Appendix
Pennsylvania Department of Transportation
Connected and Autonomous Vehicles 2040 Vision

Experts Workshop
October 3, 2013
Enola, PA

Complete Workshop Package

Submitted by
Carnegie Mellon University

On
October 10, 2013
Dear Workshop Invitee:

On behalf of the Pennsylvania Department of Transportation, it is my pleasure to invite you to attend the "Connected and Autonomous Vehicles 2040 Vision" workshop on October 3, 2013 in Harrisburg, Pennsylvania. The workshop will be held in the training center of the Pennsylvania State Association of Townships located at 4855 Woodland Drive, Enola PA 17025.

PennDOT has recently started a one-year project with researchers at Carnegie Mellon University to help us assess the implications of connected and autonomous vehicles on our state’s transportation system. Using a design year of 2040, this research will identify impacts on issues such as investment decisions, design, driver licensing, operations and maintenance. We have selected the Pittsburgh region in Southwestern PA as our focus area. The workshop will serve to educate and stimulate discussions among PennDOT staff, the Carnegie Mellon researchers and experts in the field.

We believe that your experience and insights in the field of autonomous and connected vehicles will be enlightening to our organization and audience.

Carnegie Mellon University staff will follow up with you regarding this invitation. Please RSVP to:

Stan Caldwell, Associate Director Traffic21
Carnegie Mellon University
stancaldwell@cmu.edu
412-268-9505

I hope you will honor us by accepting our invitation to participate in the workshop on October 3, 2013.

Sincerely,

Barry J. Schoch, P.E.
Secretary of Transportation
Pennsylvania Department of Transportation
Connected and Autonomous Vehicles 2040 Vision
Workshop Agenda
October 3, 2013, Enola, PA

8:00am - 8:30am  Continental Breakfast and Registration

8:30am – 8:40am  Welcome and Introduction: Allen Biehler (Carnegie Mellon University)

8:40am – 8:50am  Workshop Kick-off: Pennsylvania Transportation Secretary Schoch

8:50am – 9:00am  Workshop Objective: Allen Biehler

9:00am – 9:45am  Overview of Connected and Autonomous Vehicle Transportation
Kevin Gay (Volpe National Transportation Systems Center)
John Capp (General Motors)

9:45am – 10:30am  Impacts to Existing Infrastructure and Design
Christopher Hill (Booz Allen Hamilton)
Raj Rajkumar (Carnegie Mellon University)

10:30am – 10:45am  Break

10:45am – 11:30am  Impacts to Freight Flow
Ali Maleki (Ricardo)
Cem Hatipoglu (FMCSA)

11:30am – 12:15pm  Impacts to Driver Licensing Issues and Workforce Training Needs
Elizabeth Birriel (FLDOT)
Bernard Soriano (CA DMV)
Neil Shuster (AAMVA)

12:15pm – 1:00pm  Lunch

1:00pm – 3:00pm  Breakout Sessions
Session 1: Impacts to Existing Infrastructure, Design and Investment Decisions
(Moderator: Valerie Briggs)
Session 2: Communication Device Investments and Real Time Data Usage
(Moderator: Shelley Row)
Session 3: Impacts to Freight Flow
(Moderator: James Misener)
Session 4: Impacts to Driver Licensing Issues and Workforce Training Needs
(Moderator: Neil Schuster)

3:00pm – 3:15pm  Break

3:15pm – 4:15pm  Breakout Sessions - Wrap Up and Report out

4:15pm – 4:30pm  Closing Remarks
Allen Biehler, P.E. is a Distinguished Service Professor in H. John Heinz III College of Public Policy and Information Systems at Carnegie Mellon University. He serves as Executive Director of CMU’s University Transportation Center, a partnership of Carnegie Mellon and the University of Pennsylvania. Al served eight years as Pennsylvania’s Secretary of Transportation. He launched a Smart Transportation program that refocused highway funding to support critically needed asset repairs, stabilized the Commonwealth’s transit program, and integrated transportation design with community revitalization. Al was President of AASHTO and a member of the Executive Committees of TRB and APTA. He was a founder of the State Smart Transportation Initiative at the University of Wisconsin that assists state DOTs wishing to accelerate sustainable practices. Al was previously Vice President of the international consulting firm DMJM-Harris (now AECOM) and has extensive public transportation management experience. Al received his BS in Civil Engineering from the University of Pittsburgh and a Certificate in Traffic Engineering from Yale University.

Elizabeth Birriel, P.E. works for the Florida Department of Transportation as the Deputy State Traffic Operations Engineer. She is also the Statewide ITS Program Manager. Program areas under her responsibility include deployment of 511 Advanced Traveler Information System in the state of Florida, creation of the SunGuide® software to be used in all 12 FDOT transportation management centers in Florida, development and reporting of ITS Performance Measures and Connected Vehicle efforts in Florida. Under her leadership, the Florida Department of Transportation deployed a Connected Vehicle Test Bed in Orlando Florida in 2011, one of only a few in the nation. Elizabeth is involved in several national level efforts such as AASHTO’s Connected Vehicle Working Group and the TMC Pooled Fund Study Group. She is an active member of ITS America and ITS Florida. She is also the chairperson for the Florida Department of Transportation’s task team on Transportation Systems Management and Operations. This is a cross functional group of approximately 15 people looking into how to elevate the importance of operating our transportation systems and infrastructure in a more efficient manner in addition to integrating planning, safety and operations. Elizabeth received her BS Degree in Electrical Engineering and a Master’s Degree in Transportation Engineering. She is also a graduate of the Certified Public Manager program and is a registered Professional Engineer in the state of Florida.

Valerie Briggs is the Knowledge Transfer and Policy Team Lead for the U.S Department of Transportation’s Intelligent Transportation Systems Joint Program Office (ITS JPO) within the Research and Innovative Technology Administration. Valerie’s team is responsible for stakeholder communications, outreach, technology transfer, ITS industry professional capacity building, and policy studies for the ITS JPO. Among these duties, Valerie leads DOT’s policy and non-technical research focusing on advancing vehicle-to-vehicle and vehicle-to-infrastructure wireless communications for safety, mobility, and environmental benefits. Valerie joined U.S. DOT in 2007 from the American Association of State Highway and Transportation Officials (AASHTO’s), where she led AASHTO’s transportation operations group responsible for traffic operations, intelligent transportation systems, telecommunications, and transportation security programs. She has also consulted and conducted research in these areas. Valerie holds Bachelor’s and Master’s degrees in Civil Engineering, and a Master of Public Affairs degree, all from the University of Texas at Austin.
**John Capp** is currently Director of Electrical & Control Systems Research at General Motors R&D and is responsible for the development of advanced electrical systems and components for vehicle safety, comfort and infotainment. He’s also the strategic lead for active safety, driver assistance, and automated driving technologies. John holds a BS in Mechanical Engineering from GMI Engineering & Management Institute (now Kettering University), and an MS in Engineering from Purdue University. John has over 25 years of experience at General Motors, primarily in product engineering. John has worked on many aspects of vehicle safety and crashworthiness for many GM products, and for the past 6 years, has led the development and implementation of active safety, advanced driver assistance, and connected vehicle safety technologies within both R&D and Product Engineering organizations.

**Kevin Gay** is a certified Project Management Professional at the Volpe National Transportation Systems Center. He has over a decade of experience in managing advanced research and technology projects. Kevin is the Vehicle Automation Team Leader, where he is responsible for managing and providing leadership to all vehicle automation projects currently underway at the Volpe Center, including the development of a U.S. DOT Multimodal Research Plan for Vehicle Automation. In addition, for the past 3 years Kevin has managed the technical aspects of the Connected Vehicle Safety Pilot Program, a multi-modal year-long field operational test of Dedicated Short Range Communications (DSRC) based crash avoidance systems involving thousands of motor vehicles and corresponding roadside systems. Prior to joining the Volpe Center, Kevin worked in private industry, developing advanced transportation planning and execution software for shippers and transportation providers. Kevin earned his Bachelor’s degree in Applied Mathematics at the Georgia Institute of Technology.

**Cem Hatipoglu** is a Transportation Specialist in the Office of Analysis, Research and Technology at Federal Motor Carrier Safety Administration (FMCSA). For the past 3 years, he has been managing parts of FMCSA’s Research and Technology activities and also serving as FMCSA’s liaison in multi-modal research including the Connected Vehicle Research Program and the Automated Vehicle Research Program. Prior to joining FMCSA, he spent over 12 years in the heavy-duty trucking industry in engineering leadership capacities and also as a consultant. Most notably he led the development and deployment of Electronic Stability Control for heavy truck platforms in the North American market. Cem holds a PhD in Electrical Engineering with specialization in Automatic Control from the Ohio State University.

**Chris Hill** is a Senior Associate with Booz Allen Hamilton in Washington, DC, where he leads the firm’s Highways and ITS business. He holds a Ph.D. in transportation systems from the University of Nottingham, UK. He has worked in the field of ITS for the past 27 years. Most recently, he has supported USDOT in a variety of Connected Vehicle projects and is currently leading the development of the Connected Vehicle Field Infrastructure Footprint Analysis for AASHTO.

**Ali Maleki** is the Product Group Director of Hybrid and Electrical Systems at Ricardo Inc. His responsibilities include product areas such as ITS, connected and autonomous vehicles, hybrid systems and controls and electronics products in multiple markets including automotive, marine, defence, wind and solar. His previous work experiences were with Fisker and CODA Automotive where he was responsible for the vehicle electrical and propulsion systems including navigation and infotainment, telematics, hybrid-electric controls, body and chassis controls, battery management systems, motor-inverter controls, vehicle harnesses, powertrain controls and thermal management systems. He has held various engineering leadership roles in the development of active safety systems, infotainment and telematics, ABS, EBS, engine controls, chassis controls, embedded software, hardware and electronics with companies such as ArvinMeritor, Continental and AlliedSignal in the past 25 years. He authored the 2009 SAE Buckedale Lecture on Automotive and Truck Software Development. He holds several patents in his related fields, a BS and MS in Electrical and Computer Engineering and an MBA.
James A. Misener is a transportation and technology consultant, based in the San Francisco Bay Area since 1987. Mr. Misener was an early pioneer in vehicle-highway automation, serving as modeling and simulation lead for the National Automated Highway Systems Consortium, 1995 – 1997. His current clients range from small startups focused on self-driving cars, through large telecommunications firms (Qualcomm) and to USDOT. From 2010 – 2013, he was Executive Advisor to Booz Allen Hamilton, where he led the Federally-focused Intelligent Transportation Systems and highways business for the firm. From 2008 – 2010, served as Executive Director of the California Partners for Advanced Transit and Highways (PATH) at UC Berkeley. He was with PATH from 1995 – 2010, developing and delivering public and private sector sponsored research with government and industries, with heavy focus on the automotive sector. Mr. Misener has led the initial Connected Vehicle deployment test bed in California along Caltrans right of way, the first such facility in the United States. Mr. Misener is a member of IEE, the TRB ITS Committee for Vehicle-Highway Automation and is the Current Vice Chair for the SAE Dedicated Short Range Communication Technical Committee. He is US Expert in ISO TC/204 WG 16 – 18, which is focused on applying telematics and safety “ITS terminals” in vehicles and the infrastructure. He also is Chair of the ITS America Safety Forum and serves on the Executive Committee for the first responder-focused Transportation Safety Advancement Group. Mr. Misener is on the Editorial Board of the Journal of Intelligent Transportation Systems. He is widely published and speaks frequently at conferences, panels and with industry groups. Mr. Misener holds BS and MS degrees from UCLA and USC.

Raj Rajkumar is George Westinghouse Professor of Electrical and Computer Engineering at Carnegie Mellon University. He serves as a Co-Director for the General Motors-Carnegie Mellon Vehicular IT Collaborative Research Lab, and a Co-Director for the General Motors-Carnegie Mellon Autonomous Driving Collaborative Research Lab. He also serves as the Director of the University Transportation Center (UTC) on Technologies for Safe and Efficient Transportation funded by the US Department of Transportation, and a director of the Real-Time and Multimedia Systems Laboratory at Carnegie Mellon University. He has served as General Chair and/or Program Chair of the ACM/IEEE International Conference on Cyber-Physical Systems, IEEE Real-Time Systems Symposium, the ACM Real-Time Technologies and Applications Symposium, the ACM/SPIE Symposium on Multimedia Computing and Networking and the IEEE International Conference on Networked Sensing Systems. He is currently serving as the Program Chair for the 2013 ACM/IEEE Conference on Information Processing in Sensor Networks, SPOTS track. His work on priority inheritance protocols is known and used widely. His current research projects include autonomous vehicles, vehicular networks, FireFly wireless sensor networks, resource kernels for guaranteed enforcement of throughput and timeliness in distributed real-time operating systems, and model-based design. Six of his papers have received Best Paper Awards. He is also a Fellow of the IEEE. Raj also has a courtesy appointment in the Robotics Institute at Carnegie Mellon. His research interests include all aspects of cyber-physical systems.

Shelley Row: After a distinguished 30-year transportation career including service with Texas DOT, the Institute of Transportation Engineers and 23 years with the U.S. Department of Transportation including as the Director of the ITS Joint Program Office, Shelley Row, left her position to found Shelley Row Associates LLC. Shelley Row Associates is a two part company focusing on transportation consulting in ITS and leadership development. She is currently researching the role of intuition in leadership decision-making for which she has interviewed 70 leaders from the public, private, academic and political sectors. Ms. Row provides keynotes, workshops and breakouts on decision-making and goal achievement. She is widely-known within the transportation community for her leadership, vision and organizational skills.
**Neil Schuster** is President and CEO of the American Association of Motor Vehicle Administrators. AAMVA is the not-for-profit association representing motor vehicle and law enforcement agencies in North America. Prior to joining AAMVA, Schuster was President and CEO of ITS America for six years and Executive Director of the International Bridge, Tunnel and Turnpike Association for 16 years. He has an MBA from the University of Colorado with a major in transportation management and a BA in Economics from the Brooklyn College.

**Bernard C. Soriano** is the Deputy Director for the California Department of Motor Vehicles. He has over 30 years of engineering and management experience in the private and public sector. He previously held engineering and management positions at Hughes Space and Communications, Inc. in Los Angeles, where he designed satellite attitude control systems and was involved in their launch missions. He was also the Assistant Technical Director at the USGA Research and Test Center in New Jersey. In the public sector, Bernard was the Chief Information Officer for the Office of the Secretary of State and was the information technology task force leader on Governor Schwarzenegger’s California Performance Review. Bernard was also a member of the part-time faculty at the California State University, Sacramento, where he taught courses in the College of Engineering and the College of Business Administration. Bernard holds a Ph.D. in Engineering from U.C. Irvine, a M.S. in Mechanical Engineering from the University of Southern California, and a B.S. in Mechanical and Aeronautical Engineering from U.C. Davis. He also holds an M.B.A. from California State University, Sacramento. He was a Lieutenant in the U.S. Navy Reserve and has numerous publications and patents. His honors and achievements include selection as a finalist in the NASA astronaut program.
# Attendees

**PennDOT Connected & Autonomous Vehicle Visioning Kick-off Workshop**

**PSATS Training Center - October 3, 2013**

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
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<tbody>
<tr>
<td>Barry Schoch</td>
<td>Secretary</td>
<td>PennDOT</td>
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<tr>
<td>James Ritzman</td>
<td>Deputy Secretary</td>
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<td>Scott Christie</td>
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<td>Kurt Myers</td>
<td>Deputy Secretary</td>
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<tr>
<td>Brian Hare</td>
<td>Chief, Planning &amp; Contracts Management</td>
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<tr>
<td>Mike Bonini</td>
<td>Manager Research Division</td>
<td>PennDOT</td>
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<tr>
<td>Steve Grimme</td>
<td>Chief, Highway Safety and Traffic Operations Division</td>
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<tr>
<td>Mark Kopko</td>
<td>Sr. Civil Engineer, Traveler Information &amp; Special Projects</td>
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<td>Doug Tomlinson</td>
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<td>Brian Thompson</td>
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<td>Dan Cessna</td>
<td>District Executive</td>
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<td>Cheryl Moon-Siriani</td>
<td>Assistant District Executive</td>
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<td>Chris Reilly</td>
<td>Special Assistant to Deputy Secretary</td>
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<td>Shelley Scott</td>
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<td>Kathryn Tartaglia</td>
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<td>Benjamin Flanagan</td>
<td>Civil Engineer</td>
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<td>Tim Scanlon</td>
<td>Traffic Engineering Manager, PA Turnpike</td>
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<td>Craig Swney</td>
<td>Chief Operating Officer, PA Turnpike</td>
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<td>Jerry Guaracino</td>
<td>Assistant Chief Mechanical Officer</td>
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<td>Kevin Gay</td>
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<td>Ellen Partridge</td>
<td>Chief Council</td>
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<td><strong>Valerie Briggs</strong></td>
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<td>Jim Hunt</td>
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<td>Philip Bobitz</td>
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<td>Joe Peters</td>
<td>Director Office of Research &amp; Development</td>
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<td>Cem Hatipoglu</td>
<td>Office of Analysis Research &amp; Technology</td>
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<td>Jim Wright</td>
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<td>Greg Krueger</td>
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<td><strong>Jim Misener</strong></td>
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<td>Attendees (Cont.)</td>
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<td>Rick Schuman</td>
<td>Vice President and General Manager</td>
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<td>Chris Poe</td>
<td>Assistant Director &amp; Sr. Research Engineer</td>
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<td>Matt Smith</td>
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<td>Stan Caldwell</td>
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<td>Rick Stafford</td>
<td>Director Traffic21</td>
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<td>Raj Rajkumar</td>
<td>Co-Director GM Lab, Director University Transportation Center</td>
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<td>Courtney Ehrlichman</td>
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<tr>
<td>Sonia Mangone</td>
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<td>Corey Harper</td>
<td>Masters Student</td>
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Breakout Session Summaries

Breakout Session 1: Impacts to Existing Infrastructure, Design and Investment Decisions

The group started brainstorming what 2040 will look like. The main ideas drawn from the discussion were that demand will continue to increase but perhaps not at the same rate as today. Driver preferences, teleworking and modal shifts will change the demand rate. Transit demand may increase or decrease due to varying motivations for autonomous vehicles and/or modal shifts. Cars will be lighter and smaller and more electrified.

The group then moved into discussing how there is a real need for predicting what the future is going to look like and what the needs are going to be. Making decisions for the future will be challenging due to uncertainties and lack of information regarding the future. This also leads to challenges regarding investment decisions; how you make them and when to make them. The group mostly believed that the market will drive the direction. Therefore market forces will direct whether connected vehicles will be more of a reality over the next 20 years or autonomous vehicles. DOTs will need to follow the driving forces rather than creating those forces.

There will be more of availability of data and opportunities for public private partnerships. DOT really wants data services, information and not so much of the data itself. Real opportunities for PPP exist. Incentives for investments may change over time. It might take 25 years to change a traffic signal but in the future that may change if more capacity is created by using smarter signals. However there are institutional challenges that come with those changes. Even though you may want to invest in certain technologies, there are limited resources and limitations on how they can be allocated. There is little flexibility in terms of funding systems.

Operational issues were discussed and the fact that with the introduction of connected and autonomous vehicles they will become more safety critical. Also it was noted that we are trying to adopt the existing infrastructure of today for tomorrow’s technology; there could be breakthrough technologies that could make much different of a scenarios and result in easier operations, investments, etc. In addition it was noted that investment priorities are perhaps easier to be done on interstate levels.

Other issues discussed were:

- Need for changes in standards and manuals
- Need for better benefit-cost analysis
- Need for changes in procurement processes
- Cities vs. rural areas: While cities may use the technologies to improve mobility and help societal goals, in rural areas much of the focus will be on safety. Also new opportunities and advantages could be created as a result of autonomous vehicles in rural areas (i.e. permitting issues)
Breakout Session 2: Communication Device Investments and Real Time Data Usage

Relatively near term

There were discussions on what kind of connectivity would drive infrastructure investments in a connected and autonomous environment by first looking into the kinds of activities that State DOTs needs connected data for. Examples of such activities are 2-way traffic operations, pavements, winter maintenance, work zones, etc.

Then the group looked into DSRC and if and when it is necessary to have DSRC vs. cellular. The conclusion of the discussion was that all of the already discussed activities can be accomplished through cellular with an exception of safety applications. The challenge for State DOTs here is what it actually means that they connect everything through cellular connection.

As for DSRC the group discussed possible logical places where DSRC could be best cost effective due to time sensitivity. Possible scenarios are high crash intersections, work zones, high vehicle turn over locations, etc.

Throughout this discussion it was clear that State DOT is not able to deal with huge amount of data and they need a private entity to process the data and provide them/users with information. Also it became apparent that while there is synergy in between data, connectivity and what DOTs need for travelers, there has not been any robust discussion of a business model and what is needed to materialize this synergy.

2040

The group agreed that so much will change by 2040. Identifying what would be significantly different the group came up with the list that includes mapping, smart infrastructure, materials, etc. Then the question was if they were a State DOT what were the implications and where might DOTs start first to have realistic and useful planning. The consensus was that DOTs should start planning with simple environments such as rural interstates, rural access environments, corridors that are not challenging and have simple designs and cross sections, then some DSRC equipped corridors and lastly complicated urban environments.
Breakout Session 3: Impacts to Freight Flow

There are three dimensions of perspectives (what drives this environment): technological perspectives, regulatory perspective, and economic perspective. One or a combination of these factors will drive the environment of connected and autonomous vehicles. This diverse group of individuals from academics, suppliers, regulators, road owners, etc. had different views of progression of the environment. While some believed in incremental changes, others believe in visionary and big bang progression and the last group had some out of the box thought with respect to this environment and what it would bring forward. The three groups mentioned above along with their varying perspectives mentioned earlier form a matrix with 9 combinations of perspectives and timeframes.

The group broke down freight operations into time of day, facility type, and function, realizing there are constraints applicable to each of these factors. Automation may not be ubiquitous and even by 2040 we may have reasons to have a driver in the truck.

Fatigue and hour of service is a huge economic driver but if you are going to be tired anyway, you may very well have regulations that could act as disincentives for fully automated systems. It might even be a disincentive to some of the platooning that has been discussed.

Legislative policy changes could help a lot in terms of steps that move the industry towards automation. It could even be the first step. Demonstration and pilot tests could be another important step towards full automation. Lastly workforce is very important. This is a specialized workforce. Maintaining and operating this type of workforce within fully automated environments could be challenging. The group mostly believes that it is a difficult industry and automation might make it more difficult or not.
Breakout Session 4: Impacts to Driver Licensing and Workforce Training Needs

The group realizes that this is going to be a whole new world and the change will be incremental. It will be based on what products are in the market and how people would use them. May be in a short run all trainings will be for levels 2 and 3 automation as level 4 is further out. Driver licensing has not changed over the last 60 years. But that cannot remain the same.

There will be some training at the dealership level as dealers needs to know how to drive the cars and salesmen need to know how to explain and demonstrate features. The same holds true for rental car companies. Lots of hope that we would have trainings with simulators as VDOT is actually testing it right now.

The group also talked about insurance companies, and the whole range of issues related to them and liabilities. What might be a federal role when it comes to liabilities?

As far as workforce training more reliance on human factors is needed. We don’t want people to disable what they don’t like. Human factors will become more and more important. The group reminded themselves that FMCSA has the authority over commercial vehicles and their authority over the states have made the industry a lot safer. On the passenger side however, NHTSA does not have authority over state motor vehicle agencies when it comes to testing and licensing and this makes the procedure more challenging.

Medical issues were discussed as to how each state can identify people who could be driving or not. Medical teams can be involved providing guidance to DMVs as to what level of driving a person could undertake. Court system was discussed and how autonomous systems could help with court orders when it comes to limiting driving. Workforce retention is another challenge that needs to be taken into account as technologies become more advanced.
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<th>No.</th>
<th>Name</th>
<th>Title</th>
<th>Organization/Company</th>
<th>Breakout Session</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Scott Christie</td>
<td>Deputy Secretary</td>
<td>PennDOT</td>
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<td>Co-Director GM Lab, Director University Transportation Center</td>
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<td>Sonia Mangones</td>
<td>PhD Student</td>
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Breakout Session 1: Impacts to Existing Infrastructure, Design and Investment Decisions
Moderator: Valerie Briggs
Note Keepers: Chris Hendrickson (CMU Professor), Sonia Mangone (CMU Ph.D. Student)

Thoughts for the breakout session provided in advance to the moderator:

- What steps should a DOT be taking to foster the deployment/expansion of connected and/or autonomous vehicles?
- How will geometric designs be impacted by connected and/or autonomous vehicles? Changes of standards?
- What steps should a DOT be taking to accommodate mixed traffic (existing vehicles, connected vehicles, and various levels of autonomous vehicles on the road at the same time)?
- When should a DOT begin considering connected and/or autonomous vehicles when making investment decisions?
- What potential Private Public Partnership (P3) opportunities are there to help alleviate infrastructure investment costs in a connected and/or autonomous environment?
- Asset management (i.e. maintenance) and automation
- Considerations for road owners (i.e. toll authorities)
- Types of roadways (i.e. arterial, rural, urban, limited access, etc.)

Discussions started at 1pm:

Issues that the group thought should be covered:

- Uniformity: uniformity among DOT implementations will be important and challenging. Role of DOT is important.
- Infrastructure: How does public infrastructure change over time?
  - What: Relationship between infrastructure and needed supply and support
  - How: Relationship between decision processes and transferring those to infrastructures
  - Who: Jurisdictions/entitles in charge of activities and sub-processes for infrastructure (Vehicle to Infrastructure). Who is in charge of putting systems in controllers?
- How to determine investment strategies given the extensive existing roadway infrastructure?
  - What needs to be in place?
  - Unification of definitions of infrastructure: defining infrastructure and pieces impacted by the technology.
  - Example: Striping roles: guidelines on implementation of city roads not striped. Currently there are standards for when stripes are needed or not.

World in 2040

- What is going to change?
  - Vehicle miles – number of vehicles on roads: demand will continue to increase
  - Fleet mix will change.
  - Electrification
  - Lighter and smaller cars
  - Gas tax will be harder to use.
  - Driver Preferences will change – less emphasis on driving, fewer drivers, more multi-modal trips (e.g. commuting by bike, telecommuting)
Concerns

- A vision is needed and lacking.
- New technologies need incentives. Both autonomous and connected vehicles are ways to meet various interests.
- How to fund systems? There is no funding to increase capacity. Safety and air quality funding available. Current funding environment is sufficient for maintenance only.
- How to trace the trends? Establishing scenarios, education on trends to describe future.
- Generational gaps: need better definitions
- Other forces, events, leading parties will move us toward driving autonomous and connected vehicles and will make people more comfortable.
- Risks for DOT to invest on infrastructure that they are not sure is going to be useful. (If the agency spends in controllers and save capacity investments, it is a big benefit. If the agency retimes corridors every five years, they could get more capacity, but there is not funding to do so.)
- State DOT will have much better data but data should be managed by third parties.
- Change of paradigms: for this it is needed to know how much savings is resulted from the new technology.
- Support for complex cost: improved cost-benefit methods. Proving societal benefits can be difficult.

Design

- Guide, manuals, constructions specifications, including Highway Capacity Manual are going to have major changes (i.e. 12 feel on interstates but for arterials could potentially vary.)
- Changes in procurement processed: more outcome based specifications rather than specification based

Operational Issues

- Maintenance and operations of safety critical issues : IT systems become very critical.
- Higher level of staff training needs mode for people working in the field of transportation
- Snow, rain and ice clearance
- Sign maintenance
- Maintenance become more critical
- Traffic devices in work zones
- Struggle for designs of a more multimodal system, mixed fleet, autonomous and connected vehicles together.
- Are autonomous vehicles limited to current road way infrastructure or will radical changes be needed? Infrastructure needs to adapt to vehicles.
- Are there map-based solutions?
- Interstates are most consistent part of the network today so maybe easiest to adapt. Also they connect the rest of the system.
- Cost will be least expensive on high ADT facilities; hence DOT motivations.
- However P3 potentials may impact investment decisions.
- Interface between P3s and state investment challenges will be of importance.
• Market forces will determine direction. Infrastructure will follow. Difficult for DOTs to know when the changeover occurs.

P3s

• Data: need? Handling capacity? Who processes? Who is going produce useful information out of data?
• DOT does not have capacity to process. Slow speed. Actually the data capture is not useful
• DOT prefers for the private sector to handle data and translate to information
• Value added services:
  - Traffic data
  - Bridge condition information
  - Pavement
  - OD data
  - Snow and ice information
  - Traffic counts
    - And the list goes on...
• P3s may arise to meet investment needs. Needs are to be defined.
• Limitless P3 opportunities associated with data.

DOT Changes

• Focuses on expertise and knowledge needed to do the job: More IT plus ITS professionals
• Growing partnerships with educational institutions
• Building applications, repair technologies
• Recycling and more environmental and sustainable infrastructure and transportation measurements
• Planning process: need much shorter planning horizons (i.e. 12-20 year not working)
• It is important to address the question on funding of the systems, to see how DOT tasks and goals are going to change
• Drivers will need more information for informed decision making
• DOT: what they do is the same, but how the do it is going to be very different

Other changes

• Younger and older generations will push towards implementation of this new technology (potential regulations for older generations)
• Parking needs for space are going to drop
• Less number of vehicles

What happen in the cities?

• Less congestion
• More demand based transportation
• Congestion management is going to be different, like congestion pricing will be easier to implement
• Potentially fewer traditional transit
• Shared services/vehicles: vehicles by need on demand
- Remove parking
- Creating ADA facilities
- How do autonomous vehicles change tunnel operations?
- Traditional jobs: bus drivers, mechanics jobs, etc. will change
- Urban densities may change
- Can connected and autonomous vehicles help achieve metropolitan goals?
- Reducing cars makes alternative modes more attractive.
- How connected vehicles can help to drive trucks outside city centers.

Changes for Rural areas

- Autonomous school buses
- Reduce weight per axle of trucks through connected and autonomous vehicles; longer road and bridge lifespan
- No line painting in rural areas
- Managing farm vehicle travel will be easier and safer
- Rural roads do not necessarily meet design criteria: how does this affect autonomous vehicles?
- May be able to stop vehicles before they violate permits related to bridge weight-limits
- Can control permit routing: automated permit routing results in no violations
- More efficient special event management due to parking distribution and travel around events
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<td>11</td>
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<td>Shelley Row Associates</td>
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<td>Rick Schuman</td>
<td>Vice President and General Manager</td>
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<td>Courtney Ehrlichman   *2</td>
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<td>16</td>
<td>Corey Harper          *2</td>
<td>Masters Student</td>
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Breakout Session 2: Communication Device Investments and Real Time Data Usage
Moderator: Shelley Row
Note Keepers: Courtney Ehrlichman (Project Manager Traffic21 @CMU), Corey Harper (CMU Student)

Thoughts for the breakout session provided in advance to the moderator:

- What types of infrastructure communication devices will be needed in the near term as well as 2040?
- What existing programs or processes (e.g., traffic counts, probe data traffic speeds and travel times) could be modified or eliminated by collecting data from connected and/or autonomous vehicles?
- How is data currently being captured and used, if at all? Changes to the current system? Are there any special data needs?
- Are there core communication requirements that need to be standardized to provide a baseline system/social benefit?
- Policy issues: data security, ownership, secondary use, legal rights
- What real time data is expected to be available from connected and/or autonomous vehicles and how can that data be used to improve:
  - systems planning
  - maintenance efficiency
  - systems operations
  - modal integration
- Role of traffic control devices (i.e. signals, signs, markings) in support of automation
- Role of communication infrastructure in support of automation
- Roadway hardware – barriers, signs, cameras, sensors
- Vehicle and infrastructure interaction

Discussions started at 1pm:

Already here

- INRIX real-time road conditions. Two way connectivity. Information exchange, off board routing and navigation.
- University Of Maryland: Acquire and aggregate data from existing sources convert to useful data for DOTs for operations, research, etc...
- GM putting 4g on all cars by 2015, pipeline of information for exchange
- Basic Safety Message (BSM) is communicated through DSRC, 10x/second

Data, what can it do for DOT?

- Using INRIX on 501 site. Sharing with metro/transit partners, tying into ATMS system. For customers and situational awareness.
- Real time operations - two-way
- maintenance operations (share/monitor)
- surface/pavement
- proactive in winter operations (share/monitor)
- work zone status (share/monitor)
will want someone to process the data, to only receive information and not data
traffic signals - SPAT (share/monitor)
Vehicle counts
Transit fleet reliability/availability
Performance monitoring for transportation planning
Planning with origin/destination data

These are all functions that are susceptible to being helped by Connected Vehicles (DSRC), can be done through cellular.

DOT concern: This is easy to say, but don’t know what it means to do it. (in terms of infrastructure investments)

What are all the policy issues with all of this? Will people tolerate?

Applications doable with cellular framework (no DSRC)

- What are the implications?
- Vulnerabilities?
- Time sensitivity of Data before it decays
- There’s a lot of capability but business model and technology issues. Some states need to dive in to provide more data so we can see.

Public agency need for data from connected and autonomous vehicles

- What is needed?
- What is the justification?
- What are alternative ways to get it?
- What is the implementation strategy/cost evaluation?
- What does state get from basic DSRC infrastructure beyond BSM?
- What is the business model? What are standards for messages (set up through IEEE?) There is no federal authority yet. How about business model between public and private?
- Is there unique data that state & governments have that would be useful? Is there leverage for data swapping? (i.e. work zone, tunnel heights, traffic signal data)

If DOTs provide the data, people will figure out how to use it:
Broadcast data and hope for it to be utilized by a private or public entity to improve safety

Concerns

- Making investments today, how long to realize?
- Overloading cellular system with broadcasting messages
- DOT can’t afford managing data. Could data just be available for pickup?
- Should investments be focused on high density locations?
- Regulatory pathways are missing and are needed? Perhaps having everything ready by 2020. Consumers are generally adaptable.
DSRC

- If there is a logical case to made its best to go DSRC over cellular. DOTs will wait till a vendor has a product that they can buy that solves a problem.
- Road side infrastructure in early years to mimic DSRC data?
- What are the implications for the security system?
- What is the vendor community doing?
- Forward/backward compatibility gaps?
  - Maintenance/safety vehicles
  - Work zones
  - High crash intersections
  - Corridors
  - High vehicle turnover areas (i.e. Early adopters)
  - High crash locations

Policy issues

- Data tied into security network
- Have reasons why data needs to be collected from user cars
- Political Opposition
- National transportation issues (state traveling)
- Compatibility of technology as it advances. Will this create gaps or problems

Year 2040

What is the synergy between automotive infrastructure and DSRC? Do not be constrained by infrastructure that we have now.

- Connected and automated
- Lane marking
- Smart infrastructure
- Maps. Precision and triangulating.
- Public agency role? To provide safe infrastructure, should be more engaged in map industry to share points of reference
- Materials can emerge as a totally different communication system
- Work zone consistency and signing consistency
- Demand responsive consistency
- Dynamic info & individualized info
  - Managed lane
  - Policy transparency
- Planning
  - Interstate
  - Controlled access – rural
  - DSRC controlled corridors – problem corridors
  - NHI – simple designs
- Urban freeway/cities

- Shift in transportation towards mobility services.
- Public agency need for data from CV/autonomous vehicle
  - What is needed
  - What’s the justification
  - Where’s the opposition?
- AASHTO develops apps
  - What info, not data, will they buy
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<td>Jim Misener</td>
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<td>6</td>
<td>Jim Runk</td>
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<td>7</td>
<td>Ali Maleki</td>
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<td><strong>Rick Stafford</strong></td>
<td>Director Traffic21</td>
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Breakout Session 3: Impacts to Freight Flow
Moderator: James Misener
Note Keepers: Richard Stafford (Director of Traffic 21 at CMU)

Thoughts for the breakout session provided in advance to the group:

This 2-hour moderated session is intended to elicit from this expert and stakeholder discussion group the types of research that an agency such as PennDOT (or USDOT) may wish to consider to address a potential world of wide proliferation of automated commercial vehicle for freight movement by 2040.

Operation: What are the effects of automated vehicles on CVO? Examples include how dispatch and logistics are accomplished, and particularly, the effects on Hours of Service, issues (if any) on enforcement. Are there other operational considerations as well? Please embellish.

Do you anticipate that the projected operational benefits (e.g., the possibility of reduced aerodynamic drag adding to fuel savings and less GHG emissions, the potential for driver safety, potential reduction of driver workload and fatigue) to open the door to these changes in how carriers and states operate? In this world of automated freight movement, where do you see the benefit and thusly, implementation (or not): arterial operations, limited access roads, rural roads, freight terminals?

Technology: We have heard about platoons, implemented with mixed or single classes of vehicles. (Jim leading a discussion/clarification of the maneuvers as desired, as he is familiar with platoon operations.)

On a purely technical basis, what are issues that you foresee? (We discuss operations and policy in different threads.) Do you see connected vehicles happening before automation, automation before connected vehicles, or are they largely independent? Do you see partial or full automation by 2040? Why?

Policy: What are issues of policy that you foresee in any implementation of automated vehicles? Do they differ with different stages of automation, from “Level 1 or 2” truck following, through fully autonomous trucks? How do they evolve from the near future and lower levels of automation through 2040 and higher levels of automation? Example issues may be societal, road agency and/or enforcement acceptance, training or licensing requirements. Are there others?

Discussions started at 1pm:

Current Situation

- Jim Runk: 86% of communities dependent on freight. Interstate operation feasible; but off onto the local roads, not so.
  - Driverless truck not in the future; since driver is needed for more than driving.
  - Worries about the acceptance of platoons of vehicles without drivers.
- You will find platoons through the cloud. You will volunteer your location as a price for finding a platoon to join.
- Allen Biehler’s observation of freight warehouses and how they are routed. Could a package go from the manufacturer to your household without a driver.
Challenges and solutions

- May need to have driver (or rider) even if they aren’t driving.
- Take apart the trip to see which can be done totally autonomously and those where a driver/rider may be essential.
- Definitely see platooning for interstates.
- Jim Runk sees possibility to add capacity through platooning. Wondering whether can do away with shoulders, lines, etc.
- Freight shuttle in Texas on dedicated right of way. Initial 20 miles test. Can do several hundred miles. New class of vehicles. This would likely replace existing truck services.
- Lots of what is done for freight won’t change by 2040. It’s not just getting from point a to b.
- Difficult to imagine a truck without anyone in it.
- Technically, it is possible not to have anyone in the vehicle. But operationally, what if something happens?
- Truck “ports” might play a role.
- Ali Maleki: can do now on dedicated; when you put autonomous in a lane with other vehicles the problem is predicting what they will do. DSRC can solve this.
- ASO? Levels of failure. Ali Maleki described. Level 4 if it fails it will definitely kill someone.
- Social license to operate. Bar will be higher for the freight operators.
- How do we move towards public acceptance? On the positive side, young people are demanding more and more technology service.
- There will be failures? FMSCA maintained that we have to be prepared for all these possibilities. Cost will prevent some technologies from being introduced that are needed. Cost may also keep technology from being maintained/fixed when needed.
- Moore’s law will make computing power so pervasive by 2040, that the vehicles will be so much smarter and safer than human power.
- What will happen with driver fatigue requirements? An experimental study is needed to determine whether driver fatigue will lessen with autonomous driving. Will there be more hours of service? May still need hours of service.
- One thing that we need to categorize is that no one in vehicle; someone in vehicle but not driving; someone in vehicle but in control when necessary.
- Need to be thinking of ROI.
- Technology is unbounded.
- Other ways of accomplishing this.
- Driverless trucks may not be safe.
- Industry acceptance is uncertain, incremental, etc. They’re looking forward to the rest of this year.
- PennDOT is looking for ROI. Don’t want to build more. Get more out of existing infrastructure.
- How do you manage incidents?
- ABS is mandated 5 to 8% on tractor not working; 20% not working on trailers.
- Redundancy requirements; how do you maintain the technology.
- Workforce to maintain the technology.
- Cyber management.
- Trained workforce is an issue.
- Need to think of PennDOT itself as a fleet operator.
- Need to demo new ways of approaching the challenges of a fleet. Look at ROI. Need to address disruptive events.
• Question of longer trailer changes vs. autonomous convoys.
• Ali drew a graph that should prove useful...technology state; acceptance state.
• Really need to map out a scenario for PennDOT legislative agenda. Pa. can’t be an island. It’s statutes have to be consistent with other states.
• Doing some pilots; proof of concepts. Idea of demonstrating the technology.
• Human factors research. Acceptance of the technology by drivers.
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<td>Mike Bonini</td>
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<td>Shelley Scott</td>
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<td>Deputy Director Traffic21</td>
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Thoughts for the breakout session provided in advance to the moderator:

- How will the adoption of autonomous and connected technologies impact current testing procedures (e.g., lane departure warnings, intersection assistance, emergency braking)?
- How will autonomous vehicles (specifically Level 3 vs. Level 4) impact the minimum requirements to be eligible for a driver’s license?
- How will connected and autonomous vehicles impact driver’s education programs and the instructors that administer those programs?
- How will engineering curriculums need to change to account for the impacts of connected/autonomous vehicles?
- What new technologies and procedures will be available to assist in training and testing ability to drive an autonomous vehicle?
- Will the driver retain ultimate responsibility for the safe operation of his/her vehicle, even when in autonomous mode?
- Uniformity of skill tests and training programs among states
- Issues pertaining to law enforcement and medical reporting and impairment issues.

Discussions started at 1pm:

Questions raised by the group

- How will testing programs change?
- In driver license testing will drivers be able to use parallel parking assist or backup cameras?
- Could be an interim licensing stage as we do now with motorcycle licensing?
- What do you test the drivers for in autonomous vehicles?

Concerns

- Real world testing of technology will help refine that technology
- Concern that dealers may not be able to adequately train buyers
- Training for drivers at rental car companies
- Driver testing has not significantly changed in 60 years
- State DOTs will require manufacturers to prove vehicles are programs with the rules of the road
- Hard to evaluate private driving schools and most schools now are not providing drivers education
- The best training for drivers is on the road experience
- Simulators could be adjusted to any level of automation
- Florida looking at licensing truck drivers first while California is looking at licensing passenger vehicles first (not allowing commercial drivers to get license)
- Hours of Service
- Autonomous shuttles
- Level 3 problems of overreliance on autonomy and distraction

Possible solutions
• Level 2 training is more important than level 3 training
• Learn lessons from pilot training on auto pilot and auto navigation on sailboats
• Education
• Need more human factors training
• New education degree in this area
• Ways to avoid riders from disabling functions out of frustration

Other issues

• How will insurance companies react?
• AAA insurance / training
• Insurance companies need more data
• Where does the liability lie, drivers vs automakers
• How do we know what level of standards do we need
• NHTSA does not have control over states licensing as now done by FMCSA for commercial vehicles
• Liability for after market devices
• Software upgrades
  - How it will happen?
  - Who will be authorized?
• Safety inspection training
• Should feds regulate liability
• Uniformity among states
• Should there be federal collection of data
• Data is a revenue source for state DOTs (sold to banks, insurance, etc)
• Issues of law enforcement and medical
• Doctors need to be aware
• State medical regulations will need to be re-written
• More functionality for suspended/limited driving (i.e. only drive to work)
• Concerns with law enforcement through connection with vehicles
• Workforce concerns
  - Maintenance
  - Training for licensing and inspection
• Retraining for displaced workers (Good example is union toll workers at turnpike well transitioned through good planning and communications.)
Connected and Autonomous 2040 Vehicles Vision

Participants

USDOT
• FHWA
• RITA
• Volpe Center
• FMCSA
Pennsylvania DOT
PA Turnpike
California DMV
Florida DOT
Michigan DOT
Virginia DOT
SEPTA
AASHTO
University of Maryland

Texas Transportation Institute
Carnegie Mellon University
General Motors
SAIC
ITS America
AAMVA
PA Motor Truck Association
Ricardo
INRIX
Peloton
Consultants
• Shelly Row Associates
• Jim Misener
• Booz Allen Hamilton
Dr. Chris Hendrickson

Dr. Yeganeh Mashayekh

Carnegie Mellon University

Secretary Barry Schoch

Pennsylvania Department of Transportation
Connected and Autonomous 2040 Vehicles Vision

- One year
- Pittsburgh region focus

Workshop

- Morning presentations & discussion

- Afternoon breakout groups & report out
  - Numbers correspond to assigned group
Developing a U.S. DOT Multimodal R&D Program Plan for Road Vehicle Automation

Kevin Gay
Vehicle Automation Team Lead
Volpe Center
Research and Innovative Technology Administration

October 3, 2013
Purpose of the R&D Program Plan

- Address the Department and agency strategic priorities (safety, mobility, environment)
- Clarify the government role vs. industry role
- Identify key research areas for the modes involved in vehicle automation:
  - NHTSA, FMCSA, FTA, FHWA, RITA
- Identify lessons learned & cross-over technology from other agencies:
  - FAA, FRA, MARAD, PHMSA, DoD, DoE, NASA, etc.
- Establish the ITS road vehicle automation research agenda for the 2015 – 2019 ITS Strategic Plan

R & D Justification

- Safety
  - 5.3 million crashes, including over 32,000 fatalities (2011)
  - Over 90% of crashes ($500 billion per year) attributed to driver error
- Mobility
  - $120 billion annual cost of congestion (wasted time and fuel)
  - Potential to double lane capacity (CACC trials)
  - 54 million Americans (20%) have some form of disability
  - $5.7 billion in total operating costs for 190 million paratransit (demand-response) trips.
- Environment
  - 25% of US greenhouse gas emissions ($30 billion per year) in societal costs
  - Field trials showed 8%-16% reduction in fuel consumption from semi-automated ‘road trains’ (SARTRE, Energy ITS)
- Analysis of Benefits
  - Double counting of benefits across technologies
  - Establish credible basis for benefits
**Development of a US DOT Multimodal R&D Plan Project**

- Define key road vehicle automation research challenges
  - Focus on areas appropriate for US DOT investment
  - Prioritize research challenges

- Produce a multimodal R&D program plan for safe and connected vehicle automation
  - Define roadmap for execution of slated research
  - Focus on efforts associated with the next ITS Strategic Plan 2015-2019

- Complement, leverage, and enhance what industry activities
  - Avoid duplication of industry efforts
  - Keep pace with industry progress

---

**Input to the USDOT Multimodal R&D Program Plan**

- **US DOT Multimodal Plan ITS JPO**
  - FHWA: Improving overall roadway network performance and personal mobility
  - FMCSA: Ensuring safe in-service operations of motor carriers
  - NHTSA: Defining the need for vehicle standards
  - RITA: Coordination and development of the modal program plan
  - FTA: Improving transit vehicle safety and operations
  - Industry, Academia, Other Govt.: Request for Info, Expert Interviews, Industry Analysis, TRB Workshop

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Modal Research Interests in Automation

<table>
<thead>
<tr>
<th>Agency</th>
<th>Research Interests</th>
</tr>
</thead>
</table>
| RITA    | Provide coordination and outreach for vehicle automation program  
• Multimodal R&D program plan  
• Stakeholder outreach |
| NHTSA   | Conduct research to support regulatory process and to determine the need for vehicle automation standards  
• Human factors  
• Electronic control systems (safe reliability and cyber security)  
• System performance requirements |
| FHWA    | Improving overall roadway network performance  
• Application research (CACC, Platooning, Speed Harmonization)  
• Infrastructure requirements to support automation  
• Personal mobility |
| FTA     | Improving transit vehicle safety and operations  
• Application research (Precision Docking, Bus Lane Assist, Platooning)  
• Commercialization of automation technology |
| FMCSA   | Ensuring safe in-service operations of motor carriers  
• Enabling technology (truck / trailer coupling) |
| All Modes | Evaluation of safety, mobility and environmental benefits |

Coordination with Other Agencies

- White House  
  - Coordination of research across government agencies
- FAA  
  - Human factors issues for pilots using autopilot systems  
  - Testing of “fly-by-wire” systems  
  - Privacy & data issues with UAVs
- FRA  
  - Positive Train Control regulations
- MARAD  
  - Technology used in underwater, unmanned vehicles for mapping harbors
- DoD/TARDEC  
  - Convoy safety and fuel efficiency  
  - Personal mobility for soldiers around the base
- DOE  
  - Vehicle design, ownership models, and urban planning impacted by automated vehicles  
  - Significant reduction in energy consumption
- NASA  
  - Integrated Vehicle Health Management Systems  
  - Technology development
- NSF  
  - Cognitive and Autonomous Test vehicle research  
  - Cyber Physical Systems Research
- DHS/NSA  
  - Cyber security and cyber warfare
- Veterans Affairs  
  - Personal mobility
International Activity on Vehicle Automation

- Significant planning/investments being made in Japan and Europe
- Japan and Europe are also developing formal technology and policy roadmaps on vehicle automation
- Recently established Tri-lateral Working Group on Automation in Road Transportation.
  - Japan (Ministry of Land Infrastructure, Transport, and Tourism)
  - Europe (European Commission)
  - United States (ITS JPO)

Industry Developments in Automated Vehicles

<table>
<thead>
<tr>
<th>Organization</th>
<th>Noteworthy Developments &amp; Announcements</th>
</tr>
</thead>
<tbody>
<tr>
<td>HONDA</td>
<td>Conducting demonstrations of Traffic Jam Assist at locations around the US in 2013</td>
</tr>
<tr>
<td>Mercedes-Benz</td>
<td>MY 2014 – Steering Assist (Lane Keeping + Adaptive Cruise Control) in U.S. production vehicles; Self-driving vehicle for sale by 2020.</td>
</tr>
<tr>
<td>VOLVO</td>
<td>MY 2015 – Traffic Jam Assist (Lane Keeping + Adaptive Cruise Control) in U.S. production vehicles</td>
</tr>
<tr>
<td>Audi</td>
<td>MY 2016 – Traffic Jam Assist (Lane Keeping + Adaptive Cruise Control) in U.S. production vehicles</td>
</tr>
<tr>
<td>BOSCH</td>
<td>Traffic Jam Assist technology will be ready in 2014 for use by OEMs</td>
</tr>
<tr>
<td>NISSAN</td>
<td>Plans to release a fully self-driving vehicle by 2020</td>
</tr>
<tr>
<td>General Motors</td>
<td>Plans to release nearly self-driving vehicle by 2020</td>
</tr>
<tr>
<td>Continental</td>
<td>Partnered with Google and IBM to develop autonomous driving systems</td>
</tr>
<tr>
<td>TOYOTA</td>
<td>Researching a semi-autonomous vehicle designed to keep the driver in the control loop and takeover in case of an imminent accident</td>
</tr>
</tbody>
</table>
Key Technical and Policy Challenges

- **Technical Challenges**
  - Sensor fusion and electronic architecture
  - User acceptance of technology
  - Engagement of human in driving (driver assist vs. self driving)
  - Electronic system safety (safe reliability/cyber security)
  - Testing and certification of automated vehicles
- **Policy Challenges**
  - Varying state regulatory frameworks
  - Liability of stakeholders
  - Data ownership and privacy

Highlights of Plan

- **Main theme** → Safe & Connected Vehicle Automation
- **Currently**, a technology roadmap; policy elements need to be further developed
- **Leverage current successes of the ITS Connected Vehicle Program**
- **Address areas industry is not currently focusing on** (connectivity vs autonomy)
- **Collaborate with international interests**
- **Major objectives of plan include:**
  - Ensuring safe operation of deployed automated vehicles, especially in mixed traffic period
  - Understanding and demonstrating application & operational benefits of “connected automation”
  - Engaging relevant stakeholders to identify non-technical areas for future federal research
Safe and Connected Automation

- **Safe**
  - Meets requirements for functional safety, cybersecurity, and system performance
- **Connectivity**
  - Includes all types of communication with vehicles and infrastructure (Wi-Fi, DSRC, Cellular, etc.)

**Autonomous Automated 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 autonomous automated and connected vehicles

Benefits of Safe & Connected Automation

- Full benefits of vehicle automation achieved only through safety assurance and connectivity
- Vehicle-to-vehicle communications can enhance and enable system performance among locally connected vehicles
- Vehicle-to-infrastructure communications can optimize overall road network performance, safety, and reliability
Draft Multimodal Program Plan – Structure

- Research Tracks
  - Enabling Technologies
  - Safety Assurance
  - Applications
  - Testing & Evaluation
  - Policy & Planning Research
  - Stakeholder Events

- More details are available from Connected Vehicle Public Workshop presentation available at: http://www.its.dot.gov/presentations.htm#cvpm

- Major Milestones
  - Proof of Concepts & Field Tests
    - Individual applications
    - Application bundles
  - Capability Demonstrations
  - Requirements & Guidance
  - Strategic Plan Milestone: Automated Integrated Corridor Pilot
    - Demonstrates impacts of combined vehicle automation applications at a system level

Questions & Follow-up Contacts

- Kevin Gay – RITA / Volpe Center
  - Vehicle Automation Team Lead
  - Kevin.Gay@dot.gov
THE OPPORTUNITY

Crashes / Human Errors

Aging / Disabled

Congestion / Time

DRIVING AUTOMATED
(IN NON-AUTOMATED VEHICLES!)
EARLY GM AUTOMATED VEHICLES

NOVEMBER 3, 2007:
“BOSS” WINS DARPA URBAN CHALLENGE
NEXT STEP: SUPERCruise

HUMAN/MACHINE CHALLENGE: WHO’S IN CHARGE?
VEHICLE PERCEPTION

360° Sensing
Sensor Fusion
Maps / GPS
V2V / V2I Integration

V2V Implementation & Deployment Considerations

- Tech Readiness
- OEM / Feature Approach
- Penetration Rate
  - Business Considerations
  - Aftermarket / Retrofit
  - Regulation / Gov’t Incentive
- …
ROAD TO AUTOMATED DRIVING

Increasing Capability

Today's Driver Assist Package

Emergency Intervention (Limited Control)

Limited On-Demand Automation (Monitored Control)

Complex On-Demand Automation (Transferred Control)

Autonomous Driving (Chauffeured Driving)

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

Today

Future

Thank You
AASHTO National Connected Vehicle Field Infrastructure Footprint Analysis

Connected and Autonomous Vehicles 2040 Vision Workshop
October 3, 2013

Christopher Hill
Booz Allen Hamilton

Background

• AASHTO requested by USDOT to conduct a national connected vehicle field infrastructure footprint analysis
  ▪ Consider broad range of CV apps and scenarios
  ▪ Include safety, mobility and environmental apps
  ▪ Include light vehicles, transit, commercial vehicle and pedestrian apps
  ▪ Include urban, rural, freeway, arterial, and freight/intermodal facilities, and land border crossings
National Footprint Objectives

- Describe the justification for and value of deploying a connected vehicle infrastructure
- Assess the infrastructure, communication and data needs of priority applications
- Generate a set of generic (high-level) deployment concepts
- Identify scenarios leading to a preliminary national connected vehicle field infrastructure footprint
- Provide cost estimates and funding options
- Identify workforce, training, policy and guidance needs
- Identify implementation/institutional challenges and timing

Footprint Development Process

- Develop a Tech Memo to initiate engagement with state and local agencies
- Assess CV applications to identify deployment bundles based on shared characteristics
- Develop deployment concepts
- Develop deployment scenarios, a preliminary national footprint, and cost estimates
Tech Memo

“This is a major undertaking for AASHTO, Transport Canada, and the United States as we prepare for a safer and more productive transportation environment.”

Mike Lewis, AASHTO President and Director, Rhode Island DOT

“We are proud to invest in innovation and new opportunities to improve transportation safety and efficiency. By working together now we can lay the groundwork to align standards and regulations in North America and prevent barriers to cross-border travel and trade.”

Susan Spencer, Director of ITS Programs, Transport Canada

Footprint Applications Assessment

Application Packages
• V2I Safety
• Mobility/Environment
• Road Weather
• Smart Roadside
• Int. Border Crossings
• Fee Payments
• Agency Operations

Deployment Aspects
• RSU Requirements
• Communications Requirements
• Backhaul Requirements
• Siting Issues
• Data Needs
• Mapping Needs
Deployment Concepts

• Selected to represent settings into which an agency might deploy CV applications
• Documented with conceptual plan sheets and supporting descriptions
• Include variations and alternatives to enable broader range of applications and technologies
• Identify example applications appropriate to that setting and concept

Deployment Concepts

• Urban Intersection
• Urban Highway
• Urban Corridor
• Rural Roadway
• International Border Crossings
  ▪ Canada & Mexico
• Smart Roadside
• DOT Operations
• Fee Payments
• Freight Facility
Smart Roadside Example

Deployment Scenarios

- Interviews with agencies using application assessment and deployment concepts
- Identify how both well-informed and less familiar agencies would approach implementation
- Results will help prepare for:
  1. Infrastructure footprint for initial capabilities ~ 2020?
  2. Expand the initial infrastructure into nationwide footprint ~ 2030?
Potential Scenarios

- Metro areas with varying legacy TMC/ITS
- Statewide with varying legacy ITS
- Rural deployment
- Multi-state corridor
- Agency system management & operations
- Commercial vehicle & freight systems
- Border crossings
- Fee payment system conversions

Remaining Tasks

- Build-out from scenarios to the National Footprint
- Describe deployment activities and timelines
- Develop estimates of capital investment and O&M costs
AASHTO Institutional Support

- Create executive group to develop Board resolution
- Initiate implementation cooperation discussion within Connected Vehicle ELT
- Recast AASHTO Deployment Coalition
  - Similar to 511 Deployment Coalition
  - Peer Exchanges
  - Forum for public/private engagement
- AASHTO Subcommittee on Systems Operations & Management (SSOM)
  - Establish Connected Vehicle emphasis area

Further Information

- Footprint Analysis documents on AASHTO Site - Task 3, 4, & 5 (draft):
  - [http://ssom.transportation.org/Pages/Connected-Vehicles.aspx](http://ssom.transportation.org/Pages/Connected-Vehicles.aspx)

- jwright@aashto.org
- hill_christopher@bah.com
GM - Carnegie Mellon Autonomous Driving CRL

Raj Rajkumar
George Westinghouse Professor
ECE & Robotics
http://www.ece.cmu.edu/~raj

Connected and Autonomous Vehicles 2040
Design and Infrastructure

Society and Automobiles

• More than 1.2 million people die every year in automotive accidents globally

• Commuting and traffic delays are expensive.

• Loss of independence and self-esteem of senior and disabled citizens

Connected and Automated Vehicles will change the face of transportation

Vehicles that refuse to crash
Driver and Passenger Space

SRX Interior
2040 Connected Vehicles

With Traffic Lights

Using V2V

Public Driving

http://rtml.ece.cmu.edu/Shuster

Google “Shuster Schoch CMU”

Vehicular Networking
**Challenges**

- **Exogenous**: The complexity & uncertainty of the real world
  - Weather, lighting, and road conditions; construction; accidents; obsolete information, loss of GPS.
- **Endogenous**: Online and safe recovery from failures of sensors, actuators, computing or communications.
  - Sensors and actuators
    - Calibration, wear and tear, outright failure.
- **Assurance**: How to verify and validate safety & correctness?
- **Interactions**: Vehicular Networks
  - communicate securely and coordinate carefully
- **Reliability**
  - cost and maintenance, customer acceptance
- **Incremental** deployment
  - Semi-autonomy → on-demand autonomy → full autonomy
- **Legal** implications

---

**Design 2040**

- **Accidents, injuries and fatalities drop.**
  - Pedestrians, bicyclists and motor-cyclists use V2X.
  - Automobiles can be made lighter, and get more mileage.
- **Empty space on highways is used more efficiently.**
  - Urgency for additional lanes
  - Shoulders will continue to be needed for emergency situations.
  - Sprawl could potentially go up since people can be productive while commuting
    - Other unintended consequences?
**Infrastructure 2040**

- Infrastructure elements communicate
  - Smart traffic signs
  - Smart traffic lights
  - Smart construction zones
  - Smart tunnels
  - Smart ramps
  - Road condition sensors
  - Smart parking
- Rigs, trucks, buses and taxis become self-driving too.
  - Re-think parking, towing, emergency support.
- Lane markers get painted more frequently.

---

**Investments 2040**

- Smart infrastructure
  - Security and privacy of communications.
  - DSRC gadgets affixable to infrastructure elements.
- Localization technologies in urban canyons and tunnels.
- New regulations:
  - Licensing and operations
  - Emergency stoppage and retrieval for repair
- “Black boxes”
- Lanemarkers that last.
- Detectors for ice and snow coverage.
Summary

- Fast-moving space
- Early 2000s: “Science Fiction”
- 2007: “Feasible” – DARPA Urban Challenge
- 2010: “Wow” EN-V GM @ World Expo
- 2011: “Whoa” Google’s project
- 2013: Cranberry to PIT airport + “Me too”
- 2020 or earlier: “It’s there”
- 2040: “the future is here”
Ricardo, Inc.
Delivering Value Through Innovation & Technology
The SARTRE Project: Safe Road TRains for the Environment

Ali Maleki
Product Group Director
Ricardo, Inc.

Date: October 3, 2013
Location: PennDOT Workshop
Connected & Autonomous Vehicles 2040 Vision

Remember this computing power?
… and this I/O rate?

… but still not too portable …
… then huge step forward…

We are here … for now
On the communication front...Remember these?

Have become these
In the transportation industry, we used to drive these

... and these
Now we have these
... and these

Imagine the Possibilities: Computer+Vehicle+Wireless
“Funded by the European Commission to develop strategies and technologies to allow vehicle platoons to operate on normal public highways with significant environmental, safety and comfort benefits.”
SARTRE PURPOSE: “to encourage a change in personal transport usage by developing of roadtrains called platoons.”

- What:
  - Develop a prototype platooning system
  - Operating on public highways/freeways
  - No changes to the road and roadside infrastructure
  - Mixed traffic – shared with non-platoon traffic
  - Mixed vehicles – trucks, cars

- Why
  - Assess and evaluate the environmental, safety, congestion and convenience benefits under real world scenarios
  - Illustrate new business models

- How
  - Lead vehicle driven by a trained professional driver
  - Following vehicles have automated driving

Ricardo’s Contribution

- Project leader and coordinator
- Developed platoon control system
  - Platoon joining, leaving, etc.
  - Platoon-wide situational awareness through fusion of vehicle-level sensors
  - Exceptional scenarios
    - Intrusion of non-platoon vehicle
  - Vehicle
- Defined Safety Analysis process
  - Based on knowledge of existing processes (e.g. IEC 61508, ISO 26262)
  - Multiple automated vehicles
  - Deliberate malicious threats
  - Human factors, e.g. operator error/confusion.
Sensor sets and V2X Communication

First Platoon Master Controller

- Inter-vehicle Distance
- Relative Speed
- Lane-Offset Detection
- Yaw-Rate Sensing
- Steering Angle Sensing
- Platoon Heading Angle Calc
- Platoon State Management
- Longitudinal and Lateral Control
- Platoon Stability Control
- Platoon Position and Performance Reporting

SARTRE – Use Cases

- Significant number of factors
  - Performance/Failure of Vehicles, Braking/Acceleration/Turning Procedure, Human Behaviour, Other Vehicles, Platoon Size, Gap Size ....
Human Machine Interface

- HMI (Human Machine Interface) components
  - Touch screen
    - Status of the SARTRE vehicle
    - Status of the whole road train
    - Driver interaction with the system
  - Voice prompts
    - Important status updates
    - Driver keeps eyes on the road
  - Haptic seat
    - Alerts driver of status changes
  - Steering wheel
    - Natural override of automated lateral system
  - Accelerator and brake pedals
    - Natural override of automated longitudinal system

Demonstration System Performance

- Up to 90 km/h
  - 90 km/h is truck speed limit
  - Higher speeds tested on test track

- Test tracks and public freeway / motorway
  - Day, night
  - Rain, snow (cleared road)
  - Interactions with non-platoon traffic
Real-Life Fuel Consumption Improvements

- Fuel consumption evaluation
  - Baseline measurements: cruise control
    - Already better than most drivers
    - 16% for following vehicles
    - 8% for lead vehicle

Press Reactions to Platoon Experience

- Demonstrations to industry and to the international press
- Journalists were permitted to ‘drive’ the automated vehicles
  - “I found it surprisingly easy to trust the system once I joined the platoon.”
  - “The most alarming thing about taking your hands off the steering wheel when hurtling along the road at 90 km an hour is just how quickly you get used to it.”
  - “Within a few minutes I felt remarkably relaxed. It might sound like science fiction and a recipe for chaos and mayhem, but it works.”
Platooning is one method to bridge both the technology gaps and consumer acceptance towards fully autonomous vehicles.

Adaptive Cruise Control
Collision Avoidance
Platooning
Consumer Acceptance

CONNECTED & AUTONOMOUS VEHICLE BREAKTHROUGH!
FDOT CONNECTED AND AUTONOMOUS VEHICLE ACTIVITIES
PennDOT Connected Vehicle and Autonomous Vehicle 2040 Vision Workshop
October 03, 2013
Elizabeth Birriel, P.E.

TOPICS

• Florida Connected Vehicle Overview
• Florida Autonomous Vehicle Legislation
• Automated Vehicle Summit
FLORIDA’S CONNECTED VEHICLE PROGRAM

- 2011 ITS World Congress
- National Affiliated Test Bed
- Integrated Vehicle to Infrastructure Prototype

2011 ITS WORLD CONGRESS

- 26 Connected Vehicle Demonstrations
- 25 Roadside Equipment Devices
- 20 Miles of Covered Roadway
2011 ITS WORLD CONGRESS - SUNGUIDE® SOFTWARE

- Connected Vehicle Subsystem
- Receives & Processes Basic Safety Messages (BSM) & Probe Vehicle Data Messages (PVDM)
- Transmits Traffic Advisory Messages (TAM) as Part of Event Management

NATIONAL AFFILIATED TEST BED

- Coordinated by USDOT
- Orlando Region
- FDOT Focus on Safety & Mobility
- Agency Partnerships
FLORIDA AUTONOMOUS VEHICLE 2012 LEGISLATION

• HB 1207
• Defines Autonomous Technology
  – Technology installed on a motor vehicle that has the capability to drive WITHOUT active control or monitoring by a human operator

FLORIDA AUTONOMOUS VEHICLE 2012 LEGISLATION

• Provides for Operation of Autonomous Vehicles on Public Roads
• An autonomous vehicle registered in Florida must continue to meet federal standards and regulations for a motor vehicle
FLORIDA AUTONOMOUS VEHICLE
2012 LEGISLATION

• Provides Guidelines for Operating an Autonomous Vehicle
  – A person who possesses a valid drivers license may operate an autonomous vehicle in autonomous mode
  – Vehicle must have a means to engage/disengage autonomous technology easily accessible to operator
  – Must have means to visually indicate when vehicle is operating in autonomous mode

• Allows for Autonomous Vehicle Testing on Public Roadways
• Excludes Individual Active Safety Systems
  – Parking Assistance
  – Adaptive Cruise Control
  – Lane departure warning
• Directs Department of Highway Safety and Motor Vehicles to Prepare Report on Autonomous Vehicle Safe Testing and Operations
FLORIDA AUTOMATED VEHICLES SUMMIT 2013

• November 14-15, 2013
• Summit Goals
  – Facilitate the expansion and implementation of automated vehicle technology within the state of Florida
  – Provide attendees with a basic understanding of automated vehicle concepts, opportunities, challenges, and policy implementation
  – www.fleng.org/seminars.cfm?event_id=598

QUESTIONS?
Autonomous Vehicles in California

Bernard C. Soriano, Ph.D.
Deputy Director, California DMV

California at a glance

- Approximately 38 million people
- Over 172 thousand public road miles
- 25 million driver licenses and identification cards
- 73% commute to work alone
- 32 million actively registered vehicles
- Over 323 billion vehicle miles travelled per year
California Legislation – Senate Bill 1298

As soon as practicable, but no later than Jan. 1, 2015, DMV must adopt regulations setting forth requirements for:

• Manufacturers’ testing of autonomous vehicles on public roadways

• Operation of autonomous vehicles on public roadways

Challenges

• Definition
• Safety
• Liability
• Privacy
• Security
• Licensing
• Reliability
• Infrastructure

• Usage
• Vehicle Code
• Visibility
• Standardization
• Insurance
• Technical constraints
• Messaging
• Public perception
• Meetings and public workshops
  • Nissan • Chrysler
  • Google • Honda
  • VW Group • GM
  • Bosch • Toyota

• Autonomous vehicle technology advancing quickly
• Adoption by the public will not be dependent on technology
  – Human factors (HMI)
  – Generational norms

• Potential traffic safety improvements are immense
  – Over 30,000 traffic fatalities per year
  – Almost all (95%) of traffic fatalities were the result of human error
  – In over 35% of traffic fatalities, the brakes were not applied
  – 20% of traffic accidents involve a distracted driver

• Government and industry need to work collaboratively
  – Regulations
  – Communication

Autonomous Vehicles
Statewide Steering Committee
– California State Transportation Agency
– California Department of Insurance
– California Highway Patrol
– California Office of Traffic Safety
– California Department of Transportation
– California Department of Motor Vehicles
– National Highway Traffic Safety Administration
Regulatory Package 1
- Submission of evidence of insurance
- Marking of vehicle on DMV's database
- Data collection requirements
- Operator qualifications
- Target date of December 2013

Regulatory Package 2
- Testing requirements
- Safety standards
- Operator license requirements
- Vehicle registration requirements
- Other feasible regulations
- Target date of December 2014

Questions
Driving in an Autonomous World

Neil Schuster
American Association of
Motor Vehicle Administrators

PennDOT Workshop
October 2014

Our Focus Areas

Vehicle

Enforcement

Driver
Obvious Benefits

- Safety benefits
- Congestion relief
- Productivity
- Entertainment

and...

- Compliance transactions (inspections)
- Payments (tolls, fees, fines)
- Autonomous mode status (toll discounts)
- Validate the driver
Challenges

Driver education

Driver testing

Uniformity among states

Will your car speed?
What is the driver’s responsibility?

What is NHTSA’s role?
Self-driving trucks and buses (FMCSA role)
Thank You!

Breakout Sessions: 1pm – 3pm

Session 1
Impacts to Infrastructure, Design and Investment Decisions

Session 2
Communication Device Investments and Real Time Data Usage

Session 3
Impacts to Freight Flow

Session 4
Impacts to Driver Licensing and Workforce Training Needs