark Kopko, Pennsylvania Department of Transportation
Allen D. Biehler, Traffic 21, Carnegie Mellon University
Cem Hatipoglu, PhD, National Highway Traffic Safety Administration
Cathie Curtis, Director, Vehicle Programs, AAMVA
Preparing for the Future
PennDOT’s Approach to Connected and Automated Vehicles

7/14/2015

Mark Kopko
Manager – Traveler Information & Advance Vehicle Technologies
Bureau of Maintenance and Operations
Transportation Challenges

Safety
- 33,561 highway deaths in 2012
- 5.615 million crashes in 2012
- Leading cause of death for ages 4, 11-27

Mobility
- 5.5 billion hours of travel delay
- $121 billion cost of urban congestion

Environment
- 2.9 billion gallons of wasted fuel
- 56 billion lbs of additional CO₂

Data Sources:
- 2011 Annual Urban Mobility Report, Texas Transportation Institute (Feb 2013)
Moore’s Law

• Transistors on a chip doubles every 2 years

We will achieve more in the next 10 years than we did in the last 100
Paradigm Shift Frequency

- Telecoms (dates approximate):
  - 1876 – Landline Telephone replaces telegraph
    - 97 Years
  - 1973 - Cell Phone replaces Landline
    - 23 Years
  - 1996 – Smartphone replaces Cell
    - 11 Years
  - 2007 – First iPhone – Apps
    - 3 Years
  - 2010 – Social Media Revolution
    - 3 Years
  - 2013 – Google Glass/Wearable Tech
• 1879 – Motor car (Daimler Benz) replaces horse and carriage

…..incremental improvements for 135 years…..

• Conclusion:

Overdue for a transportation paradigm shift
Two Technologies – One Vehicle

- **Connected Vehicle**
  - Technology enables connection between vehicles, infrastructure, or consumer wireless devices (e.g., DSRC)

- **Automated Vehicle**
  - Technology enables connection between vehicles, infrastructure, or consumer wireless devices

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

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

**Connected Automated Vehicle**
Leverages autonomous automated and connected vehicles
<table>
<thead>
<tr>
<th>Levels of Autonomous Driving</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No autonomous functions (Drivers required)</td>
</tr>
<tr>
<td>1</td>
<td>Autonomy for 1 primary function (ACC, LKA, CMBS)</td>
</tr>
<tr>
<td>2</td>
<td>Autonomy of 2+ primary control functions (Traffic jam assist)</td>
</tr>
<tr>
<td>3</td>
<td>Limited self-driving: in some situations (Auto pilot: highway, parking)</td>
</tr>
<tr>
<td>4</td>
<td>Full self-driving or human driving (Driver can take control of driving)</td>
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</table>
“They will likely program their car to transport them autonomously to their destination and like any parent, if that vehicle can't speed, can't run off the road and can't run into another vehicle, I will rest much easier at night knowing that they are safer because of this technology.”

- Barry Schoch
National Activities

- **National Working Groups**
  - Connected Vehicle Pooled Fund Study
  - AASHTO Connected Vehicle Deployment Coalition
  - Vehicle-to-Infrastructure Deployment Coalition
  - American Association of Motor Vehicle Administrators (AAMVA) Automated Vehicles Best Practices work group
  - STSMO Connected Vehicle Technical Working Group
  - ENTERPRISE Pooled Fund Study

- **National Meetings/Roundtables**
  - Auto Manufacturers and Public Agencies’ Coordination Meeting
  - Automated Vehicles and the States Roundtable

- **National Research Initiatives**
  - NCHRP 20-24 (98) - Connected and Automated Vehicles Research Roadmap
Connected/Autonomous Vehicles Vision

• Partnered with CMU
  – US DOT University Transportation Center
  – 2013 Intergovernmental Agreement

• Analysis of the Impacts of Connected and Autonomous Vehicles on the Pittsburgh Region
  – 2040 Design Year

• Project Kickoff July 2013
• Final Report July 2014
2040 Tasks

• Task 1 – Expert Workshop with PennDOT leadership
  – Held October 3rd in Harrisburg
    • State DOTs
    • US DOT
    • Academia
    • Private Sector
• Task 2 – Impacts to Design and Investment Decisions
• Task 3 – Real-Time Data Usage
• Task 4 – Impacts to Existing Infrastructure
• Task 5 – Impacts to Workforce and Training Needs
• Task 6 – Impacts to Driver Licensing
• Task 7 – Impacts to Communication Devices and Investments
• Task 8 – Impacts to Freight Flow
Impacts to Design and Investment Decisions

• The impact of connected and autonomous vehicles on lane capacity from the longitudinal perspective is uncertain.
• Radio advisories and ITS message signs will be obsolete in a connected environment.
• Clear zones will need to remain in place.
• Width of lanes, medians, shoulders and clear zones can be decreased.
• Cost of construction time and congestion associated with repainting and reallocating of lanes must be taken into account for investment decisions.
Impacts to Driver Licensing

• Changes to training and driver license issues will be incremental.

• For the 2040 design year, a new license class may be introduced for those wishing to drive their manual cars or drive their automated cars manually.

• Driving and skills tests should be required for all levels of automation with an exception of level 4, where there will be no interaction between drivers and vehicles.

• Testing criteria for all levels of automation (0-3) should be updated to assure driver’s basic familiarity with electronic assist features.

• PennDOT should update knowledge and road test requirements as automation advances.

• Under level 4 automation allowances should be made for medically impaired individuals.

• The focus of training should be on automation levels 2 and 3, as level 4 is further out and would need far less involvement from drivers.
2014 - 2020

2014-2016

- Thorough evaluation of all existing and planned capacity/LOS enhancement and ITS related investments.
- Collaboration with private sector to convert data into information for sending to cloud.
- Prioritization of safety and mobility applications.
- Identification and prioritization of key locations for DSRC and roadside equipment deployment.
- Funding allocation for DSRC and roadside units.
  
  *2015: FHWA Guidance to V2I Deployment*

2016-2020

- Upgrading signal controllers, equipment and firmware where necessary.
- Early small-scale deployment of V2I applications at key locations.

2021 - 2030

- Collaboration with local and state educational institutions to enhance workforce training.
- Update of testing criteria for level 3 automation.
- Design of driver licensing training for emergency situations, system malfunctions, regulations and human interaction levels.
- Work with the trucking industry and State Police to design features tailored to these stakeholders.
- Deployment expansions – large scale deployment of equipment and applications.

2031 - 2040

- Provisions for a new license class for those wishing to drive their manual cars.
- Dedicating some highway lanes to autonomous vehicle use.
- Reconfiguration and repurposing of the lanes.
- Phasing out the freight infrastructure (e.g., over-height warnings, weigh stations) as new technologies are introduced.
Internal Working Group

• Goal:
  Ensure that Pennsylvania is prepared to facilitate the deployment of autonomous and connected vehicle technologies.

• Recognize the Implications of this Technology

• Stakeholders
  • Operations
  • Traffic Signals
  • Traveler Info
  • Maintenance
  • Planning/Research
  • Safety
  • Driver’s Licensing
  • IT
  • Legal
  • Transit
  • Districts
  • PTC
  • Academia
  • MPOs
  • FHWA

• Strategic Plan
“The car as we know it, and how it’s used in people’s lives, is going to change really dramatically and it’s going to change fast.”

Bill Ford Jr., Executive Chairman
(April 2013)

Mark Kopko
Manager – Traveler Information and Advance Vehicle Technologies
Bureau of Maintenance and Operations
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Autonomous Driving Collaborative Research Lab

Carnegie Mellon University
Automated Driving

Ready?

Al Biehler
Executive Director
T-SET University Transportation Center
Carnegie Mellon University
Carnegie Mellon University
30 Years of Self-Driving Car Research

1984
• The Terregator’s top speed was a few centimeters per second; it could avoid obstacles.
• NavLab launched. Its goal: apply computer vision, sensors and high-speed processors to create vehicles that drive themselves.

1986
Humans or computers controlled NavLab1, a Chevy van. Top speed: 20 mph.

1990
NavLab 2, a US Army HMMWV, wrangled rough terrain at 6 mph. Highway speed: 70 mph.

1995
NavLab 5, a Pontiac Trans Sport, traveled from Pittsburgh to San Diego in the “No Hands Across America Tour.”

2000
NavLab 11, a Jeep, was equipped with Virtual Valet.

2005
Sandstorm and Highlander placed 2nd and 3rd in the DARPA Grand Challenge.

2007
Carnegie Mellon’s “Boss” won the DARPA Grand Urban Challenge by outmaneuvering other vehicles along the 55-mile course.

2014
Carnegie Mellon’s 14th self-driving vehicle is a Cadillac SRX that:
• avoids pedestrians and cyclists
• takes ramps and merges
• recognizes and obeys traffic lights
• looks like other Cadillac SRXs

www.engineering.cmu.edu

Carnegie Mellon University
Autonomous Vehicle 2007

DARPA Challenge Winner  (Defense Advanced Research Projects Agency)
Autonomous Vehicle 2014

Carnegie Mellon University
ROAD TO AUTOMATED DRIVING

Increasing Capability

Driver Info & Alerts (No Control)

Emergency Intervention (Limited Control)

Limited On-Demand Automation (Monitored Control)

Complex On-Demand Automation (Transferred Control)

Autonomous Driving (Chauffeured Driving)

John Capp, Director Safety Strategies and Vehicle Programs

GM
ROAD TO AUTOMATED DRIVING

TECHNOLOGY ENABLERS:
- Perception & Algorithms
- Integrated Sensing with Maps, GPS, V2X
- Driver State Knowledge

Today

- Driver Info & Alerts (No Control)
- Emergency Intervention (Limited Control)
- Today’s Driver Assist Package
- “SuperCruise” Concept

Increasing Capability

Limited On-Demand Automation (Monitored Control)

Complex On-Demand Automation (Transferred Control)

Autonomous Driving (Chauffeured Driving)

Future
• **Distronic Plus w/ Steering Assist**
  - Stay in lane
  - Brake
  - Accelerate

• **Active lane assist**

• **Active blind spot assist** – active breaking, warning

• **Attention assist** - takes into account 75 factors to determine if driver is getting drowsy – beep alert with message

• **Night view assist** – infrared cameras identify animals, pedestrians – automatically flash headlights

• **Active parking assist** – scans row of cars for spot of sufficient width and automatically parks the car

Technology available today
“....driverless cars will be fully operational in the next six years...

...the need to perfect "machine vision" and advancements in sensor technology are the only obstacles to seeing the cars fully operational”

Elon Musk, Wall St Journal, 9-18-14
Mercedes-Benz Future Truck 2025

Autobahn Demonstration July 4, 2014
“If the legislative framework for autonomous driving can be created quickly, the launch of the Highway Pilot is conceivable by the middle of the next decade.”

Wolfgang Bernhard
CEO, Daimler Trucks

July 4, 2014
Self-driving SUV completes cross-country trip

April 1, 2015
Automated Driving

Policy Implications?
Policy Implications

Connected and Autonomous Vehicles

- Safety
- Mobility & Access
- Congestion & VMT
- Public Transportation
- Energy & Environment
- Land Use
- Economy & Jobs
Safety

• Drastic reduction in crashes / fatalities
• Regulation vs free entry
• Liability shift

Mobility & Access

• Populations with new freedom
• Lifestyle, job and education opportunities
• Societal and economic impacts

2011
- 2.2 million Injuries
- 32,000 fatalities

Current non-drivers, constrained drivers.
Congestion & VMT

Change recent VMT trends?

Urban, suburban, rural differences?

Absorb increases with more efficient operation?

Travel forecasting

U.S. congestion costs $120 billion annually.

Public Transportation

Undermine?

Advantages?

Tipping point factors / application?

Paratransit constitutes 14-18% of transit budgets
Energy & Environment

- Impact on energy consumption and air emissions
- How optimize?
- Impact on use of alternate fuel vehicles

Land Use

- Home, commercial and retail location
- Form
- Zoning requirements
- Incentivize investment choices

Connected pod-car automated vehicles could reach over 300 mpg.

Reduced CBD parking / driverless taxis.
• Impacts to manufacturing and service economies

• Crash industry
  - Insurance companies, attorneys, courts, body shops, parts manufacturers

• Displacement of good wage driving jobs

• State and local revenue
  - Parking, licensing, fuel taxes, moving violations
Automated driving is advancing quickly
Capture the benefits
Automated Vehicles and Safety

Cem Hatipoglu, PhD
Division Chief, Electronic Systems Safety Research
Advanced Driver Assist Systems – Automation
What’s Motivating Implementation?

- Over 90% of police reported crashes involve some type of driver error [http://www-nrd.nhtsa.dot.gov/pubs/812115.pdf]
- Data indicates safety benefits for driver assistance systems, i.e. “smart” technologies; more research for highly automated cases underway
- Government perspective:
  - Motivation remains strong for safety programs
    - Crash problem remains – leading cause of death ages 4-34
- Industry:
  - Integration of functions, cost reduction, and tech savvy drivers will make it attractive for OEMs
- Secretary Foxx (May 2015, Mountain View, CA):
  - “The Department wants to speed the nation toward an era when vehicle safety isn’t just about surviving crashes; it’s about avoiding them,”
  - “Connected, automated vehicles that can sense the environment around them and communicate with other vehicles and with infrastructure have the potential to revolutionize road safety and save thousands of lives.”
Focus on **Safety**

- Automation should be focused *first on safety*

- **Safety goals** include:
  - Systems safely perform intended functions,
  - Fail safe,
  - Do not introduce new safety concerns
  - Artificial Intelligence limitations, Cybersecurity, etc.

NHTSA will determine how to ensure that safety benefits are widely enjoyed and safety risks addressed for crash avoidance technologies, including for varying levels of automation.
Need to Inform/Guide Key Stakeholders (May 2013 Release)

- Described **3 major innovation areas**
  - Onboard systems (radar, camera, etc),
  - V2V,
  - Self Driving.
- Laid out a conceptual framework for analyzing safety issues related to automated vehicles
- Outlined *NHTSA Research Activities* along levels of automation
- Offered **guidance to States**
  - Testing, Licensing, etc

http://www.nhtsa.gov/Research/Crash+Avoidance/Automated+Vehicles
Inform CA’s rulemaking activities of NHTSA Research in automation

• Encouraged by the potential for significant safety benefits at all levels.

• Regulation and oversight must fulfill legitimate objectives while promoting innovation and encouraging technological progress and trade*.

• There are issues that need resolution to continue supporting the innovation that is happening

• Attached a list of current research questions (10)

Some of the research questions

- What **functionally safe design strategies** can be implemented for automated vehicle functions?
- What level of **cybersecurity** is appropriate for automated vehicle functions?
- What is the performance of **Artificial Intelligence** in different driving scenarios?
  - Automation can overcome human driver weaknesses (e.g. distraction and fatigue), how about cases where humans excel?
- What are appropriate **minimum system performance requirements** for automated vehicle systems?
- What **objective tests** of other **certification procedures** are appropriate?
- What are **the incremental safety impact potential**?
Key Areas with NHTSA/USDOT Research Underway

Human Factors Research
- Human factors evaluation of Level 2 and Level 3 automated driving concepts
- Initial Driver Vehicle Interface principles for L2/L3

Electronic Control Systems Safety (including Cybersecurity)
- Functional safety of safety-critical automotive systems and extensions to L2-L4
- Cybersecurity threats, vulnerabilities, countermeasures assessment

System Performance Requirements
- System performance requirements framework, test methods
- Objective test procedures

Benefits Assessment
- Target crash population estimation for automated vehicles L2-L4
- Multi-modal benefits framework development

Testing and Evaluation
- Controlled test track studies
- Field operational tests
Cem Hatipoglu, PhD

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Region I
Autonomous Vehicles
July 14, 2015
Cathie Curtis, AAMVA,
Director, Vehicle Programs
What is AAMVA doing to help our members prepare for Automated, Autonomous and Connected Vehicles?
AV Information Sharing Working Group


- Group has held conference calls monthly to review state laws, studies, news articles and hear from experts.

- Developed an AV Information Library on AAMVA’s website to store information on AVs.
AV Information Sharing
Working Group

• Developed an analysis of current AV state laws.

• Identified the program areas such as operator training, testing and licensing, vehicle registration and title, data privacy and security concerns, consumer safety and other areas of concern to the DMVs and Law Enforcement that will be impacted by AVs.

• Provided information to larger AAMVA community during meetings and conferences.

• 2015 - Continuing to hold quarterly calls.
Fall 2014 - Established an Autonomous Vehicle Best Practices Working Group

The purpose of the project is to form a Best Practices Working Group to:

• Work with the AAMVA jurisdictions, law enforcement, federal agencies and other stakeholders to gather, organize and share information with the AAMVA community related to the development, design, testing, use and regulation of autonomous vehicles and other emerging vehicle technology.

• Based on the group’s research, a best practices guide to assist member jurisdictions in regulating autonomous vehicles and testing the drivers who operate them will be developed.

• Funded by NHTSA
The Working Group will:

- Research and gain an understanding of autonomous vehicles and other emerging vehicle technology, the impact they will have on the AAMVA membership, and define the potential regulatory concerns the technology will create.

- Develop and draft Best Practices. 2015-2016

- Provide the draft best practices to the AAMVA Driver, Vehicle, and Law Enforcement Committees and to NHTSA for review and comment. Late summer 2016

- Review all comments and suggestions and modify the draft as appropriate. Late summer 2016

- Release and promote the final Best Practices document to AAMVA jurisdictional members and stakeholders. Fall 2016
The Working Group will consist of:

- 16 jurisdictional members; including representatives with vehicles, driver license, law enforcement, information technology and legal expertise.

- 2 Canadian jurisdictional representatives to be funded by CCMTA

- 3 positions held by NHTSA representatives.

- 4 AAMVA staff plus the project officer.

- A consultant.

- Stakeholders to act as advisors.
• Held the first meeting in February.

• Heard several presentations to level the group’s understanding of the issues.

• Divided into 3 subgroups; driver, vehicle and law enforcement.

• Each subgroup identified policy issues in their area.

• Developed the outline for the Best Practices report.

• Develop best practices for the regulation of testing and deployment of the vehicles.
• Subgroups are meeting monthly this summer.

• Each member volunteered to develop a very early draft of a best practice for the group to discuss during the next face to face meeting.

• Next meeting in September in San Francisco. Meeting with VW and Google.
Working Group Status

- Will meet twice next year to continue to research and develop best practices.

- Publish the best practices in late fall of 2016.

- Identify a path forward as this is a 2 year project, but we know the technology will continue to emerge.

- Will continue to hold calls with the Information Sharing Group.
A Few Examples of Vehicle Technology
Autonomous Vehicle
Autonomous Vehicles
Automated Vehicles

Example: Lane departure warning system
Automated Vehicles
Example: Forward Collision Warning Systems
Connected Vehicles: Vehicle to Infrastructure (V2I)
Connected Vehicles:
Vehicle to Vehicle (V2V)
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