# Introduction: The Automated Vehicles Symposium 2015

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**Abstract** The 2015 Automated Vehicles Symposium built on the successes of the predecessor meetings, with an even larger and more diverse roster of participants and a broader selection of breakout sessions. It was organized in cooperation with the University of Michigan's Mobility Transformation Center, which provided an opportunity for the Symposium participants to experience a wide range of vehicle demonstrations at their new MCity test site. The plenary and poster presentations and breakout discussions continued to provide the meeting participants with the most up-to-date and authoritative information about the current international state of development of road vehicle automation systems, making this the essential meeting for industry, government and research people interested in the subject.

**Keywords** Road vehicle automation · Road transport automation · Automated vehicles · Autonomous vehicles · Self-driving vehicles

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# 1 Overview

The 2015 Automated Vehicles Symposium was organized and produced through a partnership between the National Academies of Science and Engineering Transportation Research Board (TRB) and the Association for Unmanned Vehicle Systems International (AUVSI), continuing the pattern established by the 2014 Symposium. This meeting was organized to serve their constituencies' interests in understanding the impacts, benefits, challenges and risks associated with increasingly automated road vehicles and the environments in which they operate. It brought together key government, industry and academic experts from around the world with the goal of identifying opportunities and challenges and advancing automated vehicle (AV) research across a range of disciplines.

The symposium took place over 5 days, 20–24 July, with 3 days of core activities and ancillary sessions on the first and last days. The morning plenary sessions included presentations from the public sector, automakers and suppliers and research institutes and the afternoons were devoted to seventeen breakout sessions for deeper investigation and discussion of selected topics. Receptions and poster sessions followed the close of the breakout sessions on Tuesday and Wednesday afternoons.

The breakout sessions were each organized by committees of volunteers to address a wide range of topics. Four of the breakout sessions spanned both afternoons of the Symposium, providing more time for exploration in greater depth and breadth:

- Beyond Single Occupancy Vehicles: Automating Transit and Shared Mobility
- Human Factors in the Design of Road Vehicle Automation
- Legal Aspects of Automated Vehicles, including Liability, Insurance and Ethics
- Early Deployment Opportunities for Connected Automation Systems.

The other thirteen breakout sessions covered a single afternoon each:

- Energy and Demand
- Physical and Digital Infrastructure
- Prioritizing Public Policy Challenges for Automated Vehicles
- Truck Automation
- Wireless Connectivity for Automated Vehicles
- Cybersecurity for Automated Vehicles
- Implications of Automated Vehicles for Planning
- Integrated Traffic Flow Models and Analysis for Automated Vehicles
- Traffic Signal Control with Connected and Automated Vehicles
- Vulnerable Road Users—How Can AVs Help Keep them Safe and Mobile?
- Impact of Connected and Automated Vehicles on Traffic Management Systems and Operational Strategies
- Verification and Validation of On-Road Automated Vehicles
- Enabling Technologies for Road Vehicle Automation.

The symposium also involved several related meetings that occurred before and following the main meeting:

- Opening ceremony for the University of Michigan's Mobility Transformation Center
- AASHTO Automated Vehicle Public Policy Workshop
- U.S. DOT Listening Session
- TRB Workshop on Envisioning Automated Vehicles within the Built Environment: 2020, 2035 and 2050.
- Meetings of the TRB Automated Transit Systems Committee and Freeway Operations Committee and its subcommittees
- U.S.–Japan–EU Trilateral Working Group on Automation in Road Transportation.

In keeping with TRB practice, the plenary and breakout sessions were planned and produced by volunteers whose expertise and interests informed the content of the sessions. In keeping with AUVSI practice, the production of the symposium was professionally managed by dedicated conference and logistics managers. The AVS15 Executive Committee reflected this mix of the two organizations:

David Agnew, Continental Automotive, Member, AUVSI Board of Directors; Richard Bishop, AUVSI subject matter expert on automation; Richard Cunard, Senior Program Officer, Traffic and Operations Engineer, TRB; Bob Denaro, ITS Consultant, Chair, TRB Joint Subcommittee on the Challenges and Opportunities for Road Vehicle Automation; Jane Lappin, Volpe National Transportation Systems Center, Chair, TRB Intelligent Transportation Systems Committee (AHB15); James Misener, Qualcomm, Symposium Demonstrations Coordinator; Steven Shladover, University of California PATH Program, Chair, TRB Vehicle-Highway Automation Committee (AHB30); John Maddox, Assistant Director, University of Michigan Mobility Transformation Center and Director of Collaborative Strategies, University of Michigan Transportation Research Institute; Brian Wynne, President and CEO, AUVSI; Lindsay Voss, Senior Program Development Manager, AUVSI.

## 2 Symposium Attendees

More than 870 registrants participated in the symposium. Attendees represented a wide range of organizations from government and industry to the academic-, public-, and private-sector research communities. One of the strengths of the meeting was the breadth of interests represented, with 56.5 % from industry, 18 % from public agencies and 25.5 % from academic and research institutions. This represented a higher proportion from industry and a lower proportion from academic and research institutions than at AVS14. The industry participants included 86 people from automotive OEMs and 68 from suppliers.

These participants represented disciplines ranging from engineering to psychology to law. Twenty-four countries (with 156 participants from outside the U.S.) and forty U.S. states were represented among the meeting participants. The largest delegation from outside the U.S. came from Japan, with 46 participants. Michigan, as the host state, had the largest number of attendees from within the U.S., followed by California and the national capital region (DC, Maryland, and Virginia).

## 3 Demonstrations

The scheduling of AVS15 to coincide with the opening of the Mobility Transformation Center (MTC) made it possible to schedule vehicle demonstrations in coordination with the MTC event. Most of these demonstrations were given at the MTC site, with shuttle bus service to facilitate movements of visitors between the conference hotel and the MTC. The demonstrators included Bosch, which demonstrated automatic emergency braking for pedestrians and a lane-keeping and adaptive cruise control combination called "highway assist". Delphi demonstrated the Audi SQ5, the car that drove across the country, and a Jaguar F-Type equipped with Driver State Sensing. Xerox demonstrated its Vehicle Passenger Detection System™ which enables transportation agencies or law enforcement to monitor lane use, CloudParc parking monitoring system, and MERGE™ for parking location.

## 4 Keynote Talks

Dr. Mark Rosekind, the Administrator of the National Highway Traffic Safety Administration (NHTSA) gave the opening plenary address, discussing his agency's concerns about traffic safety and the potential for automated vehicles to improve traffic safety with a fundamentally new goal of preventing crashes before they occur. He noted USDOT Secretary Anthony Foxx's emphasis on the importance of technology innovation for transportation.

Dr. Chris Urmson, the Director of the Google X Self-Driving Car Program, gave the second keynote address, describing the motivations behind the Google program and noting that the annual fatality rate on the Nation's highways is roughly the equivalent of a 737 airliner crash every business day. He showed videos to demonstrate the progress Google has been making on the automation of driving in complicated urban scenarios with further nuanced behavior such as their automated vehicles programmed to maneuver out of other vehicles' blind spots. He also noted Google's designed-in redundancy of actuators and sensors with multiple LiDARs, cameras and radars.

## 5 Plenary Panel Sessions

Vehicle Manufacturers and Suppliers:

- Bob Denaro, Moderator
- Michael Pozsar, Vice President, Electronic Controls, Electronics and Safety, Delphi
- Dr. Kay Stepper, Vice President, Head of Regional Business Unit Driver Assistance and Automated Driving, Robert Bosch LLC
- Dr. Cem U. Saraydar, Director, Electrical and Controls Systems Research Lab, General Motors.

Identifying and Addressing Key Research Questions:

- Dr. Steven Shladover, Moderator
- Legal Issues Addressed in the EU Adaptive Project: Andreas Knapp, Daimler AG
- Key Safety Principles for Automation by Automation Level: Levasseur Tellis, Technical Specialist, Functional Safety, Ford Motor Co.
- Michigan Mobility Transformation Center Research Roadmap: John Maddox, Assistant Director, Michigan Mobility Transformation Center
- Ethical Considerations for Vehicle Automation Systems: Dr. Chris Gerdes, Professor, Mechanical Engineering, Stanford University
- EU-US Collaboration in Road Transport Automation: Dr. Peter Sweatman, Director and Research Scientist, UMTRI.

Private Investment in Vehicle Automation:

- John Casesa, Vice President of Global Strategy, Ford Motor Co., Moderator
- Philipp von Hagen, Member of Executive Board, Porsche Automobil Holding SE
- Zach Barasz, Kleiner Perkins Caufield and Byers
- Glenn Mercer, Industry Analyst
- Chris Thomas, Founder and Partner, Fontinalis.

Automated Vehicle Verification:

- John Maddox, Assistant Director, Mobility Transformation Center, Moderator
- Stephanie Dougherty, Chief of Enterprise Planning and Performance, California Department of Motor Vehicles
- Ibro Muharemovic, Continental Automotive Systems Inc.
- Felix Fahrenkrog, Manager Active Safety ADAS, Driver Assistance, RWTH Aachen University.

State and City Level Issues:

- Jane Lappin, Moderator
- Dr. Johanna Zmud, Senior Research Scientist, Texas A&M Transportation Institute
- Paul Steinman, District Secretary, Florida Department of Transportation
- Leon Daniels, Managing Director, Surface Transport, Transport for London.

## 6 Plenary Presentation Sessions

International Automated Vehicle Initiatives:

- CityMobil2 Project—Dr. Adriano Alessandrini, University di Roma La Sapienza
- The Pathway to Automation and Connectivity—Meaningful Momentum in the UK: Michael Hurwitz, Director, Energy, Technology and International, UK Department for Transport
- Drive Sweden: Jan Hellaker, Head of Automation, Lindholmen Science Park AB
- French National Automated Vehicle Program: Dr. Christian Rousseau, Renault
- World Economic Forum: Alex Mitchell, Director, Head of Automotive Industry, World Economic Forum.

User Considerations:

- Automated Vehicles and Public Perception: Kristin Kolodge, Executive Director, Driver Interaction, J.D. Power
- Human Factors Evaluation of Level 2 and Level 3 Automated Driving Concepts: Dr. Myra Blanco, Research Scientist, Virginia Tech Transportation Institute
- Automated Vehicles and Human Factors: Patrice Reilhac, Innovation and Collaborative Research Director, Comfort and Driving Assistance Business Group, Valeo
- Automated Trucking Applications: Dr. Josh Switkes, Founder and CEO, Peloton Technology Inc.
- Digital Infrastructure: Ogi Redzic, Senior Vice President, Automotive, HERE.

Public Agency Automated Vehicle Initiatives:

- Japan: Hajime Amano, President, ITS Japan
- European Commission: Ludger Rogge, Research Programme Officer, DG Research and Innovation, European Commission
- U.S. Department of Transportation: Kevin Dopart, Program Manager, Connected Vehicle Safety and Automation, Intelligent Transportation Systems Joint Program Office
- National Highway Traffic Safety Administration: Nathaniel Beuse, Associate Administrator, Vehicle Safety Research, National Highway Traffic Safety Administration
- U.S. Department of Energy: Reuben Sarkar, Deputy Assistant Secretary for Transportation, Energy Efficiency and Renewable Energy, U.S. Department of Energy.

# 7 Breakout Sessions

The breakout sessions provided opportunities for more in-depth consideration of specific topic areas among groups of people with focused interests in those areas. With smaller groups, they could be more interactive than the large plenary sessions, with ample opportunities for questions and answers and debates. The primary findings from the breakout discussions were reported back to the plenary group on the final morning of the Symposium, in four panels based on thematic groupings.

## *7.1 Infrastructure and Operations Breakout Sessions*

Early Deployment Opportunities for Connected Automation Systems

This group focused on Level 1 automation systems, with the earliest opportunities for deployment, beginning with systems that are already commercially available. Roadway operators need to be receptive to supporting field testing, including facilitating use in managed lanes, but it is not clear whether they perceive sufficient benefits yet to justify investment in infrastructure changes, such as improving roadway markings. They need to see validated benefits estimates and have their concerns about cyber security threats allayed.

Impact of Connected and Automated Vehicles on Traffic Management Systems and Operational Strategies

This group identified the need for outreach to practitioners at city and county levels so that they can be better integrated into the discussions about automation and better prepared to respond to it. They are eager to understand how the automated vehicle market will grow and when it could potentially enable the elimination of some of today's traffic management infrastructure, such as detectors. They would like to use newly available data from automated vehicles to improve traffic management procedures.

Integrated Traffic Flow Models and Analysis for Automated Vehicles

This group focused on identifying research needs and reconciling divergent goals of vehicle manufacturers, users and roadway infrastructure operators. They see the need for improved data about the interactions between drivers of conventional vehicles and automated vehicles and potential driver behavior changes that will have to be represented in improved models, and will need to use improved models to predict the effects of various market penetrations of vehicle automation on highway bottlenecks, merges and signalized intersections.

Traffic Signal Control with Connected and Automated Vehicles

The group concluded that traffic signals will still be needed 20 years from now, even as more automation capabilities become available. Key challenges are expected to involve understanding the interactions between human drivers and automated vehicles at intersections, and determining what types of new behaviors emerge from those interactions.

Physical and Digital Infrastructure

This group had separate discussions of the physical and digital infrastructure issues, since they perceived the issues to be sufficiently different. They realized that any conclusions they draw would be significantly dependent on specific operational scenarios, particularly when considering the difference between roadway facilities dedicated to automated vehicles and facilities handling mixed traffic. They see a role for government in facilitating development of common standards for digital infrastructure.

## *7.2 Technology Breakout Sessions*

Enabling Technologies for Road Vehicle Automation

This group discussed the technology trends expected for the next 3–5 years and the gaps in available technologies. They identified the lack of a common clearinghouse for information about technology capabilities as a problem, and concluded that people working on vehicle technology and infrastructure technology need to be sharing more of their knowledge. They also discussed the desirability of a free and open core set of data from operating vehicles.

Wireless Connectivity for Automated Vehicles

It was generally agreed that wireless connectivity and cooperative ITS are going to be necessary to support automation, but there were differences of opinion about the relative merits of DSRC and cellular LTE technologies for meeting automation system needs.

Cybersecurity for Automated Vehicles

This group recognized that security for automated vehicles will evolve from the current security considerations for connected vehicles, without any dramatic jump or transition. They considered cloud connectivity to be essential to automated vehicle operation, hence the need for cybersecurity. They identified the lack of a security threat catalog and of automotive security standards as an important gap, but also questioned the feasibility of defining such standards. Controversies included questions about what infrastructure support is needed, whether a secure public key infrastructure (PKI) is possible, and how to reconcile security, privacy and safety goals.

Verification and Validation of On-Road Automated Vehicles

Verification and validation were discussed in the context of a broader system engineering paradigm for vehicle system development, based on definition of requirements. Current challenges were identified to include the lack of standards and commonly accepted terminology, the lack of commonly accepted expectations of performance and safety and the high cost and complexity of the existing approaches to verification and validation.

## *7.3 User-Oriented Breakout Sessions*

Human Factors in the Design of Road Vehicle Automation

The human factors breakout group focused on identifying the most important research needs in their field, based on the recognition that if the human factors issues are not addressed effectively by the early automated vehicles there is likely to be a public backlash against automation. Important questions were identified as: What feedback should an automated vehicle give to the driver (including whether it should inform the driver about its level of confidence in its current actions)? How should the automated vehicle monitor and respond to its driver? How should the system tell the driver that it is reaching the boundary of its operational design domain, where the driver needs to take over? How should the driver be alerted to regain his or her attention? The group noted that in general the necessary symbiotic relationship between the vehicle and the person is as yet poorly understood.

Vulnerable Road Users—How Can AVs Help Keep them Safe and Mobile?

The vulnerable road user group was concerned about how limited road space will be allocated among competing users in the future, particularly if the population of automated vehicles grows significantly. How will this impact the mobility of seniors, teens, pedestrians, bicyclists and the disabled? Will they be safer if automated vehicles follow traffic rules more strictly than drivers do today?

Beyond Single Occupancy Vehicles—Automating Transit and Shared Mobility

The focus of this group was on user needs, and whether those would be better served by automating transit vehicles or changing to a shared-use fleet of automated vehicles. The group was relatively evenly divided between these alternatives, but agreed that transit needs to be emphasized early in the development of road vehicle automation in order to deter dramatic growth in vehicle miles traveled.

Truck Automation

This group focused on the challenges that need to be overcome for truck automation to realize its promise as an early deployment opportunity for road vehicle automation. Key challenges were identified to be: development of standard testing and evaluation guidelines and procedures, harmonization of state regulations for

long-distance trucking applications and the need to convincingly demonstrate the safety and acceptability (to truck drivers and the general public) of close-formation platooning of trucks.

## 7.4 Policy and Planning Breakout Sessions

Prioritizing Public Policy Challenges for Automated Vehicles

Primary themes in this breakout were the large number of uncertainties surrounding the impact of road vehicle automation and the need to educate the public and policy makers about what is actually known and unknown. Credible research and demonstrations are needed to reduce the uncertainties and to narrow the very wide range of current reactions to automation within the political world.

Legal Aspects of Automated Vehicles, Including Liability, Insurance and Ethics

This group tackled a wide range of legal issues. They concluded that the existing insurance and liability legal structures are adequate to manage the uncertainties about automation, but international harmonization of laws will be needed. They encountered some controversy in discussions about learning by doing to initiate deployment and about modernization of the Vienna and Geneva Conventions on Road Traffic, but also concluded that some of the data privacy issues are not well covered under existing laws.

Implications of Automated Vehicles for Planning

The planning group was concerned about the need to better predict an uncertain future given their work on 25-year plans and the very long time scales for development or modernization of public infrastructure. They need more clearly articulated descriptions of how future automated systems would function, and they expect to need new models to be able to predict the directions of change in vehicle miles traveled, given the uncertainties about traveler decision making. In the absence of real data, it is hard to make reasonable predictions and to educate the decision makers, especially at the elected official level.

Energy and Demand

Existing modeling tools and traveler behavior models are not well suited for representing a future with automated road vehicles, and new modeling paradigms are likely to be needed. Estimates of future road traffic energy consumption with road vehicle automation are highly uncertain because of these limitations. This group was also concerned about the potential for automation to produce highly wasteful applications, such as driverless billboards roaming the streets with advertising displays.

## 8 General Cross-cutting Observations

As the field of road vehicle automation has advanced and the level of knowledge of the issues has grown over the past several years, the areas of emphasis within the Automated Vehicles Symposium have shifted. In this most recent meeting, several general observations are worth noting:

Many of the key challenges were brought up in a variety of breakout discussions, so these are truly important cross-cutting issues that need serious attention throughout the community interested in road vehicle automation:

- Understanding driver behavior was one of the most frequently mentioned topics, so the in-depth human factors research on this topic, especially associated with how to make safe transitions from automation to manual control, will remain an important need.
- Understanding travelers' trip-making behavior became a more prominent topic than in the past. It is important to understand the propensity of travelers to choose an automated system and also to understand how the use of automation may change decisions about how frequently and how far people will be willing to travel for various purposes.
- Public agency attitudes and actions were an important topic for many breakouts because of the complicated public-private interactions that are almost inevitable in the road transportation domain. The public policies and investments (or shortfalls in investment) are likely to have a strong influence on the adoption of new automated systems and on their effectiveness in improving transportation system performance.
- The growth in the market for automated vehicle systems was one of the most frequently cited uncertainties, since the existing projections have been anything but consistent. Virtually all measures of effectiveness will vary widely depending upon whether automation systems enter the vehicle market gradually, like most previous vehicle technology changes, or whether they produce abrupt and revolutionary changes to consumers' decisions about vehicle purchase or usage.
- Another area of large uncertainty is the anticipated safety and performance of the automated vehicle technologies, and how rapidly those will improve. The world will look very different if those advance gradually from today's vehicle systems or if they make a revolutionary leap forward.
- It would have been easier to conduct the breakout discussions if there had been a well-defined and agreed upon catalog of automated vehicle operational concepts and terms so that everybody would understand each other clearly when discussing their ideas. Unfortunately, these do not exist yet, so the diverse concepts and terminology sometimes become barriers to mutual understanding.
- Multiple breakout groups noted the challenge of communicating clearly with the general public, planners and elected officials about road vehicle automation systems because of the technical complexity of the issues, the lack of standard

concepts and terminology and the widespread and misleading media hype surrounding the topic.

One important topic that was largely overlooked in the previous years' meetings but became much more prominent this year was the cyber-security challenges for automated vehicles. Although this issue transcends automation and is already a concern for all modern vehicles and for the new generation of connected vehicles, it will be seen to be even more important for automated vehicles among the general public because a computer will be doing the driving rather than a normal human driver.

Another broad concern that applied across virtually all topics was the need for credible research, models and demonstrations to reduce the large uncertainties that currently surround automation. People appear to be craving authoritative information about the technical, human factors and policy issues so that they will be better able to visualize and assess how the future will work with more widespread use of automation in road vehicles.