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Governance of the safety of automated vehicle

Submitted by NHTSA, STANFORD UNIVERSITY-CARS, WP1 BUREAU

The document is the summary report of the workshop on "Governance of the Safety of Automated Vehicle". The event was co -sponsored by: the National Highway Traffic Safety Administration, the United Nations Economic Commission for Europe -Working Party on Road Traffic Safety, and the Center for Automotive Research at Stanford University and conducted on October 20, 2016, at the CARS Facility on the Stanford University Campus in Palo Alto, California. The overall theme of the Conference was to approach the potential benefit of automotive emerging technologies and how they will affect government policies; how these fast developing technologies will affect the current methodology used for road safety assessment and road safety policies.

Workshop on Governance of the Safety of Automated Vehicles

Co-sponsored by:
the National Highway Traffic Safety Administration,
the United Nations Economic Commission for Europe Working Party on Road Safety, and the
Center for Automotive Research at Stanford University

Conducted on October 20, 2016
at the CARS Facility on the Stanford University Campus
in Palo Alto, California

Summary Report

Executive Summary

The National Highway Traffic Safety Administration (NHTSA), the United Nations Economic Commission for Europe Working Party on Road Safety (UNECE WP.1), and the Center for Automotive Research at Stanford University (CARS) co-sponsored a workshop to facilitate a discussion among governments, industry, and academia relating to alternative options for providing safety assurance for highly automated vehicles. In addition, the Workshop sought to stimulate collaboration and coordination across these sectors as transportation and roadway transportation systems transform toward a "Second Era of Mobility."

The workshop was conducted at the CARS facility on the campus of Stanford University on October 20, 2016, and was attended by approximately 150 individuals representing governments, United Nations standard-setting bodies, automotive and information technology industries, and academic institutions.

The workshop began with discussions on the traditional role of governments in providing motor vehicle and driver safety assurance. Following this historical context was a discussion of the challenges that the introduction of highly automated vehicles will present to traditional governance methods. The workshop then addressed a number of potential alternatives to traditional regulatory methods and provided an opportunity for group discussion of potential advantages and disadvantages of each.

The intent of this workshop was not to reach agreement on the best safety assurance method, but rather to provide an opportunity for attendees and participants to openly discuss potential alternatives. The impetus for conducting the workshop was the rapid emergence of highly automated vehicle technology, and increasing recognition of the need for governance strategies that can provide safety assurance for road users while facilitating the early realization of the safety and mobility benefits promised by these innovations.

Workshop discussions included a series of presentations from internationally recognized experts in technology, public policy, and safety assurance methods. Specific topics include the following:

- Methods for Incentivizing Safety Performance and Continuous Improvement
- Approaches to Enhance Government-to-Government Research and Regulation Cooperation
- Accommodating the Changing Role of the Driver
- Objective Performance Measurement of Complex Systems
- Safety Performance Measurements and Safety Management Systems
- Opening and concluding statements were provided by UNECE, Stanford University, and NHTSA leaders and representatives.

Acronyms

4 E's	Four traditional traffic safety approaches in United States: Education, Enforcement, Engineering, and Emergency Medical Services
ACAS X	Airborne Collision Avoidance System X
AEB	Automated Emergency Braking
CARS	Center for Automotive Research at Stanford University
EU	European Union
FMVSS	Federal Motor Vehicle Safety Standards (U.S.)
GNCAP	Global New Car Assessment Program
(H)AVs	(Highly) Automated Vehicles
NHTSA	National Highway Traffic Safety Administration
TCAS	Traffic Alert and Collision Avoidance System
SAE	Society of Automotive Engineers
SMS	Safety Management System(s)
UNECE WP.1	United Nations Economic Commission for Europe, Working Party on Road Safety
USD	U.S. Dollars

Background

Why have this workshop?

The emergence of highly automated vehicle technology provides new opportunities for addressing driver-related safety problems and new potential for increasing mobility across all segments of the population. However, these new opportunities are not without safety challenges. These new technologies lack the safety record that gives road users confidence in their safety performance. Governments have served a road safety assurance role for many decades using objective, repeatable, and evidence-based measures to ensure that vehicles – and their drivers – meet public expectations for crash avoidance, crashworthiness, and post-crash safety.

There is an urgent need to realize the benefits of highly automated vehicle technologies while maintaining public confidence in their safe performance. However, the best methods and strategies for assuring the safety of these emerging technologies have yet to be determined.

What was the purpose of this workshop?

This workshop convened internationally recognized experts to discuss innovation, deployment, and regulation of emerging lifesaving vehicle crash avoidance technologies – with the intent of initiating a discussion about traditional and non-traditional strategies for providing safety assurance.

Who participated in this workshop?

Over 150 participants and representatives from governments (domestic and international), automotive industry, academic and research institutes, and technology industry stakeholders were convened at this workshop for a dialogue regarding highly automated vehicles (and related emerging crash avoidance technologies) – and alternative approaches and strategies for technology safety assurance.

How was this workshop conducted?

This workshop followed Chatham House Rules and included a series of technical presentations and panel discussions to cover a diverse range of safety and technology topics. Workshop participants were encouraged to ask questions and share perspectives. The workshop was not intended to produce consensus; rather, the workshop was conducted to facilitate discussions of a range of alternative strategies government and industry could consider to ensure that safety, efficiency, and mobility are balanced for and roadway safety and transportation systems.

Following introductory comments, the first two panels addressed traditional government roles and safety assurance practices, examples of current global best practices, and perspectives on the challenges that vehicle automation will present for traditional safety assurance methods. The remainder of this workshop was devoted to considering a range of alternative methods or processes that might be considered for safety assurance in the new era of vehicle automation – the “Second Era of Mobility”.

The report is divided into the sections below:

Opening Remarks and Introduction

Panel 1 |
Framing the Discussion: Traditional Government Approaches to Vehicle and Behavior Safety Assurance

Panel 2 |
Assuring Safety: Current Best Practices and Considerations for the Future

Panels 3, 4, and 5 |
Exploration of Potential Alternative Governance Strategies for Emerging Vehicle Crash Avoidance Technologies

Closing Comments

Note that a briefing was conducted by NHTSA officials on the new Federal Automated Vehicles Policy during lunchtime and was followed by an open discussion session related to this new policy. Specific details on the Automated Vehicles Policy can be found at www.transportation.gov/AV.

Opening Remarks and Introduction

Opening remarks were provided by leaders from each of the three workshop sponsors: Stanford University, United Nations Economic Commission for Europe (UNECE), and the National Highway Traffic Safety Administration (NHTSA). The key messages from these opening remarks are summarized below:

- We are standing on the edge of a new frontier in transportation – the most fundamental change since the introduction of the automobile. Highly automated vehicles (HAVs) have the potential to drastically improve safety and extend mobility. Incorporating these new and emerging crash avoidance vehicle technologies within existing physical and institutional infrastructures will be challenging; however, the benefits are compelling. This is a time for governments, industry, academic institutions, and other relevant stakeholders to come together to define a vision for a HAV future and identify a clear pathway toward this vision while considering comprehensive transportation system development.

> We are seeking innovation and ideas for government roles that might be outside of our traditional regulatory experience. How can government, industry and other relevant stakeholders anticipate this new frontier and make decisions that will maximize the potential of this second automotive revolution – the "Second Era of Mobility"?

- Rapidly increasing motorization in countries around the world, combined with globalization of technology and markets, offers great potential and opportunity for mobility and social progress. This "Second Era of Mobility" provides new opportunities for elevating roadway safety across the globe. The new era of mobility will require unprecedented levels of cross-sector collaboration, coordination, and leadership to ensure that the mutual guiding principles of safety, security, economic growth, and quality of life (i.e., accessibility) are balanced. All four of these principles are transportation and development priorities, both domestically and globally. This workshop was intended to provide a platform to explore and discuss innovative safety assurance strategies and methods which may be outside of traditional government regulatory mechanisms and practices.

- This workshop sought innovative ideas for government roles and strategies that might be outside of our traditional regulatory experience. Overall, how can government, industry, academic institutions, and other relevant stakeholders anticipate their roles in this new frontier and make decisions that will fully maximize the opportunities presented by new and emerging vehicle crash avoidance technologies that are transforming transportation into this second automotive revolution – the "Second Era of Mobility"?

Panel 1 | Framing the Discussion:

Traditional Government Approaches to Vehicle and Behavioral Safety Assurance

This first panel reviewed the tradition of road safety governance from United States and European perspectives.

Government involvement in road safety began shortly after introduction of the automobile, but substantial engagement of governments in vehicle safety and roadway safety features, as well as traffic safety behavior, began with the work of UNECE Working Party 1 on Road Safety in 1949, and with the newly formed United States Department of Transportation (U.S. DOT) in 1966. In Europe and the United States, these preliminary traffic safety efforts serve as the foundation for a comprehensive set of performance-based vehicle safety standards, and a coordinated set of driver licensing requirements and rules of roadway behavior.

> Governments have been successful in assuring the safety of conventional vehicles with drivers on conventional roadway transportation system. NHTSA estimates that technologies mandated by Federal Motor Vehicle Safety Standards (FMVSS) have saved more than 600,000 lives in the United States since the 1960s.

Several important international road safety conventions and agreements establish guiding frameworks for road safety across the globe. Some of these important international safety conventions and agreements are summarized below:

- **1909 | International Convention on Motor Traffic, Paris:** This international treaty established preliminary motor traffic guidelines and include some of the following motor traffic elements: conditions for motor-cars to be allowed to be driven on the roadway, conditions to be fulfilled by drivers of motor-cars, issuance and recognition of international traveling passes, arrangement of identification marks on motor-cars, warning mechanisms, special provisions with regard to motor-cycles, meeting and passing of vehicles, provision of notice-boards on the roadway, and general provisions.

- **1949 | Convention on Road Traffic, Geneva:** This international treaty provides guidelines and uniform rules specific to road safety and includes the following roadway safety elements: general provisions, rules of the road, signs and signals, provisions applicable to motor vehicles and trailers to international traffic, drivers of motor vehicles in international traffic, provisions applicable to cycles in international traffic and final provisions. This is an extensive document that establishes additional provisions concerning road traffic definitions of motor vehicles, priority of passage, registration practices, identification and sign practices, international vehicle specifications, and motorist licensing.

- **1958 | United Nations Economic Commission for Europe (UNECE) Agreement concerning the Adoption of Uniform Technical Prescriptions of Wheeled Vehicles, Equipment and Parts**
  This agreement establishes regulations for all types of vehicles relating to parts and equipment for vehicles, as well as industry and consumer safety performance measurements and international trade of vehicles, equipment, and parts.

- **1968 | Convention on Road Traffic and Convention on Road Signs/Signals, Vienna:**
  In 1968, the initial 1949 Convention on Road Traffic was separated into two independent conventions. The 1968 convention provides guidelines and uniform rules on important international

road traffic and safety dimensions with the intent to serve as a potential international framework. The Convention on Road Traffic includes conditions for general provisions, rules of the road, conditions for the admission of motor vehicles and trailers to international traffic, drivers of motor vehicles, conditions for the admission of cycles and mopeds to international traffic, and final provisions with additional annexes. The second convention, the Convention of Road Signs and Signals, details general provisions, road signs, traffic light signals, road markings, and roadway classifications, essentially focusing on safe infrastructure.

- **1998 | UNECE Agreement concerning the Establishing of Global Technical Regulations for Wheeled Vehicles, Equipment and Parts**
  This agreement provides a framework for establishing global technical regulations for vehicle safety and environmental protection (e.g., electronic stability control, carbon emission tests, crash worthiness).

As a result of these initial traffic and roadway safety efforts, many UNECE member nations, including the United States, established traffic and roadway safety agencies with regulatory authority within transportation departments or ministries to conduct research and implement programs to reduce fatalities, injuries, and crashes. This traditional government-based traffic safety approach focused on developing evidence-based traffic and roadway safety efforts that include objective mandatory vehicle safety standards (e.g., United States Federal Motor Vehicle Safety Standards (FMVSS) and UNECE Vehicle Regulations), as well as behavioral interventions (i.e., the traditional 4 E's: education, enforcement, engineering, and emergency medical services).

Governments have been successful in assuring the safety of conventional vehicles with drivers on typical roadway transportation systems. For example, NHTSA estimates that technologies mandated by FMVSS have saved more than 600,000 lives in the United States since the 1960s.

Government initiated behavioral policies and programs have been similarly successful. Crash studies indicate that human error is responsible for as much as 94 percent of fatal roadway crashes. While behavioral safety concerns are far from resolved, two long-standing behavioral safety concerns – alcohol-impaired driving and seat belt use – have been substantially improved over past decades through targeted behavioral safety policies, programs, and interventions. The number of fatalities in alcohol-impaired driving crashes has dropped by about a half in the United States since the early 1980s. This corresponds with a time when States in the United States began enacting and enforcing alcohol-impaired driving legislation (e.g., *per se* laws and minimum drinking age laws). Similarly, the proportion of vehicle occupants wearing seat belts has increased from about 20 percent to 90 percent over the same period as the result of laws and enforcement efforts combined with public awareness. Traffic safety laws and enforcement – inherently governmental functions – have contributed to saving hundreds of thousands of lives in the United States alone.

It is clear that citizens expect and depend upon governments to provide a basic (yet acceptable and comprehensive) level of safety assurance for road users. However, one observation made regarding public expectations is that citizens appear to react differently to human error than to technology or corporate error. News of a relatively small number of casualties from a vehicle design flaw or construction fault has historically generated a great deal of public concern and has often led to policy change, while knowledge of far higher daily impact of fatalities and injuries from roadway traffic events (e.g., speeding, alcohol-impaired driving, etc.) does not tend to generate widespread discussion and has not motivated action toward stricter safety policies.

Reference Section of Other International Road and Vehicle Safety Conventions and Agreements

1901		International Convention on Motor Traffic, Paris
1926		International Convention relating to Road Traffic, Paris
1926		International Convention relating to Motor Traffic, Paris
1931		Convention concerning the Unification of Road Signs, Geneva
1943		Convention on the Regulation of Inter-American Automotive Traffic, Washington, DC
1949		Convention on Road Traffic, Geneva
1949		Protocol on Road Signs and Signals, Geneva
1958		Agreement concerning the Adoption of Uniform Technical Prescriptions for Wheeled Vehicles, Equipment and Parts, Geneva
1968		Convention on Road Traffic, Vienna
1968		Convention on Road Signs and Signals, Vienna
1971		European Agreement Supplementing the Convention (Road Traffic), Geneva
1971		European Agreement Supplementing the Convention (Road Signs), Geneva
1973		Protocol on Road Markings, Additional to the European Agreement, Geneva
1997		Agreement concerning the Adoption of Uniform Conditions for Periodical Technical Inspections of Wheeled Vehicles, Geneva
1998		Agreement concerning the Establishing of Global Technical Regulations for Wheeled Vehicles, Equipment and Parts, Geneva

Panel 2 | Assuring Safety:

Current Best Practices and Considerations for the Future

The second panel expanded on the foundation provided by the first panel by discussing recent trends in safety assurance methods. These trends include recent developments in safety assurance for vehicles and drivers, and extend to a contemporary discussion regarding an acceptable, basic level of vehicle and roadway safety standards globally, as well as the need for collaboration among public and private entities, especially among governments, industry, academic institutions, and other relevant stakeholders.

Recent Trends in Driver Behavior Programs

Current strategies for driver behavior improvement revolve around licensing, laws, education, and enforcement. In recent years, a number of nations have launched ambitious programs to strengthen traffic safety laws – especially for speed and alcohol-impaired driving – and increased enforcement, often through expanded use of automated speed camera enforcement. These programs and initiatives have generally been effective in improving traffic behaviors and reducing crashes. For example, in France, evaluations have indicated improvements in roadway safety when such interventions are applied and show diminished progress when these speed safety interventions are interrupted for various reasons (e.g., changes in leadership, resources, public dissonance, etc.). Many European Union (EU) governments focus on the following major road safety policy areas: driver training and education, infrastructure improvements (roadway construction codes and design principles), licensing, and automated speed cameras and enforcement.

However, changes in mobility patterns are increasing recognition of the need to protect non-motorized road users such as pedestrians, bicyclists, motorcyclists, children and the elderly. New and emerging vehicle crash avoidance technologies has potential to provide benefits in these areas. Shifts in a number of factors are likely to influence traffic safety in future years, including:

- **Mixed Modes of Transportation** – Increasingly, motorists are sharing the road with non-motorized road users including pedestrians, bicyclists, motorcyclists, and riders of scooters, e-bikes and mopeds. This mixture of transportation modes increases the exposure risk for non-motorized road users that can ultimately result in increased road fatalities and injuries.

- **Increased Use of Powered Two-Wheelers** – Powered two-wheelers are an accessible transportation mode in many parts of the world due to their low cost, fuel efficiency, and maneuverability in congested traffic. However, two-wheelers have a greater risk per mile due to their relative lack of stability and occupant protection when compared to passenger cars.

- **Public Acceptance of Strong Legislation** – Public acceptance of strong traffic laws has limits but can change over time. A paradigm shift in public attitudes toward traffic safety laws could result in mobility, convenience, autonomy, and safety benefits being considered comprehensively rather than independently. For example, speed limits may increase travel time but improve safety; driver alcohol limits place constraints on individual freedom but reduce risk for all road users; and seat belt laws restrict individual choice, but improve crash survivability. Such a shift is possible as a result of increased public concern and activism regarding road safety.

- **Value of Trust** – Further progress in reducing risks related to driver behavior is likely to require collaboration among industry and government – with support from the public. A key prerequisite for this shared interest is mutual trust. The

essential ingredients of trust include an emphasis on safety as a priority among stakeholders, effective quality assurance of developed technologies, and transparency in motives and operations among all stakeholders in the transportation system.

Recent Trends in Motor Vehicle Safety Improvement

The pace and direction of automotive safety technology development has changed remarkably in recent years. For more than 50 years, safety engineers have pursued a comprehensive approach to vehicle safety with attention to crash avoidance, crashworthiness, and post-crash safety features and technologies. However, during the past decade, new capabilities in onboard information processing have enabled tremendous progress in technologies that can supplement – or in some cases replace – surveillance or vehicle control functions that were previously the sole responsibility of the driver.

This new generation of crash avoidance technologies ranges from alert systems that inform a driver of other vehicles or pedestrians on the roadway that the driver may not have noticed, to systems that can recognize an impending incident and take partial control of the vehicle to avoid a collision. Since crash causation studies indicate that failures in driver performance are responsible for as much as 94 percent of fatal crashes, advanced crash avoidance technologies promise to be highly effective in improving road safety.

> How could governments, industry and other stakeholders collaborate to ensure that vehicles sold worldwide offer basic levels of safety performance? What basic level of safety is acceptable?

While the pace of crash avoidance technology development has increased dramatically, the capability of making over-the-air software upgrades has fundamentally expanded technology and product development opportunities by enabling auto manufacturers to perform system refinement throughout the life of a vehicle. This new capacity for reaching the vehicle outside of the established vehicle service network has further increased the rate at which the safety performance of the vehicle fleet can be improved. However, this improved and enhanced communication potential should be balanced with cybersecurity measures to protect road users, vehicle owners, and public and private organizations.

The Need to Democratize Safety

In recent years, vehicle safety technology has been recognized as a potential countermeasure for the global road safety crisis. The United Nations Decade of Action for Global Road Safety has built awareness of the problem of road safety worldwide. Each year, more than 1.25 million fatalities occur on roadways in countries around the world and non-motorized road users have higher risk of injuries and fatalities when a crash occurs. Low and middle income nations are affected much more acutely than high-income countries; pedestrians, bicyclists and motorcyclists have especially high exposure to crash and fatality risks. Emerging crash avoidance technologies and highly-automated vehicles have the potential to democratize safety on the roadways for all road users.

Comprehensive solutions involving improvements to infrastructure, road user behavior, and post-crash care as well as vehicle design are needed to address the global road safety challenge. However, inconsistent governance of vehicle safety performance – especially among low and middle income nations – has resulted in road user populations being underserved as a result of not receiving the benefits of basic vehicle safety technologies such as seat belts, frontal and side impact protection, and child passenger protection.

Workshop presenters and participants raised a number of important points that require further consideration to enable global road safety progress:

- How could governments, industry, academic institutions, and other relevant stakeholders collaborate to ensure that vehicles sold worldwide offer basic levels of safety performance? And what basic level of safety is acceptable?
- What types of data and research are required to enable the delivery of basic vehicle safety technologies around the globe?
- How could traditional cost-benefit analyses be redefined to enable this democratization of safety?
- How could an expanded collection of stakeholders be engaged to elevate awareness and commitment to improving road safety globally?

The Need for Cross-Sector Collaboration

When considering the future of both behavioral and vehicle safety programs, a consistent theme articulated in this workshop was the need for increased collaboration among public and private sectors, as well as academic institutions. Advanced vehicle technology offers tremendous promise for improving the safety for all road users, but the full benefits can only be realized if the technology advancements are accompanied by a thorough understanding of a wide range of issues including human factors, public interests, consumer preferences, and political implications. Addressing this range of needs effectively and efficiently – without slowing development and deployment of lifesaving technology – will require a mutual commitment to high levels of ongoing collaboration.

Workshop participants repeatedly stressed the need for public-private partnerships, but fully recognized the difficulties facing the facilitation of these commitments. Fragmented agendas, finite structural capacities, perceived competing priorities and limited resources can combine to reduce such collaboration. However, with progressive leadership and policies, the long-term benefits of collaboration can overcome immediate parochial concerns. Exchanging information, data, research, and best practices among stakeholders is a good place to start collaboration and offers great value on its own. The development of voluntary agreements such as the March 2016 commitment by vehicle manufacturers to install Automatic Emergency Braking on light vehicles is an example of the type of substantial benefits that are possible when decision-makers from multiple sectors focus on safety outcomes.

Challenges to Safety Assurance for Highly Automated Vehicles

Looking to the future safety assurance of highly automated vehicles and considering the issues raised above, workshop participants identified the following challenges:

- **Measuring Safety Performance of Automated Systems -** How can we ensure the safety of vehicles that incorporate intelligent systems which must continuously negotiate a near-infinite number and variety of traffic, roadway, or environmental situations without danger to occupants or other road users?
- **Re-thinking the Entire System** – How can we develop policies and technologies that prioritize safety and accommodate the requirements all of the stakeholders (i.e., government, industry, non-profits, universities, and multinational organizations)?
- **Enhancing Status Quo Toward Innovative Collaboration** – Maintaining the status quo regarding commitment and collaboration among stakeholders may not be sufficient to meet the challenges and demands for safety assurance. How do we elevate recognition of the importance of roadway

safety in the "Second Era of Mobility" – and ultimately achieve a safe and sustainable transportation system?

- **Consumer Preferences and Perceptions** – Will the public accept a transfer of control to a highly automated vehicle? Will public expectations accommodate a future system in which the safety consequences of human error are almost entirely eliminated, but technological failures still occur (on a very infrequent basis)?

- **Application to World and Global Contexts** – What will this new emerging technology look like outside of high-income nations? Will there be an opportunity for leapfrog advancement for low and middle income nations?

Panels 3, 4 & 5: |

Exploration of Potential Alternative Governance Strategies for Emerging Vehicle Crash Avoidance Technologies

The following sections summarize a series of workshop discussion points regarding potential options for providing safety assurance for highly automated vehicles. The concepts behind these options come from a range of sources including methods used in other fields of transportation and innovative ideas from policy analysts, academic leaders, and legal scholars. Each option was considered and discussed on its merits as a safety assurance strategy without comparison, final conclusive decisions, or recommendations.

Objective Performance Measurement of Complex Systems

Aviation offers a number of interesting models and experiences that may be translatable to the roadway transportation system. Commercial aviation in particular has achieved remarkable safety accomplishments with one crash per 3.1 million flights worldwide in 2015. Aviation safety improvements over the past decades have been achieved largely through collaboration of Federal regulators and industry and have resulted in the establishment of a pervasive safety culture in which the prevention of incidents is the highest priority.

One of the challenges to providing safety assurance for highly automated vehicles on the roadway transportation system is evaluating the performance of complex self-driving programs. Safety assurance for human drivers has traditionally been provided through driver examinations and licensing, and monitored through traffic law enforcement and driver deterrent programs for roadway violations. While this approach has met public expectations for human performance, the safety assurance approach for a vehicle-based driving function will need to be far more elaborate.

A useful case study regarding evaluation methods for complex systems involves the process for testing the safe performance of the current Traffic Alert and Collision Avoidance System (TCAS) and its eventual successor, the new Airborne Collision Avoidance System X (ACAS X). These complex systems provide worldwide surveillance of aircraft in-the-air and a logic function to deliver safety alerts to pilots. The ACAS X is being developed using a computational method known as dynamic programming and the performance of the system is evaluated with a statistical airspace model structured as a dynamic Bayesian network. Operational suitability of the ACAS X system is being evaluated using modeling, simulation and flight testing. Since the ACAS X system is intended to be the basis for the next international standard for air traffic collision avoidance, expectations for safety performance are very high. Lessons learned in the development and evaluation of the TCAS and the new ACAS X systems – both in terms of technical methods and in stakeholder engagement – could be very useful as safety assurance approaches and strategies are being considered for highly automated vehicles on the roadway.

Safety Management Systems

Another method or strategy that has been widely implemented in aviation is the Safety Management System (SMS). The Federal Aviation Administration defines SMS as a formal top-down, organization-wide approach to managing safety risk and assuring the effectiveness of safety risk controls. It includes systematic procedures, practices, and policies for the management of safety risk.

Traditional models of motor vehicle safety assurance used by governments involve the establishment of objective safety-related vehicle performance expectations and testing of individual vehicles or vehicle types for compliance with those expectations. The traditional system is primarily reactive – responding to new technology with the development of objective standards and testing completed vehicles against those standards. The traditional system also places a large burden on the government to develop standards that are objective, repeatable, and linked to empirical data regarding safety performance on the road.

Lessons from Aviation | A Safety Management System (SMS) would provide safety assurance differently. Perhaps the most fundamental difference is that government and industry would not act solely as regulator and regulated entity, but would act as collaborators in pursuit of a common interest in safety.

A SMS system would provide safety assurance differently. Perhaps the most fundamental difference is that government and industry would not act solely as regulator and regulated entity, but would act as collaborators and facilitate platforms to convene relevant stakeholders in pursuit of a common interest in safety. In a SMS, the government would set clear expectations and facilitate system-wide collaboration to identify safety incidents, share information about risks, and proactively analyze processes to identify and prevent future problems.

Workshop participants raised a number of important considerations regarding the potential of SMS as a future motor vehicle safety assurance method:

- In a SMS environment, government would continue to serve a strong leadership and supervisor role.
- In addition to complying with regulations, in a SMS environment, industry would share information to identify problems and actions that are required to reduce risk. Government would continue to assess performance relative to specific standards while also monitoring overall safety management effectiveness.
- Government would need to clearly articulate safety expectations – especially in defining acceptable levels of risk.
- In a SMS environment, rules would likely be a blend of performance-based requirements (focusing on specific actions or methods) and risk-based requirements (focusing on achievement of overall goals).
- High performing organizations in a SMS environment are preoccupied with tracking small failures and focused on improving operations to prevent future incidents and reduce risk.

Incentivizing Safety Performance

The rate of technology changes quickly and the potential for continuous improvement of highly automated vehicles (and related crash avoidance technologies) will require new approaches to safety assurance. Rapid developments in sensor technology and analytical methods are likely to result in a faster pace of safety performance improvement than

was previously possible, and since software can be upgraded throughout a motor vehicle's life through over-the-air updates, technology development will no longer be limited to the pre-production phase of a motor vehicle's life.

While there will likely be a continued role for standards and testing protocols, one implication of this rate of change and ongoing process of change is that conventional methods of safety assurance – in which governments conduct technology-specific research to identify objective performance measures and promulgate appropriate thresholds for safety regulation – may be too slow to be the primary means of assuring safety and, depending on how performance-based regulation is, could delay implementation of lifesaving benefits. Conventional safety assurance methods also focus performance incentives pre-sale and therefore fail to take advantage of continuous improvement capabilities.

Workshop participants heard government and academic perspectives on policy innovations that could realign incentives while protecting the public from technology and product safety failures. Key points from this discussion include:

- For highly automated vehicles, safety assessment could move from point-of-sale to point-of-use.
- With the ability (and expectation) for continuous improvement, consumers may learn to place their trust in post-sale surveillance and refinement rather than solely in pre-production engineering and design.
- Manufacturers could be expected to convince government and consumers of technology and product safety by making a "public safety case." This safety case would include details on the safety development and performance which has gone into the technology and product pre-sale, and the methods the manufacturer will pursue post-sale to continuously improve safety performance.
- Technology safety data – pre-sale and post-sale – should be available to consumers and consumer advocates for analysis.
- Free, secure, and open movement of technology safety data is vital to support the incentives needed to assure safety in this new "Second Era of Mobility".

Free, secure, and open movement of technology and product safety data is vital to support the incentives needed to assure safety in this new and emerging vehicle crash avoidance technological era.

Transition Issues: The Need for Collaboration and to Accommodate Human Factors

The final workshop discussion topic regarded the transition from contemporary vehicle technology and safety assurance practices to a future situation with a large proportion of highly automated vehicles. Two key issues regarding this transition are the need to increase collaboration and the need to understand the human factors implications that may be inherent in levels of vehicle automation which require intermittent driver assumption of control.

Workshop participants readily agreed that even though there is little certainty in what our technology or safety assurance system will look like in future years, there is an immediate need to increase information and data flow among academia, industry, and government. The full potential of the "Second Era of Mobility" - accelerated safety performance, expanded individual mobility, security from cybersecurity threats, and enhanced social purpose - assumes system-wide data access and free flow of safety-related information.

Forums such as the EU-U.S. Transportation Research Symposium held in 2015 and this Workshop on the Governance of Automated Vehicles are essential to establish connections between new partners and to share perspectives on emerging questions that include:

- Public policy and legal issues such as driver licensing, liability and insurance;
- Automated technology issues and challenges (i.e., testing, certification, and cybersecurity);
- Design and operational issues such as implications for non-motorized road users; and
- Public acceptance and consumer preference regarding automated vehicle operation.

With regard to human factors, the discussion centered on driver performance in vehicles with specific attention to the Society of Automotive Engineers (SAE) Level 3 and 4 of vehicle automation. SAE Level 3 and 4 are considered conditional and high automation levels that require less driver control of the vehicle in most driving situations. Human factors experts expressed concern about several aspects of driver performance. First, experience with analogous types of human performance suggests that the loss of driving practice may slow down the learning of new drivers and delay the familiarity of experienced drivers with the specific feedback or handling characteristics of a specific vehicle. Automated vehicle technologies and features may also result in a consequent decrease in driver diligence toward the driving task, thus increasing driver risk when driver response is required.

Perhaps the most serious question expressed by human factors experts is the concern about the ability of drivers who have been at rest during a period of fully automated driving to regain situational awareness and assume driving control in the case of an emergency situation or even a non-emergency situation. There are a number of critical unknowns regarding driver performance in such situations, including the time required to bring a driver from rest to full situational awareness and driving performance, the types of driver performance that can be expected at various intervals of notice, and the best method for alerting drivers and guiding them back into control of the vehicle.

Experience and data on driver performance when required to exercise intermittent driving control will be essential to understand these limitations and inform design of automated technologies for vehicle systems. Workshop participants agreed that effective data collection and sharing of this information among relevant stakeholders is a near-term priority.

Closing Comments

Concluding remarks were provided by the workshop sponsors and included the following key points:

The presentations and discussions in this workshop reflect a wide variety of perspectives. Professionals from government safety agencies and experts from technology industries look at safety assurance from different directions, yet there was overwhelming agreement on the critical issues facing motor vehicle safety in coming decades. First, participants agreed on the compelling benefits promised by vehicle automation and the need to implement these technologies as quickly as possible – without compromising safety. The safety and mobility potential of the "New Era of Mobility" is indisputable.

> Perhaps the key point of agreement from the workshop was recognition of the importance of increased levels of communication, coordination, leadership, and collaboration among stakeholders so that the shared objective of rapid widespread adoption of lifesaving vehicle automation technology can be achieved as quickly as possible.

Second, without identifying a specific best option, participants agreed that a range of promising alternatives exist that appear to be capable of maintaining public

confidence in safety, while allowing technology developers to quickly and safely deploy improved technologies and products.

Perhaps the key point of agreement from the workshop was recognition of the importance of increased levels of communication, coordination, leadership, and collaboration among stakeholders so that the shared objective of safe and widespread adoption of life saving vehicle automation technology can be achieved as quickly as possible. Participants left the workshop with a shared commitment to continue such dialogs on a regular basis - toward a "Second Era of Mobility."