S. HRG. 114–416

HANDS OFF:
THE FUTURE OF SELF-DRIVING CARS

HEARING

BEFORE THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED FOURTEENTH CONGRESS

SECOND SESSION

MARCH 15, 2016

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SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED FOURTEENTH CONGRESS

SECOND SESSION

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TUESDAY, MARCH 15, 2016

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Committee met, pursuant to notice, at 2:34 p.m. in room SR–253, Russell Senate Office Building, Hon. John Thune, Chairman of the Committee, presiding.

Present: Senators Thune [presiding], Wicker, Ayotte, Heller, Fischer, Gardner, Daines, Nelson, McCaskill, Klobuchar, Blumenthal, Markey, Booker, Manchin, and Peters.

OPENING STATEMENT OF HON. JOHN THUNE, U.S. SENATOR FROM SOUTH DAKOTA

The CHAIRMAN. Good afternoon, everyone. I want to thank everybody for coming today as we discuss automated vehicles and the boundless opportunities that these technologies offer.

Americans love their cars. Since the automobile first rolled off the assembly line in River Rouge, Michigan, cars in America have offered independence, mobility, and adventure. Now, profound changes are coming to our roads. Technological advancements are progressing at a rapid pace and fully self-driving cars will be here sooner than we think.

We are facing an opportunity to expand the options for transportation by car while also making it smarter and safer. Yet, technological challenges remain, and people will need to become comfortable with the idea of being passengers in their own cars. We all like that feeling of control when we hold the steering wheel.

But perhaps the greatest hurdle to the deployment of these vehicles may be a regulatory environment with a patchwork of state and Federal laws unable to keep pace with these evolving technologies. Everything from driver assist functions like lane departure warnings to completely autonomous vehicles will transform transportation and mobility, profoundly affecting safety issues that have confronted society since the invention of the car.

In 2014, 32,675 Americans lost their lives due to car accidents. More than 90 percent of these tragedies are linked to human error, driver choices, intoxication, and distraction. Automated vehicles have the potential to reduce that number dramatically. Unlike human drivers, automated vehicles don't get tired, drunk, or distracted.

Combatting drunk driving has been a particular priority for me. South Dakota's 24/7 sobriety program, which works to change be-

havior though round-the-clock monitoring, is one successful program. But I'm eager to hear how autonomous vehicles could further reduce accidents due to drunk driving.

In addition to helping reduce accidents on American roads, autonomous vehicles promise to improve the quality of life for older Americans and members of the disabled community. No longer will a lack of accessible transportation hinder opportunities for employment or community involvement. As America's population ages, families may no longer have to struggle with the difficult decision of when to take the keys away from mom or dad.

Automated vehicles could also end one of the most frustrating parts of modern urban life, the traffic jam. This alone would improve the quality of life for many commuters with more time for families as commutes shorten. And, if the car does all the driving, time spent in a car could be productive, such as reading work e-mails, checking the box score from last night's game, or catching up on the highlights on Sports Center. I'm speaking of some of my own pastimes here.

With no more gridlock, traffic will flow more smoothly and efficiently. Even fuel economy is likely to improve, since automated vehicles will be more efficient than human drivers.

These advancements also have the potential to reshape communities. Currently, parking garages and surface lots take up one-third of the land in cities. Imagine a technology that will revolutionize parking as we know it, allowing that land to be reclaimed and repurposed.

To implement this future, we need to challenge ourselves to overcome the 20th century conception of what a car must have: side and rearview mirrors, a brake pedal, a steering wheel, and even the concept of a licensed human driver. Because so much is possible, we must be careful not to stymie innovation because of a lack of imagination.

Federal and state governments may need to rethink how they regulate and license vehicles for the future. We must ensure that the United States remains the cradle of innovation and that we continue to lead the way in the development and deployment of automated vehicles.

In addition, questions regarding liability, insurance, privacy, security, and infrastructure need answers. These aren't small things, but none of them is insurmountable. And if Congress, the Department of Transportation, industry, and stakeholders work together, we will see all the benefits promised.

This morning, the Committee had the great opportunity to see some of this technology in action, when we brought self-drive to Capitol Hill. Continental, Volkswagen, BMW, and Tesla provided vehicles that gave us firsthand experience to see what the future may hold and a preview to the discussions at this hearing. I want to thank them for making those vehicles available.

This afternoon we are joined by witnesses representing Google X, General Motors, Delphi, and Lyft, companies with direct stakes in automated technology. We are also joined by Dr. Cummings from Duke University, who is also a distinguished naval aviator and a returning witness before our committee.

Dr. Cummings, thank you for your service to our country.

We look forward to hearing from all of our witnesses to learn more about what they're doing in this space and their vision for the future. But before we hear from our witnesses—some will also, by the way, play a short video, assuming the technology works, and I'm not sure, when we got underway, that it did.

But before we get to that, first up, Senator Nelson.

STATEMENT OF HON. BILL NELSON,
U.S. SENATOR FROM FLORIDA

Senator NELSON. Thank you, Mr. Chairman.

So, I'm in the Tesla, and we're coming back across the Anacostia River and getting up on the bridge to get onto the ramp for 395. I'm instructed in the driver's seat, "Engage the autonomous switch." I click it twice. "Take your hands off the wheel." All of a sudden, the car is speeding up, and they say, "It automatically will go with the flow of the vehicles in front and back."

But now we are approaching the on-ramp onto 395, and it is a sharp turn, and the vehicle is still speeding up. They said, "Trust the vehicle." And as we approach the concrete wall, my instincts could not resist, and I grabbed the wheel, touched the brake, and took over manual control.

I said, "What would have happened?" They said, "If you'd left your hands off the wheel, it would have made that sharp turn and come on around." So I'm here to tell you——

The CHAIRMAN. I'm glad you're here.

[Laughter.]

Senator NELSON.—that I'm glad I grabbed the wheel. But we know that if this is working, as it apparently is, then there are going to be many lives that could be saved by preventing preventable accidents, because what if you suddenly look down at your cell phone, and all of a sudden, the car in front of you stops, or one comes over into your lane?

Things like efficiency and productivity could also increase considerably. Underserved communities without reliable means of transportation could finally be integrated into the national economy. In so many states, this technology could be particularly beneficial for seniors and those with disabilities.

But we have to have the technology right so that self-driving cars can live up to their promise. The Federal Government has a critical role to make sure that the regulatory and legal environment, in which American businesses do business, is able to allow the development and manufacturing of these vehicles.

It also means that we're going to have to, in our case, exercise responsible oversight. As we have seen in this committee on other subjects, such as the Takata airbags and the GM ignition switch recall, individual components of vehicles with defects can suddenly snowball into major problems.

With an autonomous car, the stakes are all the more higher. You can imagine, in this world of cybersecurity and cyber attacks, what would happen to autonomous vehicles that get hacked while they're out on the road. One small defect could end up becoming a massive safety crisis. And if the problem comes up, manufacturers and regulators are going to have to get together and quickly find those solutions.

No more cover-ups, no more head-in-the-sand approaches to safety. If we are going to avoid the tragedies, we've got to be johnny-on-the-spot.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Nelson. They didn't let me get behind the wheel.

Senator NELSON. I know.

The CHAIRMAN. I suppose they figured if you could navigate a spaceship, you could probably navigate a driverless vehicle.

Senator NELSON. Well, it was a terrestrial challenge.

[Laughter.]

The CHAIRMAN. I want to ask unanimous consent to submit for the record statements from the National Council on Disability, the Global Automakers Association, and a letter from the Global Automakers and the Auto Alliance to Secretary Foxx at the Department of Transportation. So those will be included, without objection.

[The information referred to follows:]

PREPARED STATEMENT OF CLYDE TERRY, CHAIR, NATIONAL COUNCIL ON DISABILITY

Chairman Thune, Ranking Member Nelson, and Esteemed Members of the Senate Committee on Commerce, Science, and Transportation:

Introduction

Thank you for the opportunity to provide written testimony for this timely and important hearing on autonomous vehicle technology. The National Council on Disability (NCD) is an independent Federal agency charged with providing the Administration, Congress, and other Federal agencies with advice and recommendations regarding disability policy—including policy discussions around emerging technologies such as autonomous vehicle (AV) technology—to improve the lives of people with disabilities. We applaud the Committee for examining this topic at today's hearing and we offer ourselves to the Committee as an ongoing resource as you examine this topic and consider appropriate legislative responses.

An Exciting Innovation for Everyone, But a New Era for Some

Aside from being one of the most exciting innovations in transportation since the Model T began rolling off the assembly line in 1913, AV technology holds tremendous promise for many people with disabilities and seniors who currently lack access to independent transportation. In our recent report, "Self-Driving Cars: Mapping Access to a Technology Revolution," the National Council on Disability examined the challenges and advances associated with this revolution in transportation technology and proposed directions in research and development that will most benefit those people with disabilities who are the most transportation disadvantaged because their disabilities prevent them from driving even a modified conventional vehicle.

Despite significant advances in accessible public transportation, a lack of reliable and accessible transportation remains one of the biggest deterrents to employment and community involvement for people with disabilities in the United States. Accordingly, autonomous vehicles have the potential to become an essential component of their independence, economic development, and well-being. Autonomous vehicles hold great promise to advance social inclusion by offering people with disabilities independent mobility to get to school, jobs, and all places that Americans go each day. They also offer the possibility of ending the isolation that many people who are aging experience by keeping them connected with others and to activities that are often lost when we lose the ability to drive.

An Opportunity We Can't Afford to Miss

These remarkable benefits will not come at once and will not occur without cooperation among Federal and state governments, research institutions, and private industry.

Benefits will not emerge if the technology develops without universal accessibility for people with diverse disabilities, including intellectual and developmental, sensory, and physical disabilities. Accessibility must be infused in the research and development of AVs. Without explicit inclusion of accessibility in the development of

AV technologies, the potential for opportunity wanes. As an example of the importance of this type of forethought as technology evolves, during the early days of the Internet, and still today, accessibility for people with disabilities was not considered by web developers, and many people with disabilities experienced and even now still do experience unnecessary obstacles to information (*e.g.,* text that is inaccessible to screen reader software, lack of captions on audio content, keyboard-only navigation). Those obstacles diminish the opportunities available to people with disabilities that the Internet presents for people without disabilities. This is a lesson for AV researchers and engineers—the time is now to commit to and include accessibility.

From what we've seen so far, many in the industry understand the potential autonomous vehicles have to change the lives of people with disabilities, and that people with disabilities are a primary market for this technology. It's important to make sure that accessibility stays at the forefront of this conversation so that people with disabilities don't get left behind. Decisions that are made by policymakers, innovators, regulators and marketers will all impact how this technology is adopted and whether it achieves the potential it has to change the lives of people with disabilities who are transportation disadvantaged. We look forward to working with industry, advocates, and policymakers to shepherd this technology so as to result in a new era of inclusion for people with disabilities. Accordingly, we encourage you to include discussions of needs of this population as you convene future hearings on the topic of AV and to seek out the views and experiences of people with disabilities in those discussions.

Conclusion

NCD is grateful to the Committee for elevating this important topic through today's hearing and we encourage Committee members and their staff to review our report, "Self-Driving Cars: Mapping Access to a Technology Revolution" which is available on our website at: *https://www.ncd.gov/publications/2015/self-driving-cars-mapping-access-technology-revolution.* We look forward to providing further testimony at future hearings on this topic.

PREPARED STATEMENT OF JOHN BOZZELLA, PRESIDENT AND CEO, ASSOCIATION OF GLOBAL AUTOMAKERS, INC.

On behalf of the Association of Global Automakers ("Global Automakers"), I am pleased to provide the following statement for the record of the Senate Committee on Commerce, Science, and Transportation hearing entitled "Hands Off: The Future of Self-Driving Cars." Global Automakers represents international automobile manufacturers that design, build, and sell cars and light trucks in the United States. These companies have invested $52 billion in U.S.-based facilities, directly employ more than 97,000 Americans, and sell 47 percent of all new vehicles purchased annually in the country. Combined, our members operate more than 275 production, design, R&D, sales, finance and other facilities across the United States. Global Automakers and our member companies are committed to creating the safest, cleanest and most technologically advanced vehicles on the road.

The automotive industry is in the midst of an unprecedented wave of technological innovation that is redefining how we think about transportation. Advancements in connected and automated vehicle technology present significant opportunities for enhancing mobility, saving lives, improving transportation efficiency, and reducing fuel consumption and associated emissions.

Global Automakers' members have made and continue to make substantial investments in the research and development of advanced technologies, and we appreciate the opportunity to provide comment on these matters. Over the past several decades, our members have made tremendous strides in safety by improving vehicle crashworthiness: how well the interior cabin protects occupants in the event of a crash. Our members have also made initial forays into vehicle automation, equipping vehicles with the first generation of crash avoidance technologies that seek to prevent crashes from occurring altogether. The next step in this evolution is continued research, development, and deployment of a suite of automated and connected technologies that will further help us achieve this goal.

Automakers and automotive suppliers are leading the way in the development of advanced automated vehicle technology, and according to a recent report by Thompson Reuters, several Global Automakers' members were listed among the top automated vehicle innovators worldwide.[1] Through significant investments in research

[1] "The 2016 State of Self-Driving Automotive Innovation," Thompson Reuters (*2016*)

and development, manufacturers are working hard to provide increasingly automated features and functionality in their vehicles.

As we think about advanced motor vehicles, it is important to note that automated vehicle technology is much broader than the concept of a *self-driving* or *driverless* car. In fact, a number of vehicles on the road today already provide automated functionality through advanced crash-avoidance and convenience features such as crash imminent braking, lane keeping assist, and adaptive cruise control. These systems, which are often considered foundational to the development of more highly automated systems, are designed to provide support to the driver only in certain situations, and automated vehicle control is not typically sustained over an extended period of time. As these systems become more advanced, a vehicle's capability to operate without active control of the driver will increase.

As vehicles become not only more automated, but also connected through Dedicated Short Range Communications (DSRC) technology and other wireless technologies, consumers are expected to experience substantial safety and mobility benefits. An estimated 90–95 percent of crashes are attributable to driver error, whether it be a recognition, decision, or performance-related error. Advancements in vehicle sensors, communications technology, and vehicle automation have the potential to significantly reduce the occurrence or severity of crashes in the future by helping correct for these errors in human driving. Crash prevention not only saves lives, but reduces congestion, resulting in environmental benefits as well. In addition, automated and connected technologies create significant opportunities for improving vehicle efficiency and highway throughput by making it possible for vehicles to operate closer together, optimizing the utilization of existing infrastructure. Furthermore, automated vehicles provide the potential for enhanced independent mobility options for those without access to transit or those with disabilities.

For these and other reasons, automated vehicles have garnered significant media attention and have captured the imaginations of both the public and policymakers. However, the concept of increased vehicle automation is often met with mixed reactions ranging from fear, uncertainty, and doubt, to excitement and anticipation for the mobility opportunities that self-driving vehicles could provide. Because we do not know the full extent of what the future may hold, it is important that automated vehicle policy be considered in a way that is flexible and responsive to changes in technology so that the benefits of connected and automated vehicles can be achieved. It is therefore necessary to understand not only what policies may be needed to encourage the safe and widespread development, adoption, and integration of these advanced systems into the existing fleet, but also how existing laws may unintentionally act as an impediment to innovation.

In addressing the many important policy considerations related to automated vehicles, legislators and regulators at all levels of government will need to engage in an informed discussion that includes all of the key stakeholders. Automated vehicle policy questions often include, but are not limited to, issues such as:

- What additional *safety requirements* might be needed?
- How should *cybersecurity and privacy* concerns be addressed?
- What is the *role of the driver,* and will drivers need a special license?
- What approaches to *liability and insurance* are appropriate?
- Should the *policies for driverless cars* differ from those where a driver is present in the vehicle?
- How can automated vehicle technology provide greater *mobility and accessibility*?
- What *infrastructure investments* may be required to support a more connected and automated fleet?
- How will automated vehicles operate in a mixed fleet environment alongside non-automated vehicle drivers?
- Can we safely *share the spectrum* that is the backbone of DSRC connected car technology?

These are complex issues with profound cultural ramifications, and resolving them will require significant coordination between federal, state, and local government in collaboration with industry stakeholders and the public. There are distinct roles that each level of government will play in addressing specific issues, but the result should be a national approach that enables the effective and widespread adoption of technology. We believe that the Federal Government, working closely with key stakeholders, should adopt a leadership role to help provide meaningful guidance for the development of a cohesive and complementary policy that is responsive to current and future technology.

One important policy goal should be avoiding a *patchwork* of different Federal and state standards. States such as California, Nevada, Florida, and Michigan, as well as the District of Columbia, have already enacted laws related to the testing and operation of automated vehicles. Each of these states has taken a slightly different approach to the issue which presents significant challenges for the auto industry. For instance, what would happen when an automated vehicle is certified as meeting the design criteria for one state but not another state? Would the vehicle be banned from crossing the state line? From a manufacturers' perspective, a single national approach to the design and production of automated vehicles is of paramount importance. This approach should be developed at the national level, led by the Department of Transportation in consultation with other relevant agencies.

As policymakers develop a legal and regulatory framework for automated vehicles, it will be important to ensure that regulations do not get so far ahead of the technology that they stifle innovation. For instance, many state statutes take a "one size fits all" approach to automated vehicles—either a car is an "autonomous vehicle" or it is not—and they fail to account for various levels of automation. As previously mentioned, automated vehicle technology is broader than the concept of the driverless car and clear definitions are important. Some state statutes create uncertainty regarding advanced driver assistance systems already in certain vehicles.

Distinguishing between various levels of automation will be important in addressing when a vehicle become an "automated" or "autonomous" vehicle, how this may impact the roles and responsibilities of the driver, and what additional requirements might be imposed on the vehicle. While we encourage legislative uniformity in this regard, the debate over the most appropriate definitions for classifying automated vehicle technology is still ongoing.

To date, the Department of Transportation (DOT) has taken a measured approach towards automated vehicles regulation, and we commend the Federal regulators for their initial work to create a more balanced environment for innovation. By way of example:

- On May 30, 2013, the National Highway Traffic Safety Administration (NHTSA) issued a Preliminary Statement of Policy Concerning Automated Vehicles as a mechanism to provide guidance to the states permitting testing of emerging vehicle technology.[2] The document was designed to provide recommended principles that states may wish to consider with respect to automated vehicles. In addition, the agency also provided an overview of its automated vehicle research program, and sought to develop high-level descriptions explaining various levels of automation.
- On April 1, 2015, NHTSA Administrator, Mark Rosekind, wrote to the Director of the California Department of Motor Vehicles to provide an update on NHTSA's research on automation. The agency indicated that it expects to complete several research efforts over the next 24 months. In the event that NHTSA were to conclude there is a need for Federal safety standards concerning any aspect of these technologies, NHTSA's research will provide important support for those standards.
- On January 14, 2016, DOT issued an updated Statement of Policy which announced a number of initiatives, including the development of (1) guidance on the safe deployment and operation of autonomous vehicles, providing a common understanding of the performance characteristics necessary for fully autonomous vehicles and the testing and analysis methods needed to assess them, and (2) model state policy on automated vehicles that offers a path to consistent national policy. DOT also announced that NHTSA, upon request, would seek to provide interpretations for how existing Federal Motor Vehicle Safety Standards may apply to advanced technology, and that where interpretation authority were not sufficient would encourage manufacturers to submit requests to allow the deployment of automated vehicle systems. In addition, the Department also indicated that it plans to develop new tools and seek new authorities when necessary to ensure the safe deployment of the technology.[3]

Despite these steps, we believe DOT, in coordination with NHTSA and other Federal transportation agencies, must provide greater leadership on this issue, as we continue to observe a steady increase in the number of disparate legislative proposals aimed at regulating automated vehicles at the state level. As of March 1, 2016, over 25 automated vehicle bills were introduced in various parts of the coun-

[2] "Preliminary Statement of Policy Concerning Automated Vehicles," NHTSA (*2013*)

[3] "DOT-NHTSA Policy Statement Concerning Automated Vehicles (2016 Update)," DOT-NHTSA (*2016*)

try. To the extent possible, we believe the aforementioned NHTSA activities should be as inclusive as possible throughout all stages of development in an open and transparent process. Equally as important is ensuring awareness of this ongoing activity so that interested policymakers can continue to be informed when making key decisions that could affect the way in which automated vehicles are integrated as part of society. The initiatives that DOT has engaged in are an important first step towards a balanced, data-driven policy that will be national in scope; however, the Department must assume a more active and engaged role to accomplish this goal. Providing clear long-term strategic direction and leadership that extends beyond research is critical.

Federal leadership is also of paramount importance given the convergence of automated technology and DSRC technology supporting connected cars. Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) technology can be utilized to enhance and supplement the benefits of automation. DSRC technology will allow the transmission of messages between vehicles about vehicle speed, heading, brake status, and other information with range and "line-of-sight" capabilities that exceed camera or radar-based systems currently supporting automated features. DSRC is expected to augment on-board sensor information to help improve the decisions made by automated vehicles regarding safety-critical situations and also improve the transition to a more automated fleet in the future through increased situational awareness between both automated and non-automated vehicles on the road. We expect NHTSA to publish a notice of proposed rulemaking later this year that would require new motor vehicles to be equipped with DSRC equipment, and Global Automakers supports NHTSA's plans to mandate the technology.

DSRC is a critical technology to achieve the full benefits of networked, automated vehicles. For these reasons, we need to ensure that the 5.9GHz spectrum band is protected for DSRC to operate without harmful interference. We continue to work on testing in this area and hope to have a positive conclusion in the near future; however, we caution policymakers against making hurried decisions concerning whether unlicensed technologies can share operations in the 5.9 GHz band. Thorough testing needs to be completed before any consideration is given to allowing unlicensed technologies to operate in the band.

As vehicles become more connected and automated, automakers also are proactively taking steps to protect the security and integrity of automated vehicle systems and consumer data. While privacy and cybersecurity are complex issues, the enormous benefits of automated and connected car technologies outweigh the challenges that come with living in a connected world. As automakers pursue these innovations and the benefits that they bring, we recognize strong cybersecurity and privacy protections are essential to building consumer confidence.

In 2015, the auto industry established the Automotive Information Sharing and Analysis Center (Auto-ISAC) to share intelligence on immediate threats and vulnerabilities between trusted industry stakeholders. In addition, the Association of Global Automakers, Alliance of Automobile Manufacturers, and the Auto-ISAC are working collaboratively to develop cybersecurity best practices which will be modelled after the Cybersecurity Best Practices Framework the auto industry published in January of this year.[4] This Best Practices Framework, which was inspired by the National Institute of Standards and Technology (NIST) Framework for Improving Critical Infrastructure Cybersecurity, and other cybersecurity models, provides a foundation for the development of industry-led best practices that we believe provides greater flexibility to respond in a dynamic technology environment, compared to the traditional regulatory and guidelines models typically used by NHTSA.

In addition to measures to address cybersecurity, U.S. automakers proactively took steps in 2014 to protect the privacy of consumers through the responsible stewardship of information collected from in-vehicle technologies and services and the meaningful disclosure of privacy policies and practices.[5] We engaged with privacy advocates and the Federal Trade Commission (FTC) during the development of these principles. As of January of this year, all major automakers are accountable to the FTC for these privacy commitments.

The automobile industry continues to provide innovative technologies with demonstrable safety, mobility, and environmental impacts. Our industry is undergoing rapid changes as we work to meet today's safety and environmental regulations, and as we strive towards the long-term goals of saving lives, reducing greenhouse gas emissions, and providing the consumer with exciting vehicles that meet their needs. These changes take time, commitment and investment to see through. They require close collaboration and coordination among and between government, industry, aca-

[4] "Framework for Automotive Cybersecurity Best Practices" (*2016*)
[5] "Privacy Principles for Vehicle Technologies and Services," (*2014*)

demia, and other stakeholders. Global Automakers and our member companies believe that automated vehicles represent the next giant leap towards our shared long-term goal of safer and cleaner vehicles.

ALLIANCE OF AUTOMOBILE MANUFACTURERS, INC.
ASSOCIATION OF GLOBAL AUTOMAKERS, INC.
February 11, 2016

Hon. ANTHONY R. FOXX,
Secretary,
U.S. Department of Transportation,
Washington, DC.

Dear Secretary Foxx:

We are writing to you on behalf of the members of the Alliance of Automobile Manufacturers, Inc. (Alliance)[1] and the Association of Global Automakers, Inc. (Global Automakers),[2] to express strong support for your efforts to identify and address obstacles in the current regulatory framework to the implementation of safety innovations. We agree with you that this is an exciting and optimistic time for the auto industry; indeed, we believe the joint efforts of the Department and industry will further promote our shared safety, fuel economy and mobility goals.

In the spirit of your initiative, we highlight four examples where the National Highway Traffic Safety Administration (NHTSA) could help accelerate safety technologies. All four are in the pipeline. We ask that the Department move expeditiously to address the following petitions for rulemaking and requests for interpretation in order to facilitate these technologies that help allow for a safer driving experience:

Advanced Forward Lighting (Adaptive Driving Beam Headlamps): Petition for Rulemaking to amend Federal Motor Vehicle Safety Standard (FMVSS) 108 to permit Adaptive Driving Beam (ADB) headlamps that are already allowed in Europe. ADB preserves or enhances forward illumination while protecting against glare for oncoming drivers.

This petition was submitted by Toyota in March 2013 and is supported by the Alliance, Global Automakers and the Truck & Engine Manufacturers Association (EMA).

Expanded Field of View (Camera–based vision systems): Petition for Rulemaking to amend FMVSS 111 to allow the use of camera-based rear and side vision systems in lieu of side and rearview mirrors. Camera-based rear and side view monitoring systems are enablers to increased fuel economy and driver field of view, which is particularly helpful for older drivers. European regulators are moving quickly to allow these systems.

This petition was submitted by the Alliance and Tesla Motors in March 2014.

Advanced/More Efficient Powertrains (Fuel Cell & Hybrid Vehicles): Petition for Rulemaking to amend FMVSS 305 to allow physical barriers and to specify isolation resistance requirements to provide protection against electric shock. Amending FMVSS 305 as requested would enable the introduction of fuel cell and 48–volt hybrid vehicles.

This petition was submitted by the Alliance in November 2014.

Advanced Crash Avoidance Safety Systems (Automatic Emergency Braking): Request for Interpretation of the requirements of 49 C.F.R. 581 relating to low–speed bumper performance. A favorable interpretation is needed to help accelerate the implementation of advanced crash avoidance technologies such as automatic emergency braking (AEB) technology, the adoption of which is leading to a statistically significant reduction in crashes and the corresponding injuries and property damage.

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[1] The members of Alliance of Automobile Manufacturers are BMW Group, FCA U.S. LLC, Ford Motor Company, General Motors Company, Jaguar Land Rover, Mazda, Mercedes-Benz USA, Mitsubishi Motors, Porsche Cars North America, Toyota, Volkswagen Group of America and Volvo Cars of North America.

[2] The members of the Association of Global Automakers are American Honda Motor Co., Aston Martin Lagonda of North America, Inc., Ferrari North America, Inc., Hyundai Motor America, Isuzu Motors America, Inc., Kia Motors America, Inc., Maserati North America, Inc., McLaren Automotive Ltd., Nissan North America, Inc., Subaru of America, Inc., Suzuki Motor of America, Inc., and Toyota Motor North America, Inc.

This request was submitted by the Alliance and Global Automakers in January 2016.

Finally, we write to convey our agreement with you that we have entered an era in which we are rapidly reinventing personal transportation with the potential to save lives. Toward that end, we recommend that the Department consider establishing procedures for addressing regulatory obstacles to the adoption of innovative technologies on an expedited basis that are identified by industry in the future.

Specifically, we recommend that 49 C.F.R. 552 be amended to add a new subpart—Subpart C—to establish procedures for the submission and expedited disposition of rulemaking petitions and requests for interpretations that seek to eliminate roadblocks to the integration of innovative, transformative automotive technology that can significantly improve safety, mobility, and sustainability. Such procedures, if established, would not be unprecedented as similar procedures were established in 2000 to help facilitate the development of airbag dynamic automatic suppression systems (DASS) then under consideration. Of course, with any expedited rulemaking process, it will be important to make sure that all stakeholders have sufficient input to ensure that the results are scientific and data-driven.

The Members of the Alliance and Global Automakers are proud of their role in developing and implementing technologies that are making personal transportation ever safer, cleaner and more fuel efficient. We welcome your prompt consideration of these matters. We stand ready to help in whatever way we are able.

Sincerely,

Alliance of Automobile Manufacturers
MITCH BAINWOL
President and CEO

Association of Global Automakers
JOHN BOZZELLA
President and CEO

cc: The Honorable Mark R. Rosekind, Administrator
National Highway Traffic Safety Administration
Mr. Blair Anderson, Deputy Administrator
National Highway Traffic Safety Administration

The CHAIRMAN. We have before us today a great panel. I want to welcome them here. First is Dr. Chris Urmson, who is Director of Self-driving Cars for Google X; Mr. Mike Ableson, Vice President, Strategy and Global Portfolio Planning, General Motors Company; Mr. Glen De Vos, who is the Vice President, Global Engineering and Services, Electronics and Safety at Delphi Automotive; Mr. Joseph Okpaku, who is the Vice President of Government Relations for Lyft; and, as I mentioned earlier, Dr. Mary ("Missy") Louise Cummings, Director of Human and Autonomy Lab and Duke Robotics at Duke University.

So welcome to all of you. Thank you for participating today. We'll start on my left and your right with Dr. Urmson and then proceed as each of you complete. And if you could, at least as close as possible, stay to the 5-minute time allotment so we will have ample time for Members to ask questions. I think we'll have good participation today. So thank you all for being here.

Dr. Urmson?

STATEMENT OF DR. CHRIS URMSON, DIRECTOR, SELF-DRIVING CARS, GOOGLE X

Dr. URMSON. Thank you, Chairman Thune, Ranking Member Nelson, and members of the Committee. Thank you for inviting me to testify today about the potential for self-driving cars to improve the lives of people everywhere.

My name is Chris Urmson, and I've been leading the technology development of Google's self-driving car program since 2009. The video we would have shown earlier captures many of the reasons why we're excited about this technology. NHTSA estimates that

38,000 people were killed on America's roads last year, and 94 percent of accidents involve human error.

Self-driving cars can help us change that. Not only could our roads be a lot safer, but self-driving cars could bring everyday destinations and new opportunities within reach of those who might otherwise be excluded by their inability to drive a car. We believe that to actually realize all those benefits and many more, we need cars that are fully self-driving. That is, the car must be designed to do all the work so that the occupants are not expected to take control of the vehicle at any time.

We're now testing self-driving prototype vehicles in three different states. Over the last 7 years, we've driven over 1.4 million miles in autonomous mode. All our testing using real complex scenarios helps us analyze, evaluate, and improve how our cars perform.

Today, Congress has a huge opportunity to help ensure that self-driving cars can be safely deployed at scale. We currently face a growing patchwork of state laws and regulations on self-driving cars that has the potential to become unworkable. In the past 2 years, 23 states have introduced 53 pieces of legislation that affect autonomous vehicles, all of which include different approaches and concepts. If every state is left to go its own way, it would be extremely impractical to operate an autonomous vehicle across state boundaries. We are grateful to the Department of Transportation and Secretary Foxx for their vision and commitment to help in the deployment of self-driving cars.

NHTSA has issued helpful clarifications of existing safety standards. But we must remember that current regulations were written at a time when the idea that a car could drive itself was science fiction. NHTSA has indicated that new authorities may be needed to safely deploy these technologies going forward.

Congressional action is needed to keep pace. We propose that Congress move swiftly to provide the Secretary of Transportation with targeted new authority to approve lifesaving safety innovations. This new authority would allow the deployment of innovative safety technologies that meet or exceed the level of safety required by existing Federal standards while ensuring and prompt and transparent process.

We look forward to working with this committee, DOT, and NHTSA to ensure that this type of new authority can effectively achieve the safety and innovation benefits of fully self-driven cars. We also believe that it will help continue U.S. leadership on this technology for the years ahead.

The importance of getting self-driving car technology safely into people's hands is best summed up by those who need it most. During a recent California DMV workshop to discuss the technology, regulators heard from Justin Harford, a man who is legally blind. Justin said, "What this is really about is who gets to access transportation and commerce and who doesn't, and I'm frankly tired of people with disabilities not being able to access commerce." Our team at Google believes that self-driving cars can ultimately remove these transportation barriers from our society.

Thank you for your help in creating a path for this technology and for your time and consideration today.

[The prepared statement of Dr. Urmson follows:]

PREPARED STATEMENT OF DR. CHRIS URMSON, DIRECTOR, SELF-DRIVING CARS, GOOGLE [X]

Chairman Thune, Ranking Member Nelson, and Members of the Committee:

Thank you for inviting me to testify today about the potential for autonomous vehicle technology to improve the lives of people everywhere.

My name is Chris Urmson. Since 2009, I have been leading the technical development of Google's self-driving car technology. I also served on the faculty at Carnegie Mellon University and was previously Director of Technology for the team that won the 2007 DARPA Urban Challenge.

We are grateful for the opportunity to discuss the promise of this technology, including the potential for tremendous gains in safety and productivity. I will share an overview of our work on self-driving cars, including where we currently stand, and some of the lessons we have learned along the way. Perhaps most importantly for this conversation, I will discuss the crucial role that Federal policymakers have in enabling the development and deployment of this innovative safety technology for the U.S. public. Today, Congress has a huge opportunity to further this field by enabling the U.S. Department of Transportation to pave the way for the deployment of this innovative safety technology, which will help reduce the more than 6 million traffic accidents that are reported in the U.S. every year.

Google's development and testing of fully self-driving cars

When Google started working on self-driving vehicles over seven years ago, our goal was to transform mobility by making it safer, easier, and more enjoyable to get around. What drives our team is the potential that this technology has to make our roads safer. NHTSA estimates that traffic accidents killed over 38,000 Americans in 2015 and the World Health Organization estimates that 1.2 million lives are lost to traffic accidents globally every year. These are numbers that could be reduced significantly with fully self-driving cars, especially since 94 percent of accidents in the U.S. are due to human error.

In addition to improving roadway safety, self-driving cars can bring everyday destinations and new opportunities within reach of those who might otherwise be excluded by their inability to drive a car. For people who are blind, elderly, or living with conditions that would otherwise make driving difficult or impossible, this technology offers the promise of mobility and independence that has never before been available. One woman in Southern California who lost her ability to drive 15 years ago told us, "my life has become very expensive, complicated, and restricted" since she had to start paying drivers and enduring long waits for buses and trains.

The technology also has the potential to reduce current Federal spending pressures for roadways, parking, and public transit—all of which were key considerations in this Committee's work on the FAST Act. Over the next three decades, the U.S. Department of Transportation expects that self-driving cars will play a key role in reducing transit operating costs, improving highway efficiency, and freeing up existing parking infrastructure (which currently takes up a total area of 3,000 square miles in the U.S., equivalent to the size of Connecticut).[1]

These benefits are closer to being unlocked now that significant portions of the automotive industry are investing in self-driving car technology. In the years immediately following the DARPA Urban Challenge, both government and private sector investments in this technology were extremely limited, but now a wide range of companies across the auto and tech industries—including those testifying on this panel today—are placing bets on self-driving cars.

Between 2011 and 2013 our development efforts focused on autonomous driving for highways by modifying existing vehicles like the Toyota Prius and the Lexus RX450h. Our early tests involved employees driving manually up to a freeway, engaging the autonomous mode, and then monitoring the car until the exit. But in 2013, we decided that to fully realize the safety promise of this technology and serve the most people—even those without a license—our technology needed to be capable of doing all the driving, without human intervention necessary. NHTSA defines this as "fully autonomous vehicles," or "Level 4" on a NHTSA scale for automation established in 2013. Developing a car that can shoulder the entire burden of driving is crucial to safety: we saw in our own testing that the human drivers can't always

[1] U.S. Department of Transportation, *"Beyond Traffic 2045: Trends and Choices,"* February 2, 2015, *<https://www.transportation.gov/sites/dot.gov/files/docs/Draft_Beyond_Traffic_Framework.pdf>*.

be trusted to dip in and out of the task of driving when the car is encouraging them to sit back and relax.[2] The Virginia Tech Transportation Institute has measured this phenomenon extensively and found that human operators of partially self-driving cars in a NHTSA-sponsored study took up to 17 seconds to respond to alerts and take control of the vehicle.[3]

That's why in 2014, we announced that we were developing a new self-driving vehicle prototype from the ground up—one designed to require no human intervention to get from point A to point B. Exploring what such a vehicle could look like meant making big changes to the features of a car and building in some unique capabilities. For example, we were able to:

- Change the shape of the vehicle so our radar, laser, and camera sensors can be placed for an optimal 360 degree field of view and see as far out as two football fields;
- Build in backup self-driving systems for braking, steering, computing, and more in the event that one of the main systems fails;
- Build in new protections for pedestrians. The front of our prototype vehicles is padded with a special foam-like material that absorbs the energy of an impact, their windshields are made from a flexible material, and their side mirrors are magnetic and easily break away;
- Take out the steering wheel and pedals, as the software is responsible for the driving;
- Bake in defensive driving behavior to avoid having the car get into tricky situations. Our car doesn't get tired, distracted, or angry. They're designed to stay out of other drivers' blind spots, nudge away from lane-splitting motorcycles, and pause for 1.5 seconds after traffic lights turn green to avoid red light runners.

Today, our fleet includes 33 of these prototype vehicles and 23 modified Lexus SUVs. For now, test drivers are aboard all of our vehicles to monitor how the cars drive, and to provide feedback to our engineering team. All our prototype vehicles are equipped with removable steering wheels, accelerator pedals, and brake pedals that allow our test drivers to take over driving if needed while testing.

We have been testing our vehicles on California's public roads for over 7 years, and we recently expanded testing to parts of Austin, Texas, and Kirkland, Washington. So far, we've driven over 1.4 million miles in autonomous mode—that's the equivalent of 108 years on the road, based on a typical American adult driving about 13,000 miles per year.

In our 7 years of testing, we've been involved in 17 minor crashes while driving autonomously. We publish details about the circumstances of every crash on our website, regardless of its severity. While the vast majority of these incidents have been a result of distracted or inattentive driving by other human drivers on the road, we investigate each event and determine whether any improvements to our software and hardware are needed. Using our simulator, we replay and analyze each incident and test our software against hundreds of variations on the same event (for example, we simulate different speeds and positions of other vehicles). We take anything we learn and roll these changes out to our entire fleet.

Testing on public roads allows our cars to experience real, complex scenarios that help us improve our systems. We're also constantly testing, analyzing and evaluating how our software performs in multiple other ways, including on the test track and in our simulator (in which our software drives more than 3 million miles a day).

We look forward to learning how different communities perceive and interact with our vehicles.

We publish monthly reports with summaries of how far we've traveled, new capabilities we're adding, and any accident encountered.[4] Getting people's reactions and feedback is an important part of the learning process. We want to see how people might think differently about a vehicle when it ultimately requires them to do nothing but get in, buckle up, and ride. Educating people about the technology is an important step in building consumer confidence in this lifesaving innovation. So far

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[2] Google SelfDriving Car Project, *Monthly Report,* October 2015. *<http://static.googleusercontent.com/media/www.google.com/en//self-drivingcar/files/reports/report1015.pdf>*

[3] National Highway Traffic Safety Administration, *"Human Factors Evaluation of Level 2 and Level 3 Automated Driving Concepts,"* August 2015 *<http://www.nhtsa.gov/DOT/NHTSA/NVS/Crash%20Avoidance/Technical%20Publications/2015/812182__HumanFactorsEvalL2L3-AutomDrivingConcepts.pdf>*

[4] Google SelfDriving Car Project, *Monthly Reports, <http://www.google.com/self-drivingcar/reports/>*

we've found that people find it very mentally freeing and relaxing to just get in and not have to do anything more than press a button.

Federal leadership is needed to enable fully self-driving cars

The Federal Government plays a pivotal role in setting safety standards for motor vehicles with the powers that Congress vested in NHTSA more than half a century ago. We're encouraged that the Department of Transportation (DOT) has recognized the safety, environmental, and accessibility benefits of self-driving cars. Secretary Foxx has pledged to work quickly with Federal and state policy makers to ensure the right policies and guidance are in place to encourage innovation in this field. We welcomed his commitments in January to develop tools, including possible new authorities for NHTSA and DOT, to ensure that self-driving cars can be safely deployed at scale.

The leadership of the Federal Government is critically important given the growing patchwork of State laws and regulations on self-driving cars. Last December, we were disappointed that California released draft regulations for operation of autonomous vehicles that specifically excluded fully self-driving cars, despite strong public support for this technology, particularly from the disability community. Further, in the past two years, 23 states have introduced 53 pieces of legislation that affect self-driving cars—all of which include different approaches and concepts. Five states have passed such legislation, and—although all were intended to assist the development of the technology in the state—none of those laws feature common definitions, licensing structures or sets of expectations for what manufacturers should be doing. If every state is left to go its own way without a unified approach, operating self-driving cars across state boundaries would be an unworkable situation and one that will significantly hinder safety innovation, interstate commerce, national competitiveness, and the eventual deployment of autonomous vehicles.

As we work toward building a fully self-driving car, having clarity on how existing laws and regulations apply is critical for Google and others working on this technology. In November, Google wrote to NHTSA asking for an interpretation of the existing Federal Motor Vehicle Safety Standards (FMVSS) and how they may pertain to self-driving cars. NHTSA replied to our request for interpretations in early February of this year. Importantly, they agreed that for the purposes of the safety standards, a "driver" in a fully self-driving car can be the self-driving system itself.

While this clarification from NHTSA was a very positive step forward, it does not change the fact that current regulations—including most of the FMVSS—were written at a time when a self-driving car was nothing more than an idea. In certain instances, these current standards are overly prescriptive in ways that could make a fully self-driving car less safe. In situations where the car is safely making 100 percent of the driving decisions, having controls that allow a passenger to change its trajectory or operate turn signals or headlamps—for which manual controls are currently mandated in the Federal standards—may make the operation of the car less safe. As described above, various studies have documented the hazards of having human drivers "switch back" to the task of driving when they are not expecting it. There are also many Federal standards that simply are not needed when a human is not operating the vehicle, such as requirements to include a rear view mirror.

NHTSA's reply to our request for interpretation and its 2017 Congressional budget request both highlighted that "[n]ew authorities may be needed when they are necessary to ensure that fully autonomous vehicles, including those designed without a human driver in mind, are deployable in large numbers when demonstrated to provide an equivalent or higher level of safety than is now available."

We strongly support NHTSA's goals and believe that Congressional action is needed to keep pace with safety technologies being developed by vehicle manufacturers and technology innovators, including fully self-driving cars.

To achieve this goal, we propose that Congress move swiftly to provide the Secretary of Transportation with new authority to approve lifesaving safety innovations. This new authority would permit the deployment of innovative safety technologies that meet or exceed the level of safety required by existing Federal standards, while ensuring a prompt and transparent process.

We look forward to working with this Committee, DOT, and NHTSA to ensure that this type of new authority can effectively achieve the safety and innovation benefits of fully self-driving cars. We also believe that these policysetting opportunities will help continue U.S. leadership on this technology for the years ahead.

Conclusion

In the coming years, we'd like to explore driving in other cities that can teach us about different types of challenging weather and terrain. We'd also like to run pilot

programs to learn what people would like to do with fully self-driving vehicles. If the technology develops as we hope, we'll work with partners to bring this technology into the world safely.

The importance of getting self-driving car technology safely into people's hands is best summed up by those who most need it. During a recent California DMV workshop to discuss the technology, regulators heard from Justin Harford, a man who is legally blind. Justin said: "what this is really about is who gets to access transportation and commerce and who doesn't and I'm frankly tired of people with disabilities not being able to access commerce."

Our team at Google believes that self-driving cars can ultimately remove these transportation barriers from our society. Thank you for your help in creating a path for this technology and for your time and consideration today.

The CHAIRMAN. Thank you, Dr. Urmson.

Mr. Ableson?

STATEMENT OF MICHAEL F. ABLESON, VICE PRESIDENT, STRATEGY AND GLOBAL PORTFOLIO PLANNING, GENERAL MOTORS COMPANY

Mr. ABLESON. Good afternoon. Thank you, Chairman Thune, Ranking Member Nelson, and Committee members, for the opportunity to speak to you on autonomous vehicles and the way they could improve the safety, convenience, and effectiveness of our 21st century transportation system.

My position inside General Motors is Vice President of Portfolio Planning and Strategy, and in that position, I spend a lot of time thinking about what will happen to our industry over time and what opportunities there are and how to position General Motors to take advantage of those opportunities. As you may know, General Motors has been very active in the autonomous space with several recent announcements. All of these are aimed at our goal of earning customers for life by redefining the nature of personal mobility and extending our relationship with our customers beyond the car.

There are four principal areas to this initiative: autonomous driving, connectivity, electrification, and ride sharing. All of these are built on the same bedrock principle: Our top priority must be safety. I'd like to focus my few minutes today on autonomy.

GM has a long history with autonomous vehicle research and, as our recent announcements have shown, is striving to lead in automated driving technologies. From our partnership with Carnegie Mellon University, which in 2007 won the DARPA Urban Challenge by autonomously covering 60 miles at an average speed of 14 miles per hour, to our acquisition last week of Cruise Automation, GM is rapidly redefining personal mobility.

Many of today's active safety technologies, such as full-speed range adaptive cruise control and lanekeeping assist, are steps toward autonomous driving. We are deploying these technologies across more of our portfolio and are also bringing additional safety enhancing technologies like forward collision warning to vehicles at all price points, including inexpensive models such as the Chevrolet Spark.

GM expects to be the first automaker to bring Dedicated Short Range Communications, a vehicle to vehicle safety technology, to market late this year in the 2017 Cadillac CTS. This technology will enable vehicles to communicate important safety and mobility information to one another.

Super Cruise, a feature that allows hands-free and feet-free driving on the highway, will also debut in the 2017 Cadillac CT6. It incorporates many of the camera, GPS, mapping, and radar technologies that will be crucial to increasing automation in the future.

Additionally, our recent investment in the ride-sharing company Lyft complements GM's expertise in autonomous vehicles by providing a ride-sharing platform to support potential deployment programs. Our acquisition last week of Cruise Automation is another important milestone in our work to deploy autonomous vehicles.

Founded in 2013, Cruise has moved quickly to develop and test autonomous vehicle technology in San Francisco's very challenging city environment. Cruise's deep software talent and rapid development capability, when combined with GM's resources and expertise, will further accelerate our development of autonomous vehicle technology.

These efforts inside the company are being spearheaded by a recently formed, Vice President-led engineering team focused on accelerating the deployment of autonomous vehicles. But make no mistake. Our focus will be on doing this safely.

We believe that the next logical step toward public availability of the autonomous vehicles will be controlled ride-sharing projects, such as those we are planning with Lyft. These projects will allow the public to safely experience autonomous vehicles without making a significant financial investment. This could speed public acceptance of autonomous vehicles while, at the same time, protect public safety through the ownership and control of the vehicle fleet by the vehicle manufacturer. This style of deployment also encourages partnership with local and state governments, which will help ensure full public benefit of the technology.

In closing, GM enthusiastically supports policy initiatives to accelerate the development and adoption of safe, high-level automation through real-world projects. We look forward to working with Congress and NHTSA to spur development of these technologies as safely and rapidly as possible.

I look forward to answering your questions. Thank you.

[The prepared statement of Mr. Ableson follows:]

PREPARED STATEMENT OF MICHAEL F. ABLESON, VICE PRESIDENT, STRATEGY AND GLOBAL PORTFOLIO PLANNING, GENERAL MOTORS COMPANY

Good afternoon.

Thank you Chairman Thune, Senator Nelson and Committee members for the opportunity to speak to you today on autonomous vehicles and the way they could improve the safety, convenience and effectiveness of our 21st Century transportation system.

As you may know, General Motors has been very active in the autonomous space with several recent announcements. All of these are aimed at our goal of earning customers for life by redefining the nature of personal mobility and extending our relationship with our customers beyond the car. There are four principal areas to this initiative: autonomous driving; connectivity; electrification and ride sharing.

All of these are built on the same bedrock principle: Our top priority must be safety.

I'd like to focus my few minutes today on autonomy. GM has a long history with autonomous vehicle research and, as our recent announcements have shown, is striving to lead in automated driving technologies. From our partnership with Carnegie Mellon University, which in 2007 won the "DARPA Urban Challenge" by autonomously covering 60 miles of territory at an average speed of 14 miles per hour, to our acquisition last week of Cruise Automation, GM is rapidly redefining personal mobility.

Many of today's active safety technologies, such as full-speed range adaptive cruise control and lane-keeping assist, are building block technologies toward driving automation and autonomous driving. We are deploying these technologies across more of our portfolio and are also bringing additional safety-enhancing technologies like forward collision warning to vehicles at all price points, including inexpensive models such as the Chevrolet Spark.

The sensors, cameras, radars, LIDARs and computer controls required for fully autonomous vehicles are all improving quickly, but will need significant technological advancements before they are ready for universal public deployment.

That said, there are many opportunities to take advantage of much sooner and GM is at the forefront of those developments.

GM expects to be the first automaker to bring Dedicated Short Range Communications, or DSRC, Vehicle to Vehicle safety technology to market late this year in the 2017 Cadillac CTS. This technology will enable vehicles to communicate important safety and mobility information to one another.

Super Cruise, a driving automation feature that allows hands-free and feet-free driving on the highway, will also debut in 2017 on the Cadillac CT6. It incorporates many of the camera, GPS, mapping and radar technologies that will be crucial to increasing automation in the future.

Additionally, our recent investment in the ride-sharing company Lyft complements GM's expertise in autonomous vehicles by providing a ride-sharing platform to support potential deployment programs.

Our acquisition last week of Cruise Automation is another important milestone in our work to deploy autonomous vehicles. Founded in 2013, Cruise has moved quickly to develop and test autonomous vehicle technology in San Francisco's challenging city environment. Cruise's deep software talent and rapid development capability, combined with GM's resources and expertise, will further accelerate our development of autonomous vehicle technology.

These efforts are being spearheaded by a recently formed, vice president-led engineering team focused on accelerating the deployment of autonomous vehicles. One of those executives will oversee autonomous fleets in controlled environments that can provide the deep learning and experience to get us closer to fully autonomous driving.

But make no mistake, our focus will be on doing this safely.

We believe that the next logical step toward public availability of high-level automated vehicles will be controlled ride-sharing projects, such as what we are planning with Lyft.

The lessons from these projects and how these vehicles function in multiple real-world environments will also allow the public to safely experience autonomous vehicles without making a significant financial investment. This could speed public acceptance of autonomous vehicles, while, at the same time, protect public safety through the ownership and control of the vehicle fleet by the manufacturer of the automated driving system. This style of deployment also encourages partnership with local and state governments, which will help ensure full public benefit from the technology.

In closing, GM enthusiastically supports policy initiatives to accelerate the development and adoption of safe, high-level vehicle automation through real-world projects.

I look forward to answering any questions you have.

The CHAIRMAN. Thank you, Mr. Ableson.

Mr. De Vos?

STATEMENT OF GLEN W. DE VOS, VICE PRESIDENT, GLOBAL ENGINEERING AND SERVICES, DELPHI AUTOMOTIVE

Mr. DE VOS. Good afternoon, and thank you, Chairman Thune, Ranking Member Nelson, and members of the Committee on Commerce, Science, and Transportation, for giving me the opportunity to testify on behalf of Delphi Automotive. My name is Glen De Vos. I'm the Vice President of Engineering and Services at Delphi. We're a high-tech company that integrates safer, greener, and more connected solutions for the automotive sector.

We spend more than $1.7 billion annually in engineering development activities and operate major manufacturing and technology

centers across the United States. Delphi's portfolio places us at the center of vehicle evolution and innovation, making products smarter and safer as well as more powerful and efficient.

I would like to start by thanking the Committee for incorporating the Safety Through Informed Consumers, or STICRS, Act into the FAST Act, which was signed into law last year. In particular, I'd like to thank the bill sponsors, Senators Heller and Markey, as well as Chairman Thune and Ranking Member Nelson, for their successful effort to get STICRS enacted.

With the incorporation of STICRS, the FAST Act will speed the adoption of active safety technology, also known as Advanced Driver Assistance Systems, or ADAS, through increased consumer demand. The adoption of ADAS systems is a critical step on the road to automated vehicles since those same systems that will enable automated driving are part of today's active safety systems.

As noted in our video, which we were, unfortunately, not able to show, last year, we made a historic fifteen state, 3,400-mile journey from San Francisco to New York City with a car that, for 99 percent of that driving time, was driven without human input. The drive took place during daylight hours and included an engineer behind the wheel with the ability to assume control if the car encountered a situation where the vehicle could not clearly navigate on its own.

The vehicle performed flawlessly. It was able to make complex decisions necessary to drive safely across the country while, unlike human drivers, remaining alert the entire time.

One of the primary takeaways from the cross-country drive is that we have technology available today in the consumer marketplace that can dramatically reduce deaths and injuries on our roads. These technologies are not just lifesavers but, as demonstrated by that drive, the building blocks for automated cars of the future. This is true both from a technology development as well as from a consumer adoption standpoint. As a recent AAA survey confirmed, ADAS technology will help drive consumer acceptance of vehicle autonomy.

The Committee's inclusion of STICRS in the FAST Act was a major step forward in driving consumer adoption of ADAS. NHTSA has responded and has announced its intention to modernize the New Car Assessment Program to require passenger vehicles to have ADAS systems in order to achieve a five-star rating. This is great progress and should dramatically increase the availability of active safety systems on vehicles at every price point.

It is critical that we capture these safety improvements quickly. STICRS requires NHTSA to promulgate the new NCAP rule within a year of enactment, and it is important that this timeline does not slip.

In an automated future, we need to be able to communicate with not just the driver or the owner, but also the surrounding environment. Knowing when traffic signals are going to change and where vehicle traffic is heaviest not only adds to the safety of the vehicle but allows the cars to be driven or to drive themselves more efficiently. Keeping the necessary spectrum both available and free from harmful interference is critical as V2V and the Dedicated

Short Range Communication, or DSRC, systems that make it possible are rolled out.

It is also important to consider the manner in which existing vehicles can be retrofitted to accommodate DSRC requirements. There are approximately 262 million passenger vehicles registered on the U.S. roadways with an average vehicle age of eleven and a half years. Unless retrofitting is built into the planning process, the rollout of DSRC may take decades.

In addition to supporting technologies that are needed to enable automated vehicles, Congress and the administration and state governments will need to provide the flexibility and the regulatory framework necessary to enable driverless car development and deployment.

Senator NELSON. That's the hazard of not numbering the pages. [Laughter.]

Mr. DE VOS. Or the hazard of not having my reading glasses.

Finally, as we talk about cybersecurity, Delphi is keenly aware of the cyber threats associated with today's connected vehicles and is taking measures that will enable a safe and secure driving experience. We are participating in the Auto-ISAC activities to further improve cybersecurity threats through awareness and coordination across the country.

Delphi's dedicated engineering information and technology resources are focused on cybersecurity matters, and we are working with the NIST, SAE, as well as the OEM community to ensure that we meet their requirements and leverage open source and industry accepted information security protocols.

Thank you again for your time and the opportunity to testify before the Committee today.

[The prepared statement of Mr. De Vos follows:]

PREPARED STATEMENT OF GLEN W. DE VOS, VICE PRESIDENT, GLOBAL ENGINEERING AND SERVICES, DELPHI AUTOMOTIVE

Thank you, Chairman Thune, Ranking Member Nelson, and Members of the Committee on Commerce, Science and Transportation, for giving me the opportunity to testify today on behalf of Delphi.

My name is Glen De Vos, and I am Vice President of Engineering and Services for Delphi Automotive. Delphi is a high-technology company that integrates safer, greener and more connected solutions for the automotive sector. We invest more than $1.7 billion annually into engineering development initiatives. In the U.S., Delphi operates major manufacturing facilities, technical centers, and/or administrative facilities in California, Michigan, Ohio, Indiana, New York, Mississippi and Texas that employ approximately 5,000 people. Delphi's technology portfolio places it at the center of vehicle evolution and innovation, making products smarter and safer as well as more powerful and efficient.

Given our proven expertise with market-leading original equipment manufacturers (OEMs) around the world and our broad automotive systems capabilities, we welcome the invitation to testify.

I would like to take this opportunity to thank the Committee for incorporating the Safety Through Informed Consumers (STICRS) Act into the Fixing America's Surface Transportation (FAST) Act which was signed into law last year. In particular, I would like to thank the bill's sponsors, Senators Heller and Markey, as well as Chairman Thune and Ranking Member Nelson for their successful efforts to get STICRS signed into law.

With the addition of STICRS, the FAST Act will speed the adoption of active safety technology, also known as Advanced Driver Assistance Systems (ADAS), by increasing consumer demand. The adoption of ADAS systems is a critical step on the road to automated vehicles since the same systems that will enable automated driv-

ing are part of today's active safety systems. I will talk more about the importance of these technologies later in my testimony.

Delphi is particularly pleased to testify today about the future of automated driving because the elements of the automated future all fit within Delphi's core strategy of producing products that make cars *Safe, Green and Connected.* To this end, in April of 2015, Delphi completed the first automated vehicle cross-country drive.

I believe many of the lessons learned from that drive will be instructive as Congress and the administration move aggressively forward to make the needed infrastructure and legal changes necessary to make autonomous vehicles a commercial success in the future. Accordingly, I will provide an overview of the cross-country drive, the existing technology that made it possible, and discuss some of the lessons learned from the trip.

Description of cross-country drive

Delphi made history by completing a 15-state, 3,400-mile journey from San Francisco to New York City with a car that, 99 percent of the time, was driving without human input. The drive took place during daylight hours and included an engineer behind the wheel with the ability to assume control of the vehicle if the car encountered a situation the vehicle could not clearly navigate on its own.

Description of onboard technologies associated with drive

Delphi installed a broad suite of our active safety technologies on a 2014 Audi SQ5. The vehicle was equipped with the following technologies:

- *Radar systems:* Our vehicle uses a combination of short-and long-range radars—Electronically Scanning Radars (ESR) and Short Range Radars (SRR) in a 360° configuration. The ESRs specialize in long-range sensing functions, such as adaptive cruise control and cross traffic detection.
- *Vision systems:* The vehicle is equipped with three cameras for vision-based perception: an ADAS camera, a high-resolution color camera, and an infrared camera. The ADAS camera is used for pedestrian, lane, and vehicle detection. The high-definition color camera is used for traffic light detection and the infrared camera provides redundancy for pedestrian and vehicle detection.
- *Lidar:* As opposed to the externally high-mounted, spinning lidars used in many other autonomous platforms, our vehicles use a fused system of lidars which are integrated around the periphery of the vehicle. This approach enables 360 degree coverage, while preserving the aesthetics of the vehicle. The lidars generate a high-resolution point cloud that is helpful for general object detection; particularly in densely packed urban environments. Each lidar is paired with one of our ESRs, which allows us to effectively fuse radar and lidar data.
- *Sensor fusion:* The perception system on Delphi's automated vehicles leverages our experience with multiple sensors through highly complex fusion. Radar, vision and lidar-based sensors each have unique strengths and weaknesses; fusing these sensors allows them to compensate for one another and provide an accurate picture of the driving environment with robust detection of vehicles, pedestrians, and general objects.
- *V2X:* Delphi's automated platforms make use of dedicated short-range communication (DSRC) for collaborative communication with infrastructure, such as traffic lights (V2I), other vehicles (V2V) and pedestrians (V2P). V2X communications provide redundancy that is especially useful in urban environments with numerous traffic signals, vehicles, and pedestrians.
- *Localization System:* Delphi uses precision GPS information for safely traveling through the driving environment; even when the infrastructure is marginal (*e.g.,* poor lane markings). In situations with poor GPS reception, such as tunnels and urban canyons, our vehicles make use of a highly accurate IMU (inertial measurement system) for dead reckoning. Additionally, the environmental sensors on the vehicle can pick out key features of the environment for map-matching.
- *Drive-by-wire system:* The drive-by-wire system featured in Delphi's automated driving platforms is implemented in a manner that preserves the function of the production vehicle's steering and drivetrain. When manually operated, the vehicle drives exactly as a production vehicle would. When auto mode is engaged, the automated system uses the same vehicle input interfaces as a human driver, which allows passengers to directly see and feel how the vehicle is behaving. The automated driving system is completely separable from the stock system, which allows the driver to instantaneously assume full control of the vehicle at any time.

- *Driver State Monitoring:* Understanding the state of the driver is a vital aspect of automated driving. Delphi's automated driving platforms are equipped with state-of-the-art driver state sensing systems, which allow the vehicle to monitor the availability of the driver in situations where a takeover may be necessary. If the driver is found to be unavailable, the vehicle is capable of coming to a stop until it is safe to proceed.
- *Multi-domain controller:* As these active safety systems become more complex and computing technologies consume greater levels of processing power, Delphi's multi-domain controller brings together multiple electronic sub-systems, or domains, within a vehicle into a single, powerful control center. This technology makes it possible for vehicles to quickly and efficiently manage the massive flow of complex data through the vehicle, which is required for automated features to work well.

Some of these same technologies are available on cars today in consumer options such as Forward Collision Warning with Collision Imminent Braking, Lane Departure Warning, and Blind Spot Detection.

A key component of ensuring the vehicle could function was the integration of software and hardware. Vehicle technology is increasingly software based and dependent. If you don't get the software right, the car will not function.

Our vehicle performed flawlessly. It was able to make complex decisions necessary to drive safely across the country while, unlike human drivers, remaining alert the entire time.

Delphi engineers gathered more than two terabytes of data during the trip, including computer data and video footage of everything "seen" by the car. A few observations from our trip:

- Our vehicle was particularly cautious when approaching semi-trucks in adjacent lanes. In situations where our vehicle passed such large trucks, it remained in the center of its lane rather than veering slightly to the far side of the lane. Engineers were able to adjust the programming to address this scenario.
- Artificial intelligence gaps remain that require our attention—such as "which vehicle has the right of way" upon approaching a four-way stop when one vehicle nudges forward to alert the other driver of its intention.
- We noted that HOV lanes are perfect for automated driving since lane markers are very clear. The idea of a dedicated lane may prove useful as automated cars become more mainstream.

Even with the use of radar, cameras, and other sensors, aggressive or speeding drivers can quickly appear during a lane-change, compromising the effectiveness of these technologies.

Lessons learned from the drive provide a foundation for understanding where we need to go from here.

Active safety ready and needed

One of the primary take-a-ways from the success of the cross-country drive is that we have available today in the consumer marketplace technology that, if more broadly adopted, will dramatically reduce deaths and injuries on our roads. Specifically, today's active safety technologies, or ADAS, operate well enough to drive a car on its own—99 percent of the time. These technologies, when paired with a driver, can address one of the greatest causes of premature deaths—traffic crashes.

Every 30 seconds, there is a vehicular fatality somewhere in the world. That equates to 1.2 million people who die worldwide each year. It's a tragedy, and can be prevented. According to the World Health Organization, less than 20 years from now traffic injuries are projected to be the fifth leading cause of death worldwide—surpassing HIV/AIDS, cancer, violence, and diabetes. The impact is not just on lives lost, but on our global economy. Here in the United States, vehicle fatalities have declined with the use and widespread adoption of passive safety technologies such as seatbelts and airbags. However, progress toward further fatality and injury reduction has stalled, allowing over 33,000 fatalities annually in the US, and more than 200,000 serious injuries each year on our roadways. Additionally, vehicular crashes continue to be the number one cause of fatalities for people ages 4 to 34, with over 90 percent of crashes caused by driver error. The financial impact is also staggering, with one study estimating the total annual cost of road crashes in the United States alone to be over $231 billion.

Active safety technologies are the key to reducing crashes, injuries, and fatalities on our roadways. Government and industry groups have studied the benefit potential for these technologies for well over a decade. In particular, a recent study by

the Insurance Institute for Highway Safety (IIHS) states a 31 percent reduction in fatalities is possible with full deployment of active safety systems across the vehicle fleet, namely, Forward Collision Warning with Collision Imminent Braking, Lane Departure Warning, and Blind Spot Detection. This reduction amounts to a potential savings of over 11,000 U.S. lives per year.

These technologies are not just life savers, but, as demonstrated by our cross-country drive, the building blocks for the automated cars of the future. A key element of broader penetration of active safety technologies in the U.S. fleet is consumer awareness and demand.

How the government can help—Modernize NCAP

This Committee's inclusion of STICRS in the FAST Act was a major step forward in driving consumer adoption of ADAS. National Highway Traffic Safety Administration (NHTSA) has responded and has announced its intentions to modernize the New Car Assessment Program, or NCAP—which includes the 5-star rating system that appears on all new vehicle window stickers—to require passenger vehicles to have ADAS systems in order to achieve a 5-star rating.

This is great progress and should dramatically increase the availability of active safety systems on vehicles at every price-point. It is critical that we capture these safety improvements quickly. STICRS requires NHTSA to promulgate its new NCAP rule within a year of enactment of the FAST Act. NHTSA has indicated its intention to meet this deadline, but it is important that the timeline does not slip.

Vehicle-to-Vehicle and Infrastructure (V2X)—a critical element

In an automated future, cars will need to be able to communicate not just with their owner but also the surrounding environment, other vehicles and infrastructure. Knowing when traffic signals are going to change and where traffic is heaviest not only adds to the safety of the vehicle but allows cars to be driven, or drive themselves, more efficiently.

The roll-out of vehicle-to-vehicle and vehicle-to-infrastructure (together V2X) including in-vehicle Dedicated Short Range Communications (DSRC) systems that allow for V2X communication will be critical.

How can the government help? By protecting the needed spectrum and requiring V2X receivers be built into cars in the future

The Commerce Committee has already been active and helpful in negotiating an agreement that will allow the spectrum necessary for V2X to be protected from harmful interference without barring compatible uses. Obviously with any life-saving technology, any disruption in the communication signal from interference cannot be allowed. Keeping the necessary spectrum both available and free from harmful interference is critical as V2X communication systems are rolled-out in vehicles and infrastructure.

The STICRS rulemaking is not the only important policy issue requiring the release of a NHTSA rule. In August of 2014, the Department of Transportation announced it would issue a Notice of Proposed Rulemaking (NPRM) creating a requirement for adding V2V communications capacity to the U.S. light vehicle fleet and minimum performance requirements for V2V devices and messages.

V2X can deliver important safety benefits in the mid-term and is a necessity for wide-spread autonomous vehicles adoption in the long-term. The release of the NPRM will be an important step forward.

In addition, it is important to not only consider DSRC in new vehicles, but also the manner in which existing vehicles can be retrofitted to accommodate DSRC requirements. There are approximately 262 million registered passenger vehicles on U.S. roadways with the average vehicle age being 11.5 years. Unless retrofitting is built into the planning process, the roll-out of DSRC will take decades.

Rules of the road—need to permit driverless cars

In addition to supporting the technologies that are needed to enable automated vehicles, Congress, the Administration, and state governments will need to provide the flexibility necessary to enable driverless cars.

Uniform rules that allow for the safe operation of driverless vehicles in all 50 states will be critical. As production vehicles move from drive assist technology to full automation, varying requirements ranging from state mandates that licensed drivers must be in vehicles at all times, to Federal requirements dictating the positioning of dashboard controls that presume a driver, will need to be assessed and addressed.

Another example would be the need to address the variation in lane markings across states and communities. During Delphi's cross-country drive, the automated vehicle encountered some roadways with wide white stripes, while others had nar-

row yellow markings. Some lane markings were new, others were faded, and some were marked with raised bumps. Delphi will have to further train its cameras to detect all kinds of lane markings, since that's one way autonomous cars keep themselves centered in a lane.

Consumer adoption—public's trust can be earned

A March 1, 2016 AAA survey of American drivers found that only one in five would trust a self-driving car. The same survey, however, found that over sixty percent of drivers would like active safety—or ADAS—technologies on their vehicles. Active safety is clearly going to be critical to the transition to automated driving, not just because the underlying technologies are building blocks for autonomous vehicle but also because consumer acceptance of self-driving cars will develop as driver-assist technologies proliferate.

The bottom line is that the road to driverless vehicles is paved with life-saving drive-assist technologies that will make cars safer now, and into the immediate future, while setting the stage for fully autonomous vehicles.

Cyber security—a key element moving forward

Delphi is keenly aware of the cyber threats associated with today's connected vehicles, and is taking measures that will enable a safe and secure driving experience. Accordingly, Delphi has committed to participate in the Automotive Information Sharing and Analysis Center (*Auto-ISAC*) to further improve cyber security threat awareness and coordination across the industry. The Auto-ISAC provides a forum for information exchange among entities in the automotive industry for the purpose of sharing trusted and timely cyber threat information about existing or potential cyber-related threats and vulnerabilities in light duty on-road passenger vehicle electronics and associated networks.

Delphi considers all aspects of a connected vehicle and associated embedded technology—to include software, hardware, and architectural elements that connect the vehicle. While building products and systems according to OE customer specifications, our technical experts work to better understand vulnerabilities such that we can alert OEs and consumers to potential cyber threats—followed by working towards providing a solution.

Delphi has dedicated engineering and information technology resources focused on cybersecurity matters. To provide further leadership in this area, Delphi is working with several experienced organizations to ensure a coordinated approach to the safety and security of connected vehicles. These efforts are realized through various channels, including (1) active leadership and participation in the National Institute of Standards and Technology (NIST), Society of Automotive Engineers (SAE) and others; as well as working with Original Equipment Manufacturers (OEMs) to ensure that the products we engineer meet OEM specifications, and leverage open source and industry accepted information security protocols.

In addition, Delphi strategically engineers safety into technology. For example:

- Engine Control Units or ECUs—These devices are developed with a secure boot and programming functionality, so only valid and trusted programs and software are executed.
- Encryption—The wireless connectivity is protected using industry standards to protect the vehicle network and user's privacy. This includes security to authenticate and gain access (WiFi Protected Access 2 or WPA2), as well as transmission security across the wireless connection (using TLS or Transport Layer Security) across the broader network and internet.
- Device Connection—Leveraging Bluetooth to connect a user's personal devices, but ensuring that connection is via Secure Simple Pairing (or SSP) which allows for encryption of data between linked devices, thus providing additional security.

Delphi is also working with a number of organizations to ensure a coordinated approach to the safety and security of interconnected vehicles. These include:

- International Organizations: Adoption of ISO guidelines (including ISO 26262) to ensure a standardized approach to enabling a safe driving experience. Active leadership and participation in the Society of Automotive Engineers (SAE), National Institute of Standards and Technology (NIST), and others.
- Original Equipment Manufacturers (OEMs): Delphi ensures that products engineered by the Company meet the OEM specifications, and leverage open source and industry accepted information security protocols.
- Internal Structure and Governance: Delphi has a dedicated team of engineers, technology professionals, and legal professionals to provide the necessary over-

sight in the space of cybersecurity and interconnected vehicles. A steering committee meets regularly and provides appropriate guidance with respect to policies, procedures, and standards. Delphi considers this a very real threat that must be managed.

Pilots—can make a difference

The FAST Act set a great foundation to build towards the roll-out of widely-available automated vehicles. The Obama Administration's announcement of a ten-year, $4 billion effort to "accelerate the development and adoption of safe vehicle automation through real-world pilot projects" through the programs authorized by the FAST Act demonstrates the broad support for moving the U.S. to an automated future. Clearly a coordinated multi-year effort is warranted and we look forward to working with this Committee, Congress and the Administration to make the effort a success.

Federal R&D—is important

Finally, Delphi supports Federal R&D efforts in this area. The ITS program plays an important role in enhancing the government's ability to assess new technologies and lay the foundation for their roll-out. ITS has focused its efforts recently on V2V and V2I roll-out—both important objectives. ITS should place equal importance on needed analysis and research into active safety such as collision avoidance and mitigation technologies that are key building blocks for autonomous vehicles. Both V2V enabled and non-V2V enabled collision avoidance and mitigation technologies will be critical to the success of the driverless car. On-board active safety also has the added benefit of saving lives even before V2V communications technologies reach critical mass in the U.S. fleet. Furthermore, non-V2V systems continue to operate in situations where the vehicle encounters communications interference. On-board active safety should be a priority for the ITS program.

Thank you again for this opportunity to testify before your Committee today. Delphi looks forward to playing an important role on the road to automated vehicles. As we look to a driverless future, we should work to democratize the availability of today's proven technology. Broad scale adoption of active safety will not only lay the foundation for the driverless cars of the future, but will save lives now. Delphi stands ready to assist this Committee as you forge the road ahead in advanced transportation technology, and I'll be happy to answer your questions.

The CHAIRMAN. Thank you, Mr. De Vos.

Mr. Okpaku?

STATEMENT OF JOSEPH OKPAKU, VICE PRESIDENT, GOVERNMENT RELATIONS, LYFT

Mr. OKPAKU. Chairman Thune, Ranking Member Nelson, and members of the Committee, good afternoon. My name is Joseph Okpaku, and I am the Vice President of Government Relations for Lyft. Thank you for the opportunity to testify today on this very exciting and important topic.

My fellow panelists represent all the components required for the successful deployment of autonomous vehicles. You have the auto manufacturers with the expertise in designing and building autonomous vehicles. You have the parts manufacturers whose products will be vital to making these cars run. You have the best engineering minds in the world, who have made it possible for these cars to be safer than human drivers. And you have Lyft, a company perfectly suited to bring this technology to cities and consumers all across the country.

There are at least two other equally important components that will determine the future of autonomous vehicles. The first is the interaction of everyday people with these new vehicles, and the second is the much more unpredictable interface of the Government with this entirely new transportation resource. Lyft has unique experience in these two areas, and this is where I'll focus my testimony.

Lyft launched 4 years ago as the first digital platform that uses a smart phone to allow people to give other people a ride in their personal vehicle. Lyft's goal was to encourage people to give up their own vehicles and instead use the empty seats in a neighbor's car. In order to accomplish this, we knew that certain critical factors needed to be addressed.

First, it had to be safe. Extensive background checks for drivers were a must, followed by unprecedented transparency and accountability for everybody involved in the ride. Innovations that include real-time consumer feedback and automatically e-mailed digital receipts with the ride route, driver name, and driver picture are a key part of the reason for the rapid adoption of Lyft. It's also why 30 percent of our drivers and the majority of riders are women.

Second, the service had to be efficient for drivers to participate. It is easy for a driver to apply to drive on the platform—they can initiate the process from their smart phone—but difficult for them to qualify. Third, for consumers, we knew that a vehicle had to arrive within minutes of pressing a button for it to feel like a good alternative to grabbing your own keys and driving your own car.

In a few short years, these key principles have enabled an entirely new transportation industry to evolve out of preexisting and largely idle resources. By any measure, it is remarkable, and it wouldn't have happened if it wasn't safe, affordable, and convenient.

This rapid evolution of the transportation industry has clearly demonstrated that consumers are increasingly willing to give up the steering wheel and instead have a vehicle arrive at the push of a button. One recent statistic from the University of Michigan clearly underscores this shift in consumer priorities. In 1983, 46 percent of 16-year-olds obtained a driver's license. In 2014, that figure dropped to 24 percent. That's a 50 percent change in something that I was 100 percent certain that I wanted more than anything else when I was 16 years old.

Something very real and fundamental is shifting here. We are on the doorstep of another evolutionary leap in transportation and technology, where concepts that could once only be imagined in science fiction are on the verge of becoming a reality.

The partnership between Lyft and General Motors is based upon the knowledge that autonomous vehicles can bring enormous benefits in road safety, congestion, and public spending on parking infrastructure, just to name a few. This partnership is also founded on the shared understanding that the fastest way to bring these benefits of autonomous vehicles to consumers is via a ride-sharing network like Lyft's.

To be sure, there are very serious challenges to be faced in bringing the full value of autonomous vehicles to market for mass consumption. And the greatest potential obstacle is constrictive legislation and regulations. The worst possible scenario for the growth of autonomous vehicles is an inconsistent and conflicting patchwork of local, municipal, and county laws that will hamper efforts to bring autonomous vehicle technology to market.

Regulations are necessary, but regulatory restraint and consistency is equally as important if we are going to allow this industry to reach its full potential. This is an area where Lyft has vast expe-

rience and has learned very valuable lessons. Three years ago, only one state had issued a regulatory framework for the ride-sharing industry. Today, 30 states have enacted legislation for this industry, with another bill currently sitting on a Governor's desk awaiting signature.

This is the experience that Lyft brings to the table as we embark upon a mission of providing autonomous vehicles to the public. With the help of this body, a dedicated effort to tackle hard questions, and a commitment to ensure that regulation doesn't inhibit innovation, we can succeed. We look forward to working with this committee to ensure that autonomous vehicles can arrive safely and efficiently on America's roads.

I thank the Committee for holding this hearing and for working toward this common goal, and I'm happy to answer any questions that you might have.

Thank you.

[The prepared statement of Mr. Okpaku follows:]

PREPARED STATEMENT OF JOSEPH OKPAKU, VICE PRESIDENT, GOVERNMENT RELATIONS, LYFT

Chairman Thune, Ranking Member Nelson and members of the Committee. My name is Joseph Okpaku and I am the Vice President of Government Relations for Lyft. Thank you for the opportunity to testify today on this very exciting and important topic.

The development of autonomous vehicles is at a pivotal moment. Autonomous vehicle technology has the potential to bring immense benefits to consumers, commuters, city planners, and governments. Lyft is excited to take our extensive experience bringing radical innovation to transportation by way of ridesharing and applying this experience to the world of autonomous vehicles. We are also eager to be a resource for this committee, and others like it that are tasked with developing policy that fosters the growth of the autonomous vehicle industry.

My fellow panelists represent all the components required for the successful deployment of autonomous vehicles: you have the auto manufacturers with the expertise in designing and building autonomous vehicles. You have parts manufacturers whose products will be vital for making these cars run. You have the best engineering minds in the world who have made it possible for these cars to be safer than human drivers. And you have Lyft, a company perfectly suited to bring this technology to cities and consumers all across the country.

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We are on the doorstep of another evolutionary leap in transportation and technology, where concepts that once could only be imagined in science fiction are on the verge of becoming a reality. The partnership between Lyft and General Motors is based upon the knowledge that autonomous vehicles can bring enormous benefits in road safety, congestion, and public spending on parking infrastructure, just to name a few. This partnership is also founded on the shared understanding that the fastest way to bring the benefits of autonomous vehicles to consumers is via a ride-sharing network like Lyft's.

To be sure, there are very serious challenges to be faced in bringing the full value of autonomous vehicles to market for mass consumption, and the greatest potential obstacle is constrictive legislation and regulations. The worst possible scenario for the growth of autonomous vehicles is an inconsistent and conflicting patchwork of local, municipal and county laws that will hamper efforts to bring AV technology to market. Regulations are necessary, but regulatory restraint and consistency is equally as important if we are going to allow this industry to reach its full potential.

This is an area where Lyft has vast experience and has learned very valuable lessons. Three years ago, only one state had issued a regulatory framework for the ridesharing industry. Today, 30 states have enacted legislation for this industry, with another bill currently sitting on a Governor's desk awaiting signature.

Over this period, we have spent thousands of hours meeting with lawmakers, regulators, and law enforcement in order to help craft innovative and appropriate legislation. We've met with the foremost academic minds and industry experts. We've given testimony at hundreds of proceedings. This is the experience that Lyft brings to the table as we embark on the mission of providing autonomous vehicles to the public.

With the help of this body, a dedicated effort to tackle hard questions, and a commitment to ensure that regulation doesn't inhibit innovation, we can succeed.

We look forward to working with this committee to ensure that autonomous vehicles can arrive safely and efficiently on America's roads.

I thank the Committee for holding this hearing and working towards this common goal. I'm happy to answer any questions you may have.

The CHAIRMAN. Thank you, Mr. Okpaku.

Dr. Cummings?

STATEMENT OF DR. MARY ("MISSY") LOUISE CUMMINGS, DIRECTOR, HUMANS AND AUTONOMY LABORATORY; DIRECTOR, DUKE ROBOTICS; PROFESSOR OF MECHANICAL ENGINEERING AND MATERIAL SCIENCE; PROFESSOR OF ELECTRICAL AND COMPUTER ENGINEERING, DUKE UNIVERSITY

Dr. CUMMINGS. Thank you. Thank you for having me back. Good afternoon, Chairman Thune, Ranking Member Nelson, and distinguished members of the Committee. Thank you for the opportunity to appear before you to discuss issues about the future of self-driving cars.

I am the Director of the Duke Robotics Program and Duke University's Humans and Autonomy Laboratory, which focuses on the multifaceted interactions of humans and autonomous systems and complex socio-technical systems. I have conducted driving research

and provided future technology recommendations to automotive manufacturers for more than a dozen years, including Ford, Nissan, Toyota, Google X—thanks, Chris.

I was the Program Manager for a $100 million Navy robotics helicopter that carries the very same sets of sensors that you'll see on many autonomous cars today. I am also currently conducting research for the National Science Foundation on the interaction of self-driving cars and pedestrians.

While I enthusiastically support the research and development of self-driving cars, I'm less optimistic about what I perceive to be a rush to field systems that are really not ready for widespread deployment. Here are a few scenarios that highlight the limitations of current self-driving cars.

The first is operation in bad weather, including standing water on roadways, drizzling rain, sudden downpours, and snow. Coupling these limitations with the inability of self-driving cars to follow a traffic policeman's gestures, especially on a rainy day in a poncho, means that self-driving cars should not really be operating near elementary schools at this time.

Another major problem with self-driving cars is our vulnerability to malevolent or even prankster intent. For example, it is relatively easy to spoof the GPS of self-driving vehicles, which involves hacking into their systems and guiding them off course. Without proper security systems in place, it is feasible that people could commandeer self-driving vehicles to do their bidding, which could be malicious or simply just for the thrill of it.

And while such hacking represents a worst case scenario, there are many other potentially disruptive problems to be considered. It is not uncommon in many parts of the country for people to drive with GPS jammers in the backs of their trunks to make sure no one knows where they are, which could be very disruptive to the system.

Additionally, recent research has shown that a $60 laser device can trick self-driving cars into sensing objects that are not there. Moreover, we know that people will attempt to game and spoof self-driving cars, in effect, trying to elicit or prevent various behaviors in attempts to get ahead of the cars or simply to have fun.

Last, privacy and control of personal data is also going to be a major point of contention. These cars carry cameras that look both in and outside the car and will transmit these images and telemetry data in real time, including where you are going and your driving habits. Who has access to this data, whether it is secure, and whether it can be used for other commercial or government purposes has yet to be addressed.

So given that these and other issues need to be addressed before widespread deployment of these cars takes place, but understanding very much that there are clear potential economic and safety advantages, how can we get there with minimal risk exposure? In my opinion, the self-driving car community is deficient in its testing programs with no leadership that should be provided by NHTSA.

Google X, Chris just told you, has advertised that its cars have driven 1.4 million miles, and I applaud this achievement. But New York taxicabs drive 1.4 million miles in just a little over a day.

This assertion is indicative of a larger problem in robotics in self-driving cars and in drones, which we've discussed before, where demonstrations are substituted for principle testing. Rand says that to verify self-driving cars are as safe as human drivers, 275 million miles must be driven fatality free.

So that means we need a significantly accelerated self-driving testing program, but it is not simply good enough to let these cars operate in California or southern Texas to accrue miles. NHTSA needs to provide leadership for a testing program that ensures that self-driving cars are rigorously tested for what engineers call the corner cases, which are extreme conditions in which these cars will operate.

We know that many of the sensors on self-driving cars are not reliable in bad weather, in urban canyons, or places where map data bases are out of date. We know gesture recognition is a problem. We know humans will get in the back seat while they think their cars are on autopilot. We know people will try to hack into these systems.

Given self-driving cars' heavy dependence on probabilistic reasoning and the sheer complexity of the driving domain, there are many unknowns that these systems will encounter. But there are also many known knowns in self-driving cars that we are aware of that are not being openly tested in a principled and rigorous manner that would be expected in similar transportation settings.

For example, the FAA has clear certification processes for aircraft software, and we would never let commercial aircraft execute automatic landings without verifiable test evidence approved by the FAA. However, any certification of self-driving cars will not be possible until manufacturers provide greater transparency and disclose how they are testing their cars. Moreover, they should make such data publicly available for expert validation.

Let me reiterate that as a professor in the field of robotics and human interaction, I am wholeheartedly in support of the research and development of self-driving cars. But these systems will not be ready for fielding until we move away from demonstrations to transparency and evidence-based testing, including human-autonomous system interaction and sensor and system vulnerabilities in all environmental extremes. To this end, in collaboration with private industry, NHTSA needs to provide much stronger leadership and guidance in this space.

Thank you.

[The prepared statement of Dr. Cummings follows:]

PREPARED STATEMENT OF MARY CUMMINGS, PH.D., DIRECTOR, HUMANS AND AUTONOMY LABORATORY DIRECTOR, DUKE ROBOTICS, PROFESSOR OF MECHANICAL ENGINEERING AND MATERIALS SCIENCE, PROFESSOR OF ELECTRICAL AND COMPUTER ENGINEERING, DUKE UNIVERSITY

Good afternoon Chairman Thune, Ranking Member Nelson, and distinguished members of the Committee. Thank you for the opportunity to appear before you to discuss issues related to the future of self-driving cars in the United States.

I am the Director of Duke Robotics and the Duke University Humans and Autonomy Laboratory, which focuses on the multifaceted interactions of humans and autonomous systems in complex sociotechnical settings. I have conducted driving research and provided future technology recommendations to automotive manufactur-

ers for more than a dozen years including Ford, Nissan, Toyota, and Google X.[1] I was the program manager for a $100 million Navy robotics helicopter that carries sensors very similar to those on self-driving cars. I am also currently conducting research for the National Science Foundation on the interaction of self-driving cars and pedestrians.

While I enthusiastically support the research, development, and testing of self-driving cars, as human limitations and the propensity for distraction are real threats on the road, I am decidedly less optimistic about what I perceive to be a rush to field systems that are absolutely not ready for widespread deployment, and certainly not ready for humans to be completely taken out of the driver's seat.

The development of self-driving car technologies has led to important advances in automotive safety including lane departure prevention and crash avoidance systems. While such advances are necessary stepping stones towards fully capable self-driving cars, going from automated lane changing or automated parking to a car that can autonomously execute safe control under all possible driving conditions is a huge leap that companies are not ready to make.

Here are a few scenarios that highlight limitations of current self-driving car technologies: The first is operation in bad weather including standing water on roadways, drizzling rain, sudden downpours, and snow. These limitations will be especially problematic when coupled with the inability of self-driving cars to follow a traffic policeman's gestures.

Another major problem with self-driving cars is their vulnerability to malevolent or even prankster intent. Self-driving car cyberphysical security issues are real, and will have to be addressed before any widespread deployment of this technology occurs. For example, it is relatively easy to spoof the GPS (Global Positioning System) of self-driving vehicles, which involves hacking into their systems and guiding them off course. Without proper security systems in place, it is feasible that people could commandeer self-driving vehicles (both in the air and on the ground) to do their bidding, which could be malicious or simply just for the thrill and sport of it.

And while such hacking represents a worst-case scenario, there are many other potentially disruptive problems to be considered. It is not uncommon in many parts of the country for people to drive with GPS jammers in their trunks to make sure no one knows where they are, which is very disruptive to other nearby cars relying on GPS. Additionally, recent research has shown that a $60 laser device can trick self-driving cars into seeing objects that aren't there. Moreover, we know that people, including bicyclists, pedestrians and others drivers, could and will attempt to game self-driving cars, in effect trying to elicit or prevent various behaviors in attempts to get ahead of the cars or simply to have fun.

Lastly, privacy and control of personal data is also going to be a major point of contention. These cars carry cameras that look both in and outside the car, and will transmit these images and telemetry data in real time, including where you are going and your driving habits. Who has access to this data, whether it is secure, and whether it can be used for other commercial or government purposes has yet to be addressed.

So given that these and other issues need to be addressed before widespread deployment of these cars, but understanding that there are clear potential economic and safety advantages, how can we get there with minimal risk exposure for the American public? In my opinion, the self-driving car community is woefully deficient in its testing and evaluation programs (or at least in the dissemination of their test plans and data), with no leadership that notionally should be provided by NHTSA (National Highway Traffic Safety Administration). Google X has advertised that its cars have driven 2 million miles accident free, and while I applaud this achievement, New York taxi cabs drive two million miles in a day and a half. This 2 million mile assertion is indicative of a larger problem in robotics, especially in self-driving cars and drones, where demonstrations are substituted for rigorous testing.

RAND Corporation says that to verify self-driving cars are as safe as human drivers, 275 million miles must be driven fatality free. So that means we need a significantly accelerated self-driving testing program, but it is not simply good enough to let self-driving cars operate in California or southern Texas to accrue miles. NHTSA needs to provide leadership for a testing program that ensures that self-driving cars are rigorously tested for what engineers call the "corner cases", which are the extreme conditions in which cars will operate. We know that many of the sensors on self-driving cars are not reliable in good weather, in urban canyons, or places where the map databases are out of date. We know gesture recognition is a serious problem, especially in real world settings. We know humans will get in the back seat

[1] See the attached paper, Cummings, M.L., & J. C Ryan, "Who Is in Charge? Promises and Pitfalls of Driverless Cars." TR News, (May–June 2014) 292, p. 25–30.

while they think their cars are on "autopilot". We know people will try to hack into these systems.

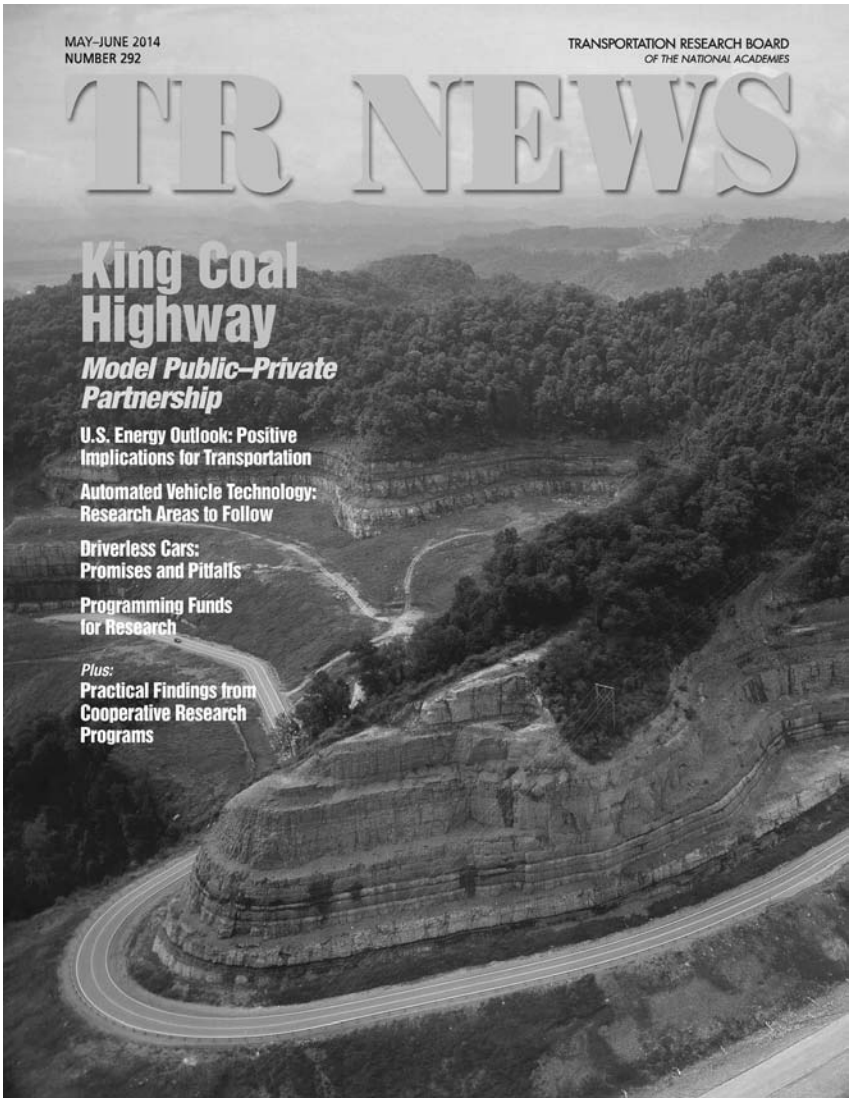
Given self-driving cars' heavy dependence on probabilistic reasoning and the sheer complexity of the driving domain, to paraphrase Donald Rumsfeld, there are many unknown unknowns that we will encounter with these systems. But there are many known knowns in self-driving cars that we are absolutely aware of that are not being addressed or tested (or test results published) in a principled and rigorous manner that would be expected in similar transportation settings. For example, the FAA (Federal Aviation Administration) has clear certification processes for aircraft software, and we would never let commercial aircraft execute automatic landings without verifiable test evidence, approved by the FAA. To this end, any certification of self-driving cars should not be possible until manufacturers provide greater transparency and disclose how they are testing their cars. Moreover, they should make such data publicly available for expert validation.

Because of the lack of safety evidence, I agree with California's recent ruling that requires a human in the driver's seat. However, while I generally support individual state governance on these issues, the complexity of the operation and testing of robotic self-driving cars necessitates strong leadership by NHTSA, which has generally been absent. But as I testified in front of this committee two years ago,[2] the U.S. Government cannot and has not maintained sufficient staffing in the number of people it needs who can understand, much less manage, complex systems such as self-driving cars. So it is not clear whether NHTSA or any other government agency can provide the leadership needed to ensure safety on American roads.

Let me reiterate that as a professor in the field of robotics and human interaction, I am wholeheartedly in support of the research and development of self-driving cars. But these systems will not be ready for fielding until we move away from superficial demonstrations to principled, evidenced—based tests and evaluations, including testing human/autonomous system interactions and sensor and system vulnerabilities in environmental extremes. To this end, in collaboration with private industry, NHSTA should be providing strong leadership and guidance in this space.

[2] "The Future of Unmanned Aviation in the U.S. Economy: Safety and Privacy Considerations", January 15th, 2014.

ATTACHMENT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POINT OF VIEW

Who Is in Charge?

The Promises and Pitfalls of Driverless Cars

M. L. CUMMINGS AND JASON RYAN

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With the move toward driverless cars, including automated driving assistance in the short term, the appropriate levels of shared authority and what the interaction should be between the human driver and the automation remain open questions. How robust driverless cars may be against system failures—including human failures—and operating in degraded sensor environments is unclear; more principled research and testing are needed.

Automation on board vehicles is inherently brittle and can account only for what it has been programmed to consider. Communication between a technically complex system and humans with a varying range of driving and attention management skills is difficult, because the driver must be appropriately informed about the state of the system, including its limitations, and will need to build appropriate trust—neither too much nor too little—in the capabilities of the automation.

Further complicating the problem is that automated systems can lead to boredom, which encourages distraction, as a significant body of research has demonstrated. The operator therefore may be unaware of the state of the vehicle—leading to mode confusion—and may not respond quickly and appropriately in an accident. Over time, the degradation of operator skills as a result of automation can reduce the ability to respond to emergent driving demands and will likely lead to risk homeostasis—the increased tolerance of risk—even in normal operations.

Photo: Dave Jakubiec, Ryan

Automated cars will depend on a complex and changing interaction between technological systems and a human operator.

Tests and Design Considerations

These issues are well-known to the human systems engineering community, but it is unclear whether driverless car designers are considering these issues or whether manufacturers are conducting appropriate human-in-the-loop tests with representative members of the driving population. Until tests show that the vehicles account for these issues, driverless cars will not be safe for unrestricted access and use on U.S. roadways.

Moreover, significant sociotechnical considerations do not appear to be a concern in the push to introduce this technology on a wide scale. The utilitarian approach, quoted by many in the press, is that driverless cars eventually will kill people, but that this is acceptable because of the likely reduction in total deaths. Nonetheless, the likelihood of a reduction is not yet proved. The utilitarian approach demonstrates insensitivity to a deontological perspective—that is, to moral obligations—which causes many people to be uncomfortable about a significant shift of responsibility and accountability from humans to computers.

Driverless or Driver Optional?

Driverless car technologies in development include the ability to navigate roadways, change lanes, observe traffic signals, and avoid pedestrians, without human input. These technologies require Global Positioning System (GPS) information, internal navigation maps, outward-facing cameras, and possibly the use of laser and other range-finding systems—the specifics of the systems vary by company.

The first two of these technologies allow the vehicle to understand where it is in the world, where it should be going, and how to get there; the latter two allow the vehicle to track where it is on the road and where other vehicles, traffic indicators, and pedestrians are. The active cruise control (ACC) systems now in some vehicle models are early forms of this technology; this limited form of autonomy can serve as a forerunner to more advanced systems.

Although termed driverless, the vehicles are better classified as driver optional, particularly under the National Highway Traffic Safety Administration's (NHTSA's) Levels 2 and 3 of automated driving, in which human operators have either primary or secondary control responsibilities (*1*). Although these vehicles supposedly are capable of driving in any traffic situation without requiring the human driver to apply pressure to the pedals, shift, or steer, the driver still may choose to do so and may play a role in avoiding crashes.

In the distant future, the driver will not be needed; the current autonomous driving systems, however, require a human to be in the driver's seat and allow and—in some cases, expect—the driver to assume control at specific points. This is the problem: as long as a human operator has some expectation of shared authority—whether primary or secondary—the design of the automation must ensure that the operator fully understands the capabilities and limitations of the vehicle, maintains full awareness of what the system is doing, and knows when intervention might be needed. Failure to do this may lead to a variety of automation- and human-induced crashes.

Interacting Weaknesses

Google's driverless cars already have logged more than 300,000 miles, with two reported crashes (*2*). One occurred when the car was traveling under manual control on roads not previously mapped into its system (*3*). The actual causal chain is disputed, but the event illustrates the brittleness of automation—the car may not be able to handle uncertainty in its internal model, and this can be exacerbated by human error.

These problems are aggravated by an inherent human limitation known as neuromuscular lag—even when paying attention perfectly, a person experiences a lag of approximately one-half second between seeing a situation develop and taking a responsive action. Instances of human error like this are not the fault of the human alone but of the interaction between the human and the automation and

Photo © Volvo Car Group. Photo: Arrives, SE-405 31 Göteborg, Sweden

Test equipment for a Volvo prototype of autonomous driving support technology includes radar sensors and a camera to control speed, brakes, and steering to help a driver stay in the lane and follow traffic flow.

the weaknesses of each—the human's imperfect attention and execution of a response and the automation's brittleness in perception and in generating a solution.

Although computing reliable accident statistics would be premature, if driverless cars could sustain this crash rate, they would be an improvement over teenage drivers. According to the Insurance Institute for Highway Safety, teenagers are three times more likely to have a crash than drivers age 20 or older.

Lessons from Aviation

The driverless car community can look to aviation for lessons learned from the introduction of automation to relieve pilot workload and—in theory—improve safety. Since the introduction of increasing automation in flight control and navigation systems in the mid-1970s, the accident rate in commercial jet operations has dropped from approximately 4 per million departures to 1.4 (4).

Automation has been key in reducing this accident rate. Nevertheless, many accidents labeled as human error by the Federal Aviation Administration (FAA) and the National Transportation Safety Board would be better categorized as failures of human–automation interaction. These include the following examples:

◆ A faulty indicator light that appeared on final approach caused the 1972 crash of Eastern Airlines Flight 401. Distracted by the disagreement between the warning light and other gauges, the crew failed to notice that the autopilot had been disengaged accidentally. No alert or warning notified the pilots, who focused on the indicator problem and failed to notice that the aircraft was descending steadily into the Everglades.

◆ Air France 447, which crashed off the coast of Brazil in 2009, involved two failures: failure of the automation and a failure of the displays to present information to the operator. A clogged pressure sensor caused the autopilot system to act as if the altitude of the airplane was too low. The autopilot put the aircraft into an increasingly high climb, eventually triggering the stall warning alert. With the aircraft on autopilot, the pilot was distracted and was not fully engaged in monitoring the aircraft; this is a common occurrence. When the stall warning activated, the pilot was not aware of what was happening and made the worst of all possible decisions—he attempted to increase the aircraft's climb angle, which worsened the stall and contributed to the crash.

◆ Northwest Flight 188 overshot Minneapolis, Minnesota, by roughly an hour in the fall of 2009 as a consequence of operator boredom and resultant distraction. With the aircraft on autopilot, both pilots became distracted by their conversation and failed to monitor the aircraft and its status. As they opened their laptops to obtain information to supplement their conversation, they misdialed a radio frequency change, missed at least one text message sent by air traffic control inquiring about their location, and only realized what was occurring when a flight attendant asked about the landing time. Luckily, the result was only a late landing; more severe consequences could have occurred.

PHOTO: ROBERTO MACEDO, TV BRASIL

Wreckage of Air France Flight 447, which crashed in May 2009 off the coast of Brazil, is returned to land at the Port of Recife. The pilot had become distracted and was not monitoring the aircraft while it was on autopilot, leading to a series of actions that stalled the plane and led to the crash.

Attention and Distraction

These issues are common to many other domains involving human interaction with automated systems and are well known to the human systems engineering and experimental psychology communities. In general, the research community agrees that human attention is a limited resource to be allocated, and that the human brain requires some level of stimulus to keep its attention and performance high.

Without this input, humans seek it elsewhere, leaving them susceptible to distraction by either endogenous or exogenous factors. Operators may miss important cues from the automation or from the environment—as in Eastern Flight 401; or they may see the cues but not have all of the information required to make a correct decision—as in Air France 447; or they may use their spare capacity to engage in distracting activities, leading to a loss in situational awareness—as in Northwest Flight 188. An operator also may enter a state of mode confusion and make decisions believing that the system is in a different state than it actually is.

Although these examples and research come from aviation, the role of a pilot monitoring an aircraft autopilot system is similar to that of the human driver in a driverless car. Recent research in human–automation interaction has expanded to automated driving systems and is showing the same

POINT OF VIEW presents opinions of contributing authors on transportation issues. Readers are encouraged to comment in a letter to the editor on the issues and opinions presented.

Photo: SAFFIE Photo & Electrical Connection

Studies on human interaction with automated systems have shown that human attention is limited and distraction common when automation is active.

effects (5, 6). Drivers in an autonomous or highly automated car were less attentive to the car while the automation was active, were more prone to distractions, especially to using cellular phones, and were slower to recognize critical issues and to react to emergency situations, for example, by braking.

In tests, automated systems used at lower average speeds and with greater separation between vehicles yielded benefits, but at the cost of poorer performance by humans in emergency situations (5, 6). In other words, when the automation needed assistance, the operator could not provide it and may have made the situation worse. The operator cannot be assumed to be always engaged, always informed, and always ready to intervene and make correct decisions when required by the automation or the situation. This applies to highly trained pilots of commercial airliners, as well as to the general driving population of the United States and other countries, who receive little to no formal training and assessment.

GPS is essential to help automated vehicles determine routes; if a signal is lost, the vehicle may not function correctly.

Technology Robustness

Much of the development of driverless cars is proprietary, and the exact capabilities of the technologies are not known. This prevents definitive statements about a specific vehicle, but not comments on the limitations of the technology overall or specific questions of concern. Google's autonomous car—generally regarded as the most advanced—relies on four major technologies: lidar, or light detection and ranging; a set of onboard cameras; GPS; and maps stored in the vehicle's onboard computer. The GPS signal tells the car where it is on the stored map and where its final destination is, and from this, the car determines its route. Cameras and lidar help the vehicle sense where it is on the road, where other vehicles are, and where to find and follow stop signs and streetlights.

Each of these systems is vulnerable in some way, and the extent of redundancy is not known, or whether the car will function correctly if any one of the four systems fails. If the GPS or maps fail, the car does not know where it is on its route and where it should be going. If the lidar fails, it may not be able to detect nearby vehicles, pedestrians, or other features. If the cameras fail, the vehicle may not be able to recognize a stop sign or the color of the traffic light. Also not clear is how much advance mapping and how often map updates are required to maintain an effective three-dimensional world model by which the onboard computer makes decisions. Moreover, GPS signals can be unreliable in urban canyons in which tall buildings, tunnels, and other forms of structural shielding cause a lost or degraded signal.

Flaws in the Systems

The security of GPS is questionable. Spoofing or mimicking a GPS signal to provide false location information, as well as jamming or forcibly denying a GPS signal, has been observed by the U.S. military (7, 8) and in civilian applications (9). An individual or group of individuals spoofing GPS signals in major metropolitan areas during rush hour, for example, could force cars off the road, into buildings, or off bridges, or could cause other damage.

Google's researchers admit that they have yet to master inclement weather and construction areas (2). Precipitation, fog, and dust create problems for lidar sensors, scattering or blocking the laser beams and interfering with the image detection capabilities of the camera. As a result, the vehicle is unable to sense the distance to other cars or to recognize stop signs, traffic lights, and pedestrians.

Other research has noted that the technology cannot currently handle construction signs, traffic directors—a task that requires sophisticated recognition of gestures—and other nonnormal driving conditions (2). A related question is how well the system can anticipate the actions of other drivers; avoiding a car calmly changing lanes is entirely different from anticipating the actions of a reckless and irrational driver. Previous research has shown that people are prone to distraction; any failures or degradations in a technology that requires monitoring by humans will increase the likelihood of a serious or fatal crash significantly.

Trust and Skill Degradation

How drivers adapt to the presence and performance of the automation is not a trivial issue. If the automa-

Patric Vanier, DOT

Current automated vehicle technology is not capable of interpreting hand signals and movements of traffic directors and road workers during temporary road work and other irregular traffic conditions.

tion is perceived to be unreliable or not proficient, then the operator refuses to use the system, despite the potential benefits. When automation is perceived as proficient, however, operators rely more heavily on the technology and fail to use their own skills. This leads to a loss of skill and increases reliance on the automation, possibly leading back to mode confusion, as discussed earlier.

Skill degradation from overreliance on automation is a problem in aviation; FAA recently released a safety notice recommending that pilots fly more often in manual mode than with the autopilot. Risk homeostasis is another possible concern—drivers perceive the automation to be more capable and begin to accept more risk; this leads to increased distraction and overreliance on the automated system.

Research into ACC systems already has observed some of these concerns. The 2014 Jeep Grand Cherokee owner's manual states that ACC "is a convenience system…not a substitute for active driving involvement," and the *BMW Technology Guide* notes that "the system is not intended to serve as an autopilot" (*10*). Nevertheless, studies addressing public knowledge of the capabilities of ACC systems show that the public is not fully aware of the limitations of the technology and has a poorly-defined sense of when to trust the autonomy and when driving should be a manual operation. In a series of experiments, many drivers displayed riskier behavior when given the ability to use the limited autonomy of ACC systems, including the failure to shut off the automated systems when conditions were not suitable (*5*).

Providing appropriate feedback to the operator on the performance of the operator and of the automation is crucial to mitigate these problems, but designing a system for appropriate trust is a challenge (*11*). The automation should be capable of describing its performance and its limitations to the driver, who should then be able to learn how best to use the automation in the course of driving. The automation also should be able to sense when the human operator is performing poorly, or even dangerously, so that it can either support the driver or take control. The end result is more of a partnership—each side understanding and accounting for the abilities and limitations of the other.

Sociotechnical Considerations

A common argument in favor of inserting driverless car technology as soon as possible is that accidents and fatalities will be reduced dramatically. According to Google's Sebastian Thrun, "more than 1.2 million lives are lost every year in road traffic accidents. We believe our technology has the potential to cut that number, perhaps by as much as half" (*12*). Although a logical argument in keeping with rational decision-making theory, such a utilitarian approach is not universally shared. A deontological approach could assert that machines should not be allowed to take the lives of humans under any circumstances—which is similar to one of the three laws of robotics drawn up by author Isaac Asimov.

A lower fatality rate is not a guarantee with autonomous cars, particularly at NHTSA Levels 2 and 3, but if the fatality rate is lower than that with human-operated vehicles, the killing of a human by a machine, even accidentally, will not resonate well with the general public. Recent intense media and public campaigns, for example, have protested autonomous weaponized military robots. Similar issues are likely to be raised if driverless or driver-assisted technology is responsible for a fatality or a serious accident that receives intense media attention.

Furthermore, the chain of legal responsibility for driverless or driver-assistive technologies is not clear, nor is the basic form of licensure that should be

Photo: Chris Jaeckel, Ryan

Drivers may overrely on an automated system and fail to shut it off and take control when necessary.

required for operation. Manufacturers of driverless technologies and the related regulatory agencies are responsible not only for considering the technological ramifications but also the sociotechnical aspects, which have not been addressed satisfactorily.

Tenuous Transition

Driverless car technology promises potentially safer and more efficient driving systems, but many questions remain. The robustness of the technology and the interaction between the human driver and the driverless technology are unclear. Boredom and distraction, mode confusion, recovery from automation errors, skills degradation, and trust issues are major concerns and have been observed in experimental and real-life settings. Solutions to these problems will come through proper design, supplemented by extensive testing to confirm that the solutions are having the intended effect.

Manufacturers have not provided any documentation, including extensive, independent, and principled testing, describing how their designs have addressed these issues. Moreover, these issues lie outside the typical tests that regulatory agencies perform in assessing safety. Until these issues have been addressed through independent human-in-the-loop testing with representative user populations, these vehicles should remain experimental. Public- and private-sector organizations alike should develop testing programs, as well as programs to test the reliability and robustness of the core technologies such as GPS and lidar, and should set requirements for driver training, continuing education, and licensure related to these vehicles.

The development of driverless car technologies is critical for the advancement of the transportation industry. The majority of the promises and benefits will likely only be realized when all cars are equipped with these advanced technologies, enabling NHTSA's Level 4 of fully autonomous driving. This is a tenuous period of transitioning new and unproved technologies into a complex sociotechnical system with significant variation in human ability.

In addition, public perception can become a major but surmountable obstacle. Great care should be taken, therefore, in experimenting with and implementing driverless technology—an ill-timed, serious accident could provoke unanticipated public backlash, which also could affect other robotic industries.

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The CHAIRMAN. Thank you, Dr. Cummings.

I think we do have—we can try this. If you want to turn to the monitor there, this is something I think from Delphi and Google.

[Video presentation.]

The CHAIRMAN. Great. Well, thank you again, all of you, for being here and for sharing your thoughts on this subject. We'll get into some rounds of questions now. I wanted to start by just asking kind of a general one, because I think we're talking about something that often was thought of as very futuristic, and there are manufacturers who expect that these cars are going to be on the market in just a few years.

All of you have different roles in this area. But when do you think these types of cars will be ready and available in the marketplace? I'll just open that up to the panel if anybody would like to respond to that. What's the time frame we're talking about?

Mr. ABLESON. From GM's perspective, the way we envision introducing this technology into use in the public is through the idea of a ride-sharing fleet. We think this gives access to a wide part of the public, including underserved communities.

We would introduce it originally as vehicles with drivers, because we do agree we need to collect data and make sure that the systems are operating as we expect them to before we actually start deploying the vehicles without drivers. We think this offers a framework that we can develop and deploy this technology in a very safe way.

To your question on timing, we would expect the vehicles with drivers to appear within the next couple of years, and then when they actually start working without drivers will depend on how the technology develops and what the criteria agreed with the regulators are.

The CHAIRMAN. Mr. Okpaku, how will Lyft's partnership with GM on autonomous vehicles more rapidly advance the future of mobility? How does that bear on the timing question?

Mr. OKPAKU. Sure. Chairman Thune, thank you for the question. I think the starting point for the answer is our experience in the explosion of the ride-sharing industry. A few short years ago, as I mentioned in my testimony, the idea of getting into a stranger's car was pretty much unheard of. It was something that your mother warned you against. And yet through the safety innovations that Lyft implemented, we got people very comfortable with the idea of riding in a stranger's car, and we did so at a scalable rate that allowed us to expand to nearly 200 different cities in less than 4 years.

So it's this ability not only to use innovation to enhance the customer experience and to ensure safety, but to reach a mass audience that we think we will be using to ensure the quick deployment of autonomous vehicles to the community at large. We have the ability to reach a nationwide audience very quickly with our technology.

And, frankly, given the cost that will most likely be involved with the first generations of autonomous vehicles, this will be the most cost effective way of getting it to the public as well. So this is the role that Lyft envisions for itself as part of this process.

The CHAIRMAN. If I could get some of you to react to some of the concerns that were raised by Dr. Cummings. She mentioned weather, hacking, privacy, obviously, the transparency of the test and that sort of thing. When you talk about them not performing as well under those types of circumstances, to those of you who are involved in the development and testing of these things, how do you respond to some of those concerns?

Mr. DE VOS. I think the first thing to know is when we talk about automated driving cars, we're talking about multiple types of sensors, radar, lidar, vision, as well as V2V and V-to-X. So each of those technologies has strengths and weaknesses. In some cases, vision or lidar may be compromised by weather, but radar is very strong in weather and, similarly, with other conditions.

So the key is by having a multi-modal or a multi-sensor approach, you expand your range of coverage and your performance envelope. So it's absolutely true that sensors have strengths and weaknesses, but by combining those sensors, you end up with a much, much more capable package, certainly greater perception capability than an individual driver relying on vision alone.

The CHAIRMAN. Dr. Urmson, in response to a Google inquiry, NHTSA has said that some Federal motor vehicle safety standards will require additional rulemaking in order to allow for Google's self-driving car features. Are you concerned that Google's ability to continue to develop and deploy these technologies will be impeded by NHTSA's need to update its rules through what could be a very lengthy rulemaking process?

Dr. URMSON. Chairman Thune, that's really, I think, an important question, because many of the companies at the table here have been involved in developing this technology, and America is currently very much in a leadership position in this space. With that said, we look at what's happening in Europe, we look at what's happening in China and Japan, and they're hot on our heels. And, in fact, not a day goes by where a company, particularly from China, is not trying to recruit engineers from our team and poach talent.

From our perspective, this technology is advancing at an incredible rate, and we need to see the safety benefits, we need to see the mobility and access benefits, and we need to see the economic benefits in America first. And by finding a way to give NHTSA an approval process that would allow them to expedite in a very safe way innovative technologies in transportation, that will allow us to continue this technology here in the United States.

The CHAIRMAN. And this question could be to the companies that want to respond to this. But NHTSA recently determined that Google's self-driving system could be interpreted as the driver for purposes of NHTSA rules. Conversely, the California DMV has proposed requiring a licensed operator to be present in an autonomous vehicle.

So how will the concept of driver change with deployment of self-driving cars, and how should we resolve potential conflicts such as the one I just mentioned?

Mr. ABLESON. I think to the point of the technology without the driver, at some point, you need to designate the vehicle can operate without a driver. So I think the NHTSA interpretation, in order to

encourage the rollout of this technology, is entirely appropriate. As far as working with the states, we at General Motors will continues to work with the various states to try and craft legislation, understanding the complementary roles that the Federal Government and the states play in this area.

The CHAIRMAN. Do you see the Federal role in all of this, in terms of the way the government plays—or, I should say, having a role when it comes to ensuring that there's a nationwide market? Does the Federal Government have a role in this?

Mr. ABLESON. So what obviously would be an issue for any of us working in this area is if we end up with the states—with a widely varied patchwork of regulation that's inconsistent from state to state. Obviously, we all, when we develop these vehicles, would envision them crossing state lines. So we absolutely need and support NHTSA's initiative to give guidance to the states on legislation in this area and look forward to that initiative and that helping us in working with the states.

The CHAIRMAN. My time is up.

Senator Nelson?

Senator NELSON. We do a lot of neat things to protect the national security—cyber attacks, worms, GPS jamming, et cetera.

Dr. Cummings, what are we going to do to protect this technology?

Dr. CUMMINGS. I think that this problem of cyber physical security is not just unique to drones. It's certainly present in all transportation industries. So I think that there are many lessons to be learned. Certainly, the military is working on some technologies that are helping. There are a lot of companies that are getting into the anti-drone community that are bringing new technologies to bear.

So I think it's a maturity of the industry that we're going to have to see, and it's going to be a multidimensional solution. It's not going to be easy. But I'm hoping that my peers who are at the table—and I'm sure that they will—we're just going to have to start having dedicated focus in these areas instead of just leaving it up to the military, for example, to develop.

Senator NELSON. Well, it's interesting that you mention drones, because tomorrow, in this committee, we're going to mark up the FAA bill. And one of the things that we're concerned about is putting the drone in the flight path of either an inbound or an outbound airliner. If the drone gets sucked into the jet engine, that's a catastrophic failure.

There are technologies available, which have already been demonstrated to the Chairman and me, that take over that drone. And sooner or later, we're probably going to have to employ such technologies in the vicinity of airports.

So what are the needed protections for autonomous vehicles? You saw the *60 Minutes* program where researchers completely take over the car. What's the answer? Anybody?

Mr. ABLESON. So from GM's standpoint, we think cybersecurity is, obviously, an important issue in this area, and it's something that we've spent time thinking about. We have more 4GLTE data connected vehicles on the road by far than any other OEM.

We started an in-house cybersecurity organization. It's the first one and the only one as far as we know in the industry. Inside of that cybersecurity organization, we use a technique learned from other industries, employing a red team that goes in and actively tries to identify vulnerabilities in our systems.

The senior executive in charge of this cybersecurity organization reports on a regular basis to both the CEO and the board on these matters. Jeff Massimilla, that senior executive, also happens to be the Vice Chairman of the Auto-ISAC Committee that was set up to share information among OEMs in the industry on vulnerabilities, and that committee, we believe, has been very effective.

Senator NELSON. So you think that there will be the capability of protecting against cyber threats, even without it being extremely expensive. Let me flip now. What about privacy?—Mr. Okpaku?

Mr. OKPAKU. Yes, Senator Nelson. Thank you very much. Lyft, as I mentioned in my testimony, has to be a safe platform for it to work, and part of that safety is ensuring the privacy of its users and its drivers. It's something that we have been 100 percent committed to since we launched. It's something that we devote an enormous amount of resources to, because we know that our platform involves a lot of people across the country.

We have an internal team that is constantly reviewing our privacy policies. Approximately one-fifth of our overall team constitutes engineers and a similar number of people who are dedicated to trust and safety. So this demonstrates how many resources we dedicate to ensuring the safety and in this respect the privacy of our users.

Senator NELSON. So what you're saying is that technology will allow you to protect people's privacy, even in an autonomous vehicle with all the gadgets in it?

Mr. OKPAKU. Senator Nelson, I think technology is the means that we'll use. But I think it first starts with a commitment and a dedication to ensuring it, and I think that's the point that I'm trying to make here. It's part of the reason that we wanted to partner with a company like General Motors, because we knew of their commitment to ensuring that the deployment of autonomous vehicles had to be done in a way that was safe and protected not only the safety but the privacy of the people relying on these services.

This is something that we've had a lot of experience in over the last three to 4 years, going from a company that serviced just one state back in 2012 to a company that services nearly 200 cities now.

Senator NELSON. Maybe you ought to confer with Apple, since Apple seems to be pretty good on privacy, in terms of being able to get into the iPhone of a terrorist.

Anybody, is the Federal Government's agency, NHTSA, prepared to deal with all this?

Mr. DE VOS. I don't think it's just the responsibility of NHTSA or any one particular part. It really will take a collaborative effort between industry, the technology developers, as well as the regulatory agencies. So it really is important that as we talk about Auto-ISACs and those initiatives, we're working together to promote standardization and a uniform approach, but also to do so in

an effective regulatory framework. So I think the key message for us is it has to be a collaborative activity in order for it to be truly effective.

The CHAIRMAN. Thank you, Senator Nelson.

I have Senator Heller up next.

STATEMENT OF HON. DEAN HELLER,
U.S. SENATOR FROM NEVADA

Senator HELLER. Mr. Chairman, thank you, and thanks for your leadership on this issue. I'm disappointed that I didn't get a chance to see one of the cars earlier this morning. I really would have enjoyed that.

But the Chairman—and, by the way, thank you for being here and for your expertise in this particular area. The Chairman asked the question that everybody was asking, and that's when are these things going to—when will this be available? I guess the next question is: Is it integrated into the current car that you own, or do you have to actually buy an autonomous vehicle in order to use one of these things?

Mr. ABLESON. So we believe very strongly that for some of the cybersecurity reasons that were cited, we need to design a vehicle with this in mind and look at its entire electrical and information system to make sure that we can get the highest level of protection into the vehicle. We believe that going forward, you're going to buy vehicles that may look similar to vehicles on the road, but inside we'll have designed in the cyber protection and the redundancy that autonomous vehicles need to operate safely.

Senator HELLER. So it would be a new car?

Mr. ABLESON. Yes, it would be a new car. And I think that one of the great advantages in applying this ride-sharing model is that we can let members of the public experience the technology without having to go out and buy a new car. So some of the questions about adoption and how people will react to this technology I think we can see with real human beings in real settings, again, without them having to spend money on buying a vehicle.

Senator HELLER. What would you anticipate the price range being?

Mr. ABLESON. I think like any technology, the autonomous technologies are going to be very expensive when you start, because, as was referenced earlier, you need an array of different sensing technologies as well as some pretty sophisticated computing power on board to make it work. It's hard for me to predict what they're going to cost because, as with any new technology, much depends on how quickly we can build to scale and deploy in volume. Again, as Mr. Okpaku explained in his testimony, we think this ride-sharing model lets us move forward in volume, even at a relatively high initial cost of the vehicles.

Senator HELLER. You anticipate to use this with electric engines or combustion engines?

Mr. ABLESON. We think it's very interesting to use this with electric vehicles because of some of the environmental benefits. Obviously, in the ride-sharing model, we'd be operating in urban environments where I think everybody is interested in reducing pollution and the environmental impacts of the automobile.

Senator HELLER. Thank you.

Mr. Urmson, I think Nevada was the first in the U.S. to issue a license for testing of the vehicles for Google. In fact, I noticed on the screen there that most of those shots were on the Las Vegas strip or somewhere near to it.

Dr. URMSON. The Delphi vehicle——

Senator HELLER. Yes, very good. It's my understanding, Mr. Urmson, that you were also very involved with the testing—is this accurate—working directly with the Department of Motor Vehicles in Nevada?

Dr. URMSON. Yes, Senator. That's correct.

Senator HELLER. What was the extent of your exercise in testing?

Dr. URMSON. The state of Nevada wanted to be a leader in this space and passed legislation instructing their Department of Motor Vehicles to create language that would be a first in the Nation kind of rule set for self-driving vehicles.

Senator HELLER. How important was that?

Dr. URMSON. I think it definitely placed a line in the sand, I guess, around how important this technology was and kind of brought it to national attention. At the same time, I think that it kicked off something that I think many of us are worried about with this potential patchwork of state by state regulations that would, you know, potentially lead to a challenge in delivering the technology broadly.

Senator HELLER. Mr. De Vos, also based on what Dr. Cummings said a little bit, you had a vehicle at CES, if I'm not mistaken, and I understand you had an unexpected obstruction there. Can you explain to us what that unexpected obstruction was?

Mr. DE VOS. Sure. One of the reasons we really enjoyed testing in Las Vegas is because it does provide a lot of diversity of use cases in a really challenging environment, including some of the pedestrians that are there in that environment, who may either be intoxicated or maybe a little bit unpredictable in terms of where they're going on the roadways.

So as we were driving around downtown Vegas, on a fairly regular basis, we had pedestrians coming out into the path of the vehicle and the vehicle, of course, seeing them accurately and taking the precautionary measures of slowing down. You know, there's a lot of pedestrian traffic in Vegas, so there were all different points of the vehicle. And it really highlighted to us the fact that the sensors looked all the way around, 360 around that car at all times.

So the car sees much, much better than we as a human driver would actually see. So it never failed to find the person and avoid them.

Senator HELLER. I understand one did step out in front of you and it did avoid that individual.

Mr. DE VOS. It did, yes.

Senator HELLER. Very good. Thank you very much.

Mr. Chairman, thank you.

The CHAIRMAN. That's your home state, and that city would be a good test case for a lot of things.

Mr. DE VOS. It certainly was.

The CHAIRMAN. I have Senator Booker up next.

STATEMENT OF HON. CORY BOOKER,
U.S. SENATOR FROM NEW JERSEY

Senator BOOKER. Thank you very much, Mr. Chairman.

One of the big concerns I've had since coming to Washington is that our global economy is being fueled more and more by innovation, and America is by far the global exporter of innovation ingenuity. We have been for generations in this country.

The problem I'm seeing more and more in Washington is we're not creating a regulatory regime here, an environment that really cultivates and spurs innovation and keeps us competitive. I've seen this with the FDA on inhibiting companies like 23andMe. I've seen this with the FAA and what they're doing with drone technology that now is being investigated and innovated upon more outside of our country than inside of the country. So this is definitely one of those areas where I feel the same significant amount of concern.

My goal, principally, is safety. But in this time of great research, innovation, and development, it's difficult for me to hear companies like Audi say—they describe this current patchwork of rules as an impediment to testing their cars in the U.S. and prefer to continue the testing in Europe. I just don't like to see us falling behind with creating an environment for testing, especially because if we had regulatory regimes like this—I always say if this was around during the time of the Wright brothers, we would have never gotten off the ground in exploring air travel.

So we were the first to introduce legislation trying to permit the testing of autonomous vehicles. But other countries now are clearly leap-frogging over us by offering more flexibility to companies to test this technology. The UK, for example, is rapidly moving forward. Those wishing to conduct tests in the UK are free to drive all over the country. Japan has allowed Nissan and Toyota to test their vehicles there since 2013.

So my question really is: In your experience, are we falling behind because other countries are creating a better regulatory environment for testing? What is the regulatory environment like in terms of dealing with the development of this technology? And what can we, as legislators, do to ensure that our regulations in this space keep up with the pace of innovation? And I don't mean just keep up with the pace of it, but ensure that America leads. I'll open that to anybody.

Mr. DE VOS. I think one of the key things has really already been done, and that's passage of the STICRS Act and the FAST Act, because that really sets the stage for adoption of ADAS technologies, which are foundational for automated driving. So the faster we can deploy that, get the NCAP standards increased, and get that out there, both from a technology and development as well as a consumer acceptance standpoint, that's good for the U.S., and it's good for these technologies, and it builds on success as you do that.

I think the other piece that is important is, you know, in terms of how do you support really standing up or evaluating real-life use cases or proof of concepts or pilots, if you will. And that's what we're seeing other countries doing, is helping support and actually get these systems up and running to learn from them as quickly as possible. That takes infrastructure support. That takes things that, really, the Government is best equipped to help execute and

manage. I think that's another big area where we would really welcome the support of these agencies.

Senator BOOKER. So when you're talking about infrastructure, we're planning smart cities. We're investing in the infrastructure. We need to be thinking five years ahead, 10 years ahead——

Mr. DE VOS. Correct.

Senator BOOKER [continuing]. In terms of the ability for us to have smart devices, smart signs and the like.

Mr. DE VOS. Exactly. The vehicle-to-infrastructure piece of it, the markings on the roadways, basically equipping the infrastructure to be ready for these technologies.

Senator BOOKER. So if we're talking about large investments in infrastructure coming from the Federal Government, we as legislators should be looking into that.

Mr. DE VOS. Federal and state. I think the MCity in Ann Arbor is a good example, where the MDOT and U of M and a number of companies have come together to create a test bed both in Ann Arbor and the surrounding areas, as well as a dedicated test track there on the campus grounds.

Senator BOOKER. Mr. Ableson, you were about to chime in?

Mr. ABLESON. I was only going to say we've been very encouraged by the way that Secretary Foxx has approached this and recognizing that it's important to allow us to work together to develop the technology safely and to find ways to deploy it. So we certainly don't know at this stage of the technology development all the answers, and I think we've seen flexibility to learn as we go and respond to what we learn.

Senator BOOKER. So instead of promulgating rules, trying to imagine what the future is going to look like, shouldn't we just be really focusing on testing right now and rules with a focus on creating a good environment for testing?

Dr. URMSON. Senator, actually, we so far have found that we don't actually have particular challenges with testing, and the technology is advancing very rapidly. Where we're most concerned is about bringing this to market and regulations that would limit the opportunity to use the technology. That's where we think that the Congress and the Federal Government can help pave the way.

Senator BOOKER. Thank you. And I wanted to just give a public thank you to GM for being such a good partner on the spectrum issues. You all leaned in, really, and worked with us in a cooperative manner. That meant a lot to me as a Senator.

Mr. ABLESON. We very much appreciate your support of that issue as well.

Senator BOOKER. Thank you very much.

The CHAIRMAN. Thank you, Senator Booker.

Senator Peters is up next.

STATEMENT OF HON. GARY PETERS,
U.S. SENATOR FROM MICHIGAN

Senator PETERS. Thank you, Mr. Chairman.

I just have to say as a Senator from Michigan and representing the Motor City that I'm very excited about these incredible developments in our auto industry and to see auto manufacturers coming together with suppliers, with technology companies, all cooperating

together to create some partnerships that will ultimately create an awful lot of new jobs and are going to just lead to some extraordinary breakthroughs in terms of vehicle safety as well as performance and, as we've heard from your testimony and others, to deal with some of our mobility challenges, generally, for various individuals.

So I want to thank the witnesses for being here today to discuss this frontier, particularly connected and automated technologies and their lifesaving benefits. Now, we know there are still some significant challenges that we're going to be facing as policymakers in order to actually see this realized. I think it's clear that what we are on the cusp of is disruptive technology in the auto sector probably unlike anything we've seen for I can't imagine how many decades. But it's many, many decades since we've seen this sort of disruptive technology.

As we've heard today—but I think it's really important to repeat—is that we know that over 38,000 people died on our highways last year, and your companies are developing technologies that could very well dramatically reduce that number, savings tens of thousands of lives. That's why I believe that, as members of Congress and my colleagues here, that we have to do everything we can to make sure that your efforts are not delayed or unnecessarily deterred.

That means that Congress has to ensure that the FCC, the DOT, and the NTIA are thoroughly testing any proposal for spectrum sharing in the 5.9 Gigahertz band between the DSR safety critical signals and unlicensed Wi-Fi devices. Connected vehicle technologies should not be compromised by someone connected to a toaster or a light switch.

The technologies of today and tomorrow must be safe from cyber threats and protect users' privacy as well. We must avoid a patchwork of State regulations that will only stunt the development and deployment of these technologies and instead work to implement a consistent national policy. And we must think carefully about the insurance implications as well of connected and automated cars and the possibility of liability shifting to the manufacturers as human control of the vehicles dissipates.

And, finally, we must increase our investment in connected and automated vehicle research and development. I support the administration's 10-year, $3.9 billion proposal for this purpose and, particularly, the $200 million in the DOT Fiscal Year 2017 budget request for funding a large-scale pilot program that will accelerate these technologies.

I think it's particularly essential that a portion of this money go toward funding a designated national facility where academia, industry, and government can all come together to conduct connected and automated vehicle research, testing, product development, and certification. As we've heard, countries like Sweden, Korea, China, and Japan have already established these test sites. We need to do it as well.

I certainly appreciate the comment about MCity associated with the University of Michigan, which is involved in some detailed testing on a track which brings all the manufacturers together. And perhaps I'll just get some comments from some of you as to how

important it is to have a national testing facility that can bring all the manufacturers together, suppliers together, to make sure that all of these technologies actually work together.

It doesn't do any good to have a great product if it's not working in conjunction with the Toyotas and the Hondas and the GMs and Fords and everybody else out on the road and, as was mentioned, in all weather conditions as well. Snow and ice is important to test. But perhaps some of your comments as to how important it is for us as government officials to be focusing on creating a national center where we can do this sort of testing.

Dr. CUMMINGS. Can I address that, Senator? I think that would be great. My one concern would be that the test data was made available to a more academic, slash, expert base community for that validation that these tests are meeting the standards that we think they should.

Senator PETERS. So that should be led by an academic center?

Dr. CUMMINGS. An independent group, not necessarily academic. But, sure, I'd be happy to.

[Laughter.]

Senator PETERS. I take that as you're volunteering. Thank you.

Folks from industry?

Mr. ABLESON. I think to your point, Senator Peters, it's very important that we do find a way to thoroughly test these technologies. As you indicate, it will take a lot of work amongst various companies and suppliers and regulators. So I do think that having a way that we can approach this in a coordinated fashion would be very important to us going forward.

Senator PETERS. Anyone else?

Dr. URMSON. We very much value the opportunity to test in all kinds of weather conditions. That's part of the reason why we've done as much testing as we have in different locations, and we'd certainly love to learn more.

Senator PETERS. Well, I also wanted to pick up from a report that the Department of Transportation just released last week posed to automated vehicles under the current motor vehicle safety standards. The report concluded that many of the standards assume the presence, as you know, of a human driver and for cars that deviate further from this conventional vehicle design, vehicle certification becomes a lot more difficult, dependent on some new standards and how we interpret those standards.

So I would certainly encourage your companies to continue to submit questions for interpretation to NHTSA so that, working together, the automotive industry and government can determine how to address potential regulatory advances, which all of you have expressed we need to have in order to move this technology forward. I also encourage you to share testing data with NHTSA as well to assist them in developing these new national standards for automated vehicle functions.

So perhaps some comments from you as to how you're working now with NHTSA, sharing information. There was a discussion about some new targeted authority for NHTSA as well. If you could elaborate on some of those ideas, I'd appreciate it.

Mr. ABLESON. We continue to work very closely with NHTSA as our regulatory agency. Obviously, being an OEM, we have a very

long relationship with NHTSA. We have worked together collaboratively with them around this topic of autonomous vehicles.

We look forward to learning more on both sides and continuing to work with NHTSA on appropriate regulatory authority, because, as I think we've emphasized many times, we want to develop and deploy this technology safely, and safety is our primary concern, and making sure that we can do it safely is very important to the company before we actually introduce these to the public.

Dr. URMSON. Senator, I couldn't agree more. Safety has to be front and foremost in this, and for the last six years, we've been engaged with NHTSA, sharing our lessons from the road and taking their feedback and incorporating that into our program. We're actually very excited about Secretary Foxx's initiative in building guidelines over the next 6 months and look forward to taking part in the public workshops that will be happening which will, I think, bring a degree of transparency to the process that is important to build confidence in it.

Senator PETERS. Right. Thank you.

The CHAIRMAN. Thank you, Senator Peters.

Senator Klobuchar, then Senator Daines.

STATEMENT OF HON. AMY KLOBUCHAR,
U.S. SENATOR FROM MINNESOTA

Senator KLOBUCHAR. Yes. Thank you very much, Mr. Chairman. In 2014, 3,179 people were killed in distracted driving crashes, and another 431,000 were injured. But right now, too few states are receiving Federal funding. Senator Hoeven and I worked on this. It got included in the FAST Act to make sure states besides Connecticut were able to receive some of the funding for educational efforts on distracted driving. We know these incentive grants are helpful.

Could you talk about what advances in automated vehicles would we need for reducing the incidents of distracted driving? We know it's just a major issue. It's expanding. It's not just kids. It's adults, too.

We just had today in our newspaper on the front page two people hurt—a man killed, getting—he was a school bus driver, 79 years old, and he went out—he lived in a rural area. He was just going out like he did every day to get his newspaper at the mailbox, and it turned out the woman who hit him was doing a text, and, of course, she's been charged with a crime. That just was today, and every single day, there's something like that.

So could you talk about how the automated vehicles—whoever can take it would be helpful.

Mr. DE VOS. I think what that unfortunate and tragic example highlights is the role that ADAS systems can play immediately, basically. With systems like lane departure warning, collision, and braking, and other driver alerts, and then, ultimately, the car taking evasive action, as it gets more and more automated—those are direct countermeasures to the effects of distraction where the driver is not really paying attention to what the car is doing.

That's that immediate safety benefit that ADAS systems that are commercially available now can bring, which is why we're so excited about the implementation of the STICRS Act and getting that

out there into the consumer base. But as you continue down that path, automated driving and the sensors that go with it are what really enable the car to avoid those situations regardless of what the driver is doing. That's the ultimate safety benefit, not just for distracted driving, but all forms of driver-related accidents.

Mr. ABLESON. I think the distracted driving incidents are tragic. But to the point, autonomous vehicles can also address the very large percentage of our accidents that are due to drunken driving or over-speed-related accidents. So there's a very large percentage, over 90 percent, of accidents that are attributable to some sort of driver error, and autonomous systems and automated vehicles should be able to address that in a very substantial way.

Dr. URMSON. Senator, this is really at the heart of why we're engaged in this work. When we look at the 35,000 people that NHTSA estimates were killed last year on America's roads, it's really an unacceptable status quo, and there's so much opportunity to do good here. Now, the technology will never be perfect, but the opportunity to reduce those accidents and those tragedies is incredible.

Senator KLOBUCHAR. Go ahead.

Mr. OKPAKU. Senator, this is one of the key things that we think Lyft brings to the equation. Looking at the issue of drunk driving, specifically, it has now been determined by more than one research project that the advent of ride sharing has significantly reduced the incidents of drunk driving across the country.

The ability to deploy AV technology to the consumers on a mass level is where Lyft really can contribute to this discussion. So by enabling a ride-sharing platform like Lyft, we can bring these safer options to the public at a mass scale and get it ready for mass consumer adoption much quicker than other models could.

Senator KLOBUCHAR. Dr. Cummings?

Dr. CUMMINGS. Sure, but if I can just weigh in here, all of these things are absolutely true. My specialty is human error, so this is definitely something that's going to help address these problems.

I think the real trouble that we're up against is the hybrid time. We're in a very strange time where you're going to see more and more autonomy start to be introduced into cars, and that's actually going to increase people's distraction. Recently, Tesla suffered from one of their drivers getting in the back seat of their car while the car was on autopilot when, in fact, Tesla made it quite clear that you were supposed to be in the seat.

So this is the funny thing about human behavior. If humans just think the car is pretty good, then their behavior is going to be even worse. The best thing that we could do is for everyone to get out of their cars today and have them all be driverless with no steering wheels tomorrow. That would be the safest thing that we could do. But until then, where we have Gremlins on the same road as the Teslas, on the same road as the no-steering-wheel Google car, we're really going to have to be careful about how we set up that human autonomy interaction.

Dr. URMSON. If I may, we've seen this—you know, completely agree with the research. A few years ago, we were at the point where we had technology that could drive well on the freeway. Imagine a product where you get in the car, drive it, put it on the

freeway, press a button, and then it drives for you. We had 140 employees test that capability, and they loved the product. They thought it was fantastic.

I think Larry Burns, a former Vice President to General Motors, has said that for their customers, driving is the distraction, and we saw that live. It really comes down to the fact that at some point, automation technologies are just so good that people over-trust them, even when they're told they shouldn't and have to be there, so, again, why we're taking that leap toward fully self-driven vehicles.

Mr. ABLESON. I would have to add the technologies exist to make sure that if people are going to climb into the back seat or aren't paying attention to the road that the system can warn them and get their attention back on the road.

Senator KLOBUCHAR. OK. And I'll put on the record just another question, because I'm out of time here, about autonomous vehicles and increased mobility for senior citizens, as we're seeing. But I no longer call it a silver tsunami because that's too negative, Mr. Chairman. I've been told by my senior groups to call it a silver surge of more seniors.

[Laughter.]

Senator KLOBUCHAR. So I'll ask some questions on the record later about how there can be some hope for some seniors as well.

Thank you very much.

The CHAIRMAN. Those are good questions, and we're going to be there soon. Actually, this is my neighbor from Minnesota.

Thank you, Senator Klobuchar, by the way, for those questions. This will have great application for people who need an autonomous car to keep them awake until they get to South Dakota as they're driving across Minnesota.

[Laughter.]

Senator KLOBUCHAR. You mean when they're driving through South Dakota to get to Wall Drug.

[Laughter.]

The CHAIRMAN. Senator Daines from Montana.

STATEMENT OF HON. STEVE DAINES, U.S. SENATOR FROM MONTANA

Senator DAINES. Thank you, Mr. Chairman. It's the perfect segway here talking about the big, wide open country we have out West.

Thank you for testifying today. I can tell you, as a guy who was in the technology business for many, many years, it's refreshing to hear about the innovation and the job creation that's actually occurring outside Washington, DC, lo and behold. So kudos.

My home, Montana, is the fourth largest state. We have the second highest rate of vehicle ownership. We've got 75,000 miles of public roads. Ninety-five percent of those are rural. On our interstate highways—generally, you can go 80 miles an hour. That is the speed limit. So I see these autonomous vehicles as having the potential for significant safety improvement. I want to talk through some safety issues and get your comments. They've been addressed a little bit here already.

First of all, driver fatigue. My wife and I were heading out for dinner this weekend, and we saw where the highway patrol was investigating—there clearly had been a rollover, most likely driver fatigue, and it claimed the life of a man from my hometown. Billions of dollars in losses every year—billions of dollars. Thousands of lives lost because of driver fatigue.

How will autonomous vehicles help reduce driver fatigue injuries and fatalities?

Dr. URMSON. Senator, if I may. Well, in our model, they're not driving anymore, and so the issue is mediated. Even in the case of the study that I talked about earlier, where we had 140 people use the vehicles, one of the most touching stories was a woman who lives about an hour and a half from work and commutes every day. She told us that coming in that she wanted to cook for her family and exercise and that she didn't have the time anymore.

She used our car for a week, and she said every day that week, she got home, and she was able to go for a run and cook for her family, because she was not exhausted from fighting traffic. So I think these, what I'll call, maybe the softer elements, the social benefits of this technology, are going to be innumerable and hard to quantify up front.

Mr. DE VOS. We're also developing systems that—you know, for advanced ADAS or for highway pilot or some of these semi-autonomous vehicles, where we look at the driver. We have cameras that look at the driver to sense where the driver is looking. Are their eyes on the road? Are they blinking? Are they shut?

So we can now determine the state of the driver and whether fatigue is a factor, and then take the appropriate countermeasures to either stimulate or re-engage the driver. So those technologies will roll out here toward the end of this year along with that broader suite of autonomous driving capability.

Senator DAINES. And it's probably more the semi-autonomous where we're at here.

Mr. DE VOS. Yes.

Senator DAINES. I appreciate that. That's helpful.

I want to pivot over now and talk about drunk driving, just touch on it a little bit. How will this reduce drunk driving? Let's talk about maybe the semi-autonomous mode here as well. How do we reduce drunk driving injuries and fatalities?

Mr. ABLESON. As you indicated, in the fully autonomous mode, it's a very obvious answer.

Senator DAINES. Yes. How about semi-autonomous?

Mr. ABLESON. Semi-autonomous—there are technologies under development to try and interpret whether a driver is capable of responsibly driving. To be honest, I think at the pace that autonomous technologies are moving, I would hope that we can get to these autonomous vehicles relatively quickly, and they will be a solution for several of these issues around driving.

Senator DAINES. And this is related to drunk driving, too. We had a horrible wrong-way crash on Interstate 94 in eastern Montana that killed three people 2 weeks ago. Thinking about the way that Google is working—maybe this is for you, Dr. Urmson—is there some way it could detect if you are in the eastbound lane of

westbound—to detect a wrong-way situation and prevent it? How would that work? Is that possible?

Dr. URMSON. Yes, I'm quite sure that that's a technology that could be developed. Obviously, we're building vehicles that wouldn't make that mistake. But geo-fencing, geo-modeling kind of technologies, I'm sure, could be in place to help address that.

Senator DAINES. And animal-vehicle collisions. That's another big issue out—actually around the country. Deer populations are up, and out in Montana, it's not just deer. It's also elk and moose as well. It's a little different collision. Again, billions of dollars, hundreds and thousands of deaths, potentially. How can this help reduce animal-vehicle collisions?

Mr. ABLESON. I think, importantly—and reference was made to it earlier—these autonomous vehicles use an array of sensors, not just cameras. And between radar, lidar, and cameras, I think the potential exists that the vehicles could be even more perceptive of when animals are approaching the roadway than human beings are. In Michigan, we have a significant issue with deer on the highway, and I think these sorts of technologies offer a real opportunity.

Senator DAINES. And oftentimes at night, right, when it happens, when they're coming up?

Mr. ABLESON. Absolutely.

Senator DAINES. And as I've taught my kids, you're better off if you don't swerve. It's the swerving that oftentimes results in the significant injuries.

Last, privacy was talked about a little bit here. For Mr. Ableson, we've all heard the stories of current vehicles' operating systems being hacked. There was a famous one from last summer. As the Internet of things continues to grow, this threat becomes ever more real. What is GM doing to ensure consumers' current vehicles are secure?

Mr. ABLESON. As far as cybersecurity, in particular, we have a dedicated organization that spends time on these issues. It is managed by a senior executive in the company. We have learned from other industries on how to approach cybersecurity issues. We employ red teams that are not involved in designing our systems, but only spend time trying to find vulnerabilities.

I would tell you just a week ago, I spent time with one of these engineers who brought in a module and demonstrated to me all the things he did to try and get in and compromise this module. It's really very impressive.

As we said, we also now have an industry group, Auto-ISAC, that shares best practices as well as threat reports and vulnerabilities across the industry. We're very proud that Jeff Massimilla is the Vice Chairman of that group. So we take cybersecurity very, very seriously, and we think going forward the car needs to be designed from the ground up with cybersecurity in mind, and that is our intent.

Senator DAINES. All right. Thank you.

The CHAIRMAN. Thank you, Senator Daines.

Senator Gardner?

STATEMENT OF HON. CORY GARDNER,
U.S. SENATOR FROM COLORADO

Senator GARDNER. Thank you, Mr. Chairman, and thank you to the witnesses for your time and testimony today. I think there has been a lot of great questions today and obviously a lot of interest and intrigue in how this will move forward and what technologies will emerge as a result. The questions, I think, are just the tip of the iceberg here as we all try to figure out and understand how this is going to affect our culture, our society, our innovation, our safety, and our economy.

A couple of things. I think it was around 2005 when auto-steer tractors really became the latest rage in agriculture, a useful economic tool for productivity. Today, based on that over-a-decade-long experience, I think if you want to get down to, say, a 12-inch accuracy in the field, whether you're planting corn or drilling wheat, it probably costs around $7,000 to retrofit an old piece of equipment, a tractor that's 10 or 15 years old or so. To have it down to a 1-inch accuracy, it's probably around $28,000 to retrofit an old tractor that didn't come off the factory assembly line with auto-steer capabilities on it.

If you're dealing with a car that's going down the interstate, though, the question of accuracy is not something that you—well, we had the accident because we had 24-inch accuracy. This is satellite guidance versus radar, lidar, cameras on the vehicle itself. We're not talking satellite in any of these vehicles, correct?

Mr. ABLESON. The vehicles will use GPS, but they also use an array of other sensors and some very high-definition maps to understand exactly where the vehicle is in the world and position itself very accurately.

Senator GARDNER. So as you're rolling vehicles off the assembly line that could have autonomous technologies or capabilities off the factory line, and we retrofit older vehicles to it, how are we going to make sure that—what is the responsible body from a regulatory landscape to make sure that that used car that's 10 or 15 years old that has an aftermarket autonomous system placed on it is up to the same sort of calibration or specifics as a factory line car?

Mr. ABLESON. In our view, for some of the reasons that we've discussed earlier, cybersecurity and safety, we don't see this technology necessarily being applicable as far as retrofitting to vehicles. To do an autonomous vehicle successfully and safely, you need to touch a number of the fundamental systems in the car, you need to design them—redundancy is not here today. So the idea of trying to take that system and somehow retrofit it on an existing car we don't think is practical.

Senator GARDNER. But somebody's going to develop that, don't you think? Just like they did for a piece of farm equipment, somebody's going to figure out how to retrofit an old car, and who is going to be responsible for that?

Mr. ABLESON. As I said, we don't see a path to be able to do that.

Senator GARDNER. OK. The other question I have—is there a state—I mean, a lot of this is the question between Federal and state. Is there a state that's getting it better than some states in terms of allowing this innovation to flourish? And, if so, who is that, and what are they doing that's so good about it?

Dr. URMSON. Senator, I think that is an important question. I think we've seen many states that have expressed enthusiasm about this technology and looking for ways to kind of ensure that the technology will come to their state. What we've found, actually, is in most places, the best action is to take no action, and that, in general, the technology can be safely tested today on roads in many states, and that what we really are looking for is the leadership that Secretary Foxx has announced around—you know, at a Federal level bringing some guidelines for innovation.

Senator GARDNER. I guess the other question would be: Who is doing the best job of not doing anything?

[Laughter.]

Dr. URMSON. I'm sure I don't have a good answer for that.

Senator GARDNER. The other question I have, just out of curiosity more than anything, is the example of the deer. If you're driving down an interstate in Colorado, and you have an animal on the side or perhaps even a child that runs out after a soccer ball or something onto a road—how are we going to address issues of sort of the moral choice that a computer is going to have to make, that a car is going to have to make, whether it veers left, if there's a car next to it, if it veers right into the ditch? Maybe the car itself is carrying passengers, obviously carrying passengers.

How do we address that? How do we research that? How do we study that? How do we make that happen?

Dr. URMSON. Senator, I think this is a very important point. This is a question that humanity has struggled with for hundreds and hundreds of years, and there isn't a right, kind of philosophical answer. So the approach we're taking is to try and reduce this to practice in a way that we can actually implement something and see the broader safety, economic, and mobility values.

So the way we think about this is let's try hardest to avoid vulnerable road users, pedestrians, cyclists, and then beyond that, try hardest to avoid other vehicles, and then beyond that, avoid the things that don't move in the world, and be transparent and say that if you're in this vehicle, this is the way it'll behave, and then you can make the decision—am I OK with that or not? And others may have different judgments about the right way to do that.

Mr. ABLESON. I would only add that I think the intent, as we talked about with the various sensing technologies, is to do absolutely the best we can to make sure these vehicles never get put into those situations in the first place. So, again, with the emphasis on developing these with safety preeminent in our minds, I think there are real opportunities here.

Senator GARDNER. Obviously, in Colorado, we added about 100,000 new residents to the state in 2014–2015. We're the second fastest—depending on what numbers you look at—growing state in the country, 80 percent of that population growth occurring on the front range between Pueblo, Colorado, and Fort Collins, Colorado. This technology, I think, is one of the keys to allowing a thriving ski resort industry up in the mountains where you're limited to the amount of tunnels you can put through a mountain, both from a cost perspective and from a physical—a sort of physics perspective as well.

So I think this is an incredibly fascinating opportunity, and I just look forward to learning more from you as we progress. Thank you.

Thank you, Mr. Chairman.

The CHAIRMAN. There are lots of reasons people are moving to Colorado.

[Laughter.]

Senator GARDNER. And automation is probably a good thing for that.

The CHAIRMAN. We may need more autonomous cars in Colorado for that reason. But, thank you, Senator Gardner.

Senator Markey?

STATEMENT OF HON. EDWARD MARKEY,
U.S. SENATOR FROM MASSACHUSETTS

Senator MARKEY. Thank you, Mr. Chairman, very much.

You know, these new vehicles are computers on wheels. It's absolutely amazing what is happening. I just went out onto the highway, crossed the 14th Street Bridge to 395 in a Tesla vehicle, and I looked right, I looked left, and it was like, "Look, Ma, no hands."

So I'm just driving along down the highway at 11:30 this morning in one of these demonstration vehicles, and it was just absolutely amazing, very impressive. Clearly, we're still at the dawn of the era. But the promise is there, and we can see it, and I'm very glad I took the demonstration this morning.

Back in 2013 and again last year, I asked 20 automakers what they are doing to protect our computers on wheels, and what I found is that they're not doing enough. After reviewing the original responses from the automakers, I released a report, and the report is entitled "Tracking and Hacking Security and Privacy Gaps Put American Drivers at Risk."

Here's what we learned from the study, that thieves no longer need a crowbar to break into a car. They just need an iPhone. Today's connected cars are also collecting tremendous amounts of personal driving information. Cars know where you are, where you've been, how fast or slow you drive, and even the mileage since your last oil change. Some of that is good. Some of it is important to have gathered. But if all the vehicles out there were fully autonomous, and we were all relying upon computers and not a human driver from the start to get to where you are, to get to where you want to go, those vulnerabilities will become more pronounced in our society.

So I just have a couple of questions for the panel. Number one, we need enforceable rules of the road to protect driver privacy and security. I introduced with Senator Blumenthal, the Security and Privacy in Your Car Act, or the SPY Car Act, that directs the National Highway Traffic Safety Administration and the Federal Trade Commission to establish Federal standards to secure our cars and protect our drivers' privacy.

So for each of the panelists, if you would, I would like you to answer this question on mandatory cybersecurity standards, including hacking protection—that means all access points in the car should be equipped with reasonable measures to protect against hacking attacks—data security measures—that means that all collected information should be secure to prevent unwanted access—

and hacking mitigation so that vehicles are equipped with technology that can detect and report and stop hacking attempts in real time.

So, Dr. Cummings, what do you think? Do we need rules of the road that are formally——

Dr. CUMMINGS. I'm in general agreement with all of those issues. But I will tell you as a university professor on the cutting edge of this technology the concerns that I have and that I testified 2 years ago in front of this same committee is that it's happening so quickly that the government institutions cannot keep pace. The government cannot hire the same people that Chris is hiring at Google X. He's got——

Senator MARKEY. No, this would just be to say to the companies, "Build in the hacking protections."

Dr. CUMMINGS. I agree, but I also think that you need a regulatory framework that can ensure this is happening.

Senator MARKEY. And that's what I'm asking. Should we say to NHTSA and to the Federal agencies——

Dr. CUMMINGS. I say yes, but I'm saying I don't think NHTSA, at least today, has the people on the staff that they would need to do that.

Senator MARKEY. Right, and, again, that's the problem with the Securities and Exchange Commission. They had a bunch of lawyers and no economists——

Dr. CUMMINGS. Absolutely.

Senator MARKEY.—to deal with the meltdown that occurred because it had been computerized. They moved to a different trading model. So, obviously, the agencies have to get the technical expertise they need. But it would be important, though, to have the rules if they had the personnel to do it.

Dr. CUMMINGS. I agree, but I think that's a real challenge.

Senator MARKEY. I understand. We have to meet the challenges of the future.

Mr. Okpaku?

Mr. OKPAKU. Thank you for the question, Senator Markey. We at Lyft are not only fully committed to ensuring that we prevent any instances of cyber hacking or violations of our user privacy, but, yes, we are in support of well thought out principles that would codify our previously existing attempts to ensure that.

I think it's important, though—and I know this has been discussed before—that these principles be very well thought out, that there be a consistency of what these principles look like. We're dealing with a technology that is going to be deployed across the country, and in order to do so, we need to make sure that whatever principles are put in place to ensure the privacy and safety of our users—that it's consistent across the country.

Senator MARKEY. I think the Chairman is going to catch up to me. Yes or no? Do we need mandatory standards or not?

Mr. De Vos?

Mr. DE VOS. I think we really haven't determined whether we think we need mandatory standards or not. But what we have determined is that it does help to standardize, standardize in the testing, standardize in the approaching. So the question for us is how do we get there?

Senator MARKEY. Mr. Ableson?

Mr. ABLESON. We support the Auto-ISAC as a way to trade information across the OEMs and suppliers. I think the point of regulation trying to stay ahead of this very fast-changing area—we think a more flexible approach is preferable.

Senator MARKEY. Dr. Urmson?

Dr. URMSON. Google is attacked on a regular basis. We have hundreds of people dedicated to cybersecurity, and what we've learned through that is that it's a very dynamic space, and that it's important to be able to adapt the principles with which you defend over time.

Senator MARKEY. OK. I understand what you're saying. But witnesses sat here 30 years ago and said the same thing about airbags and seatbelts and how they should just leave it to the individual companies, that it was hard to mandate a specific airbag, and it would be very expensive. So I understand the consistency over the decades. But at the same time, people expect airbags to protect their children, and they're going to expect certain standards that are going to be mandated across the board that are going to protect people.

I was hit by a car when I was five, running across the street, and I was chasing two 9-year-olds. I was only five, and I could see how difficult it was for the driver, in retrospect, to know I was going to do it.

But as we're moving forward, we just want to make sure that we don't have unnecessary accidents, you know, and, clearly, hackers are going to have the ability to be able to break into these vehicles. There's going to be a whole bunch of very smart young people who are going to start playing games with this technology going forward.

So the kinds of protections you build in can be voluntary, but if 10 companies do it and 10 don't, then those 10 are going to be identified by the hackers as the ones they're going to be playing games with out on the highways. I just think we need minimal standards that every company is going to meet. I just think the sooner we start the discussion and accept that as a responsibility, the better off we'll be.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Markey.

Senator Blumenthal?

STATEMENT OF HON. RICHARD BLUMENTHAL,
U.S. SENATOR FROM CONNECTICUT

Senator BLUMENTHAL. Thank you, Mr. Chairman, and thank you all for being here. May I respectfully suggest that the answer to the question—should there be mandatory safety and privacy standards—is yes. And I didn't hear that from all of the witnesses.

I heard answers that basically implied, "maybe there should be." But with the clear need, it seems to me, and for the sake of this technology, the answer should be yes, because that's the credibility and faith that you want to establish—that your technology is meeting mandatory standards.

Let me ask Ms. Cummings: Is NHTSA equipped right now to establish those standards, in your view?

Dr. CUMMINGS. No, they are not, in my opinion.

Senator BLUMENTHAL. And in your opinion, should this technology be implemented widely until there are such standards?

Dr. CUMMINGS. No. I think that we need to address these issues before there is wide dissemination of the technology.

Senator BLUMENTHAL. Do any of the other witnesses disagree?

Mr. ABLESON. I would say yes. I want to speak a little bit about privacy, because we talked somewhat about cybersecurity, but from a privacy standpoint, GM is very clear. Privacy is very important. We operate only with an opt-in principle. We operate only where customers know what the data is being used for, and we only retain that data as long as we need to.

Senator BLUMENTHAL. So you agree there should be mandatory standards?

Mr. ABLESON. No. I think that we are operating with privacy as a very important part of how we implement this. I think that we'll continue to work with regulators on what is appropriate.

Senator BLUMENTHAL. You know, I have to say—and I'm not a technology person. I'm just a country lawyer from Connecticut. But if I ask somebody, "Do you think that a red light means stop?" and they came back and said, "Well, you know, let me put it this way, and under these circumstances, maybe, and we have great respect for stop lights, and et cetera," I would say the answer is "yes," because, again, the credibility that this technology has may become exceedingly fragile if people can't trust standards that are uniform and mandatory, not necessarily for you, but for all of the other actors that may come into this space at some point.

So I don't want to belabor this point, but it's one of the reasons why Senator Markey and I have introduced this legislation. And for everyone who says, you know, the private sector companies can do it voluntarily, I would have more trust in that argument if the answer to this question was yes—that we will respect mandatory standards that are applicable uniformly throughout the industry.

I went for a ride today in one of the vehicles that uses the current technology, and it's impressive. It occurred to me, when I heard the comparison between the open spaces of the Dakotas and Minnesota and Montana that I was also driving yesterday in downtown New York, Manhattan, in the midst of a rain storm. I was not driving myself. I was riding, thankfully. And I just don't know how this technology will fare in terms of safety in that kind of environment.

So I would just close by suggesting that there really is a need to develop rules of the road here—standards—and distinctions in spaces to assure the driving public that safety and privacy will be respected.

Thank you very much for being here today, and I look forward to working with you. Thank you.

And I yield to my friend from Massachusetts.

Senator MARKEY. I thank the gentleman.

So can we go down on the privacy issue as well? We dealt with the question of safety. But what about privacy? Do you think there should be a mandatory minimum for privacy protection which is put on the books so that owners have to be made explicitly aware of collection, transmission, retention, and use of driving data, pro-

viding owners the right to say no to data collection without losing access to key navigation or other features and ensuring that personal driving information not be used for advertising or marketing purposes without the owner clearly opting in?

Dr. Cummings?

Dr. CUMMINGS. Yes, Senator Markey. I think these are issues that we're facing across a number of industries and a number of technologies. And the fact of the matter is that these cars are going to be one big data-gathering machine—visual images, telemetry data, all of your personal data. So I see it in a way that once this happens—and, right now, the cars really do need to talk to each other, and they need to talk back to the manufacturers to let them know what's going on.

So for the near term, they need to talk. But they are going to be gathering a lot of data, and it's not clear who is going to be doing what with that data. I, personally, would feel better to know that there was some set of standards in place that were protecting my personal data or at least, like you said, allowed me to know what's happening.

Senator MARKEY. So you think there should be rules that the information can't be used for marketing purposes, being gathered about your driving and using some of that information.

Dr. CUMMINGS. Absolutely.

Senator MARKEY. Do you agree with that, Mr. Okpaku?

Mr. OKPAKU. Senator Markey, thank you for the question. Similar to what Mr. Ableson said, Lyft has very strict policies in place where personal data cannot be used for any other purpose without strict opt-in by its users.

Senator MARKEY. But should it be mandatory?

Mr. OKPAKU. Well, the way I would address that, sir, is that there should definitely be standards. How the standards are developed is really the question. And if I can draw this back to the ridesharing industry, which is where my area of experience is, what we've examined there is that when we first launched, we put upon ourselves a lot of high standards with respect to safety, with respect to privacy, with respect to insurance.

As an example, we developed a whole new type of insurance that provided a million dollars of coverage for all of our passengers. This had not been required by any law——

Senator MARKEY. Let's just take me as a passenger and another 100 people who live in the Boston area, and somebody just wants access to the names of all the people and where they went, using your service. Do you think there should be a privacy protection for that that you're bound by, that you can't sell that information even though people would want to know who was coming into that area? Don't you think there should be an absolute prohibition on your selling the information as to where people are going inside of your cabs?

Mr. OKPAKU. There should definitely be privacy protections. I guess the only point I'm trying to raise is that there are very unique situations that can't always be foreseen in the development of new technology that we need to be mindful of in developing standards for this type of thing, and that's what we've——

Senator MARKEY. Assuming you're already doing the right thing, which is what you're saying, then why would you have a problem with kind of just working to create a standard, then, that could be used across the industry?

Mr. OKPAKU. Well, if you will, sir, that was the point I was going to make, that in Lyft developing these policies internally, we've now seen policies that Lyft and other ride-sharing companies have enacted of their own volition become kind of the standard for the industry. But I think that it is important to make sure of the involvement of the industry to ensure what the appropriate standards were.

Senator MARKEY. And, again, my time is going to run out.

So you've already heard the options here, Mr. De Vos. Yes or no? Mandatory?

Mr. DE VOS. We haven't really taken a position on mandatory. But what I would say is we would like to be part of that discussion to formulate how do you approach it.

Senator MARKEY. But you should first just decide yes or no, though. That would be helpful.

Mr. Ableson?

Mr. ABLESON. We'll continue to work with the regulatory agencies on what we think is required.

Senator MARKEY. So you don't have a yes or no on it, then, in terms of mandatory minimal privacy standards.

Mr. ABLESON. I believe we fulfill——

Senator MARKEY. I know you do, but all the bad companies out there that aren't as good as your company. That's what I'm saying. You know, we don't pass murder statutes for our mothers. They're not going to murder anybody. Can we do it for the people who we think might murder people? So you need kind of a minimal standard.

So assuming your company never does anything wrong, you still need a statute for people who might do things wrong. So you don't think we need that statute?

Mr. ABLESON. Senator, we'll continue to work with——

Senator MARKEY. OK. Good. I appreciate that.

Dr. Urmson?

Dr. URMSON. Google has a variety of policies that we use around privacy. It's foundational to our business, and we're very public in trying to——

Senator MARKEY. What do you think about making that foundation a standard, though, that would have to be met statutorily?

Dr. URMSON. I would have to submit an answer for the record on that. I'm not in a position to comment on that for Google.

Senator MARKEY. Again, I think, ultimately, yes is the right answer so that there's a minimal standard, and, hopefully, we'll reach that day.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Markey.

And there is no requirement for the panelists to agree with him. [Laughter.]

The CHAIRMAN. So you can answer the question any way you want.

I just have a couple of questions to sort of close things out. One has to do with this whole issue of consumer acceptance, because this is a very new technology, and any time a new technology comes onto the market, you have consumers who may welcome that technology because it's new and exciting and it affords a lot of, in this case, mobility benefits that I think people would find very valuable and certainly not met by traditional cars.

But then you've got other consumers who prefer the look and feel of traditional driving and may resist autonomous vehicles because they have reservations about giving up control of the car. So I guess I would just say from the consumer standpoint, what are the biggest challenges that you see in terms of spurring demand, if you will, for autonomous vehicles?

Mr. ABLESON. I think what's important is to get the technology exposed to a large part of the population, including some of the underserved communities we talked about earlier. We think that deploying this technology in this ride-sharing model allows us to do that in a very effective way, where, again, we'll do it in a very safe way, but people don't need to purchase an autonomous vehicle to get their first experience with the technology. I think, like with all new technologies, as people gain experience with it, they'll get more comfortable with it.

Mr. DE VOS. I would add the AAA report that was on—you know, are people ready for automated, where it showed that the minority were. It also showed, though, that ADAS systems are really helping prepare and lay that groundwork and gain consumer acceptance of those technologies. That's why we think it's really important that we have a broad application of ADAS technologies for the safety benefit, but also for the consumer acceptance piece of it.

Dr. URMSON. Senator, our experience is that when someone first hears about the idea of a self-driving car, it comes across maybe alien and very, you know, far out there. And, without fail, when someone comes in thinking that this is all smoke and mirrors or that this is never going to happen, within about 5 minutes of riding in one of our vehicles, they're in the back, on the cell phone, as if this was any other day.

I think part of it is that people are so used to riding in vehicles that have been driven by someone else, whether it's their parents or their loved ones. So I think having people have the chance to experience it will increase adoption very quickly.

The CHAIRMAN. And just as a follow up to that, during your tests, what have been the reactions of people, consumers, who have ridden in self-driving cars? Do they feel safe? I mean, you indicated that you feel like they have an experience that—it seems like it would be initially a little bit hard because of the instinct that you want to control things.

Dr. URMSON. We've done some studies of this, and what we find is the first 5 minutes is a little tense. You know, this car is driving itself. And then in 10 to 15 minutes, it feels like it drives pretty well, and 15 minutes on, you know, it drives better than me is their impression. So we're fairly confident that once people try it out, they're going to enjoy it and really appreciate the value.

The CHAIRMAN. Mr. De Vos?

Mr. DE VOS. One of the other comments we get frequently is people say it's kind of boring. They basically say it's not that exciting. The cars don't accelerate harshly or slam on the brakes. They obey the traffic laws, and very quickly the ride becomes—you know, the driving is no longer the activity that you're focused on. You're focused on whatever it is you're doing.

That's exactly what we want the technology to bring. It's not about the drive. That just fades away into the background, and it's about doing whatever it is you really need to do or want to do during that time.

Mr. OKPAKU. From our perspective, sir, in order to make sure that this is readily available for the consumers at large, it has to be safe, it has to be convenient, and it has to be cost effective, and this is where Lyft really thinks it can help in making sure that all of those three factors are met in deploying this technology to the people at large. This is essentially the same challenges that Lyft faced a few years ago when launching a purely peer-to-peer platform, and that idea was considered fairly out there at the time that we brought that product to market. And as I mentioned before, a few years later, it's already become probably one of the most popular modes of transportation today.

So in order to really ensure that consumers are ready to adopt this, we need to convince them that it's safe, which I think everyone here is committed to doing. And in order to make sure that it is cost efficient, I believe that a ride-sharing platform like Lyft must be involved.

Dr. CUMMINGS. Senator Thune, I'd like to add just one thing, and this is really a critical point. Timing is everything. There is no question that someone is going to die in this technology. The question is when, and what can we do to minimize that.

I think I speak for many people in the robotics community to say we are strong advocates of this technology, but if a death, a fatality, were to occur soon, at the wrong time, it could really set back the integration of this technology, which I fully think will help prevent those deaths on the road. So that's why I think we're very—we, being many academics in this community, are very concerned that we do want the safety testing data out there so that an accident that could have been prevented did not happen.

The CHAIRMAN. Well, thank you all very much. This has been very helpful. In just looking at the technology, it seems like there's enormous potential there on so many levels, and first and foremost, of course, is safety. If we could reduce by any amount the number of fatalities we have on America's roadways in a given year, that would be a remarkable accomplishment.

But I think in terms of the economic and the gains in productivity, quality of life, environmental, congestion, all these things that we talk about in our society today, it seems to me at least that we could have enormous benefits, but always, of course, with an eye toward the safety and making sure that we're doing things in the right ways.

One of the questions that's been raised a lot today, as many of you responded to, is the issue of cyber attacks, hacks, and that sort of thing, and cybersecurity, and measures being taken, and I think that's something that people will inevitably raise a lot of concerns

about, given just the overall cyber threats that we face in the world today. So, certainly, with autonomous vehicles, there's going to be no exception.

And I'm interested in some of the responses that you all gave to that question, because I think it's—and, particularly, some of it, too, with redundancy that's built into the vehicles, any types of gaps that occur if there were some sort of disruption in the connectivity—I mean, it sounds like you've given a lot of thought to this, and there has been a lot of testing and a lot of research already done.

So we encourage that and want to continue it and want to make sure that we do our job to ensure that it's done in the safest manner possible, but not in a way that inhibits or imposes any kind of a barrier or impediment to what we think is something that has tremendous upside and tremendous potential for the American economy and for the safety of our Nation.

So thank you all for making your time available to us today and for your thoughts and insights. We look forward to continuing the conversation about this, and the sky seems to be the limit, so to speak, in terms of where we can go with this. So thank you all very much.

I would just conclude that the hearing record remains open for 2 weeks, during which time Senators are asked to submit any questions for the record, and upon receipt, the witnesses are requested to submit their written answers to the Committee as soon as possible.

Thank you all very much. This hearing is adjourned.

[Whereupon, at 4:33 p.m., the hearing was adjourned.]

A P P E N D I X

HARMAN
Stamford, CT, March 22, 2016

Hon. JOHN THUNE,
Chairman,
United States Senate Committee on
Commerce, Science, and
Transportation,
Washington, DC.

Hon. BILL NELSON,
Ranking Member,
United States Senate Committee on
Commerce, Science, and
Transportation,
Washington, DC.

Dear Chairman Thune and Ranking Member Nelson,

HARMAN was very pleased to see the Senate Committee on Commerce, Science, and Transportation participate in the important dialogue between government and industry about a future with connected and autonomous vehicles. HARMAN is an industry leader in connected car technology, working every day at the industry's cutting edge to create the technology that ensures a safe and enjoyable driving experience.

Autonomous and connected vehicle technologies are at the forefront of innovation and pose many benefits in the public interest. Like many of those who testified, HARMAN is eager to work with the government as it develops a regulatory framework that fosters innovation and growth.

As autonomous vehicles inch closer to market, we agree that safety and privacy are things that should be taken very seriously by everyone involved. This commitment to cybersecurity and customer privacy is evidenced by our recent acquisition of TowerSec, the leading automotive cybersecurity firm. We have also implemented a robust multilayered automotive cybersecurity architecture that outlines the best practices in designing security features across the critical points of vulnerability in the connected and autonomous cars. HARMAN's leadership in these areas have received numerous industry accolades including the Business Intelligence BIG Innovation Award for automotive sector and the industry analyst firm Frost and Sullivan award for product innovation in cybersecurity.

In addition to software security, a safe driving experience on the road naturally dominated this Senate hearing. We understand that safety is the foremost concern for lawmakers in an autonomous car future. However, HARMAN has developed numerous technologies that improve driver safety, not in the near future, but today. HARMAN's camera-based vision technologies, advanced navigation capabilities, pedestrian detection solutions, and head-up display products are all designed to help enrich the safety experience in the car while minimizing driver distraction. In addition, our company develops software that allows for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2X) communication. HARMAN's secure communications technology serves as the vehicles central nervous system, broadcasting and collecting surrounding information to ensure increased road safety. This technology has a more immediate impact on road safety and the standards currently being crafted for this technology should foster further innovation and product deployment.

HARMAN is very excited to play a role in the innovative work being done in this field. It's a pleasure to see that the Senate and those in government have an interest in working with the industry to allow for meaningful and safe innovation.

Sincerely,

PAULA DAVIS,
Vice President, Corporate Affairs
and Communications.

NATIONAL FEDERATION OF THE BLIND
Baltimore, MD, March 22, 2016

Hon. JOHN THUNE,
Chairman,
Senate Committee on Commerce,
Science, and Transportation,
Washington, DC.

Hon. BILL NELSON,
Ranking Member,
Senate Committee on Commerce,
Science, and Transportation,
Washington, DC.

Dear Chairman Thune and Ranking Member Nelson:

I write on behalf of the National Federation of the Blind (NFB), the Nation's oldest and largest organization of the blind, to thank you for conducting last week's hearing on autonomous vehicles. It was my great privilege to attend the hearing last Tuesday afternoon and listen to the five witnesses as well as the insightful questions posed by members of the Committee.

As a blind husband and father, the prospect of being able to drive using an autonomous vehicle excites me. I am not inclined to ask my wife and son to cart me around wherever I need to go. My blind colleagues in the NFB feel the same way. You should know that I am not writing to express a mere pipe dream.

At Daytona International Speedway, on January 29, 2011, just before the start of the 2011 Rolex 24 at Daytona, the National Federation of the Blind conducted the Blind Driver Challenge. Mark Riccobono, who is now President of the NFB, became the first blind person to independently drive a car on the racetrack. We were pleased that Congressman John Mica of Florida was able to participate in the festivities of that historic day, and we believe that his position on the House Committee on Transportation and Infrastructure will be helpful in our continuing dialogue with Congress on this topic. Last week's hearing was a positive step. However, we expect that in the midst of all of the excitement about expanding opportunities for people with disabilities through the proliferation of autonomous vehicles, Congress and the private sector will engage the disability community.

We anxiously anticipate the day that all blind people will have the opportunity to drive independently, and we believe that autonomous vehicles will make this day possible. This is why the National Federation of the Blind has done more work related to including blind people in the class of drivers than anybody in the disability space. As blind people, we know that we can live the life we want, and that with effort and American ingenuity we can transform dreams into reality. We know that blind people have the capacity to act with the controls under our hands including when those controls are installed in autonomous vehicles.

Please do not hesitate to contact us with any questions you have about our experience and expertise in this area. We look forward to working with Congress in the near future, as we endeavor to expand opportunities for blind people with regard to an activity that most believe impossible for the blind. Thank you again for your attention in this important matter.

With kind regards, I am,

Sincerely,

PARNELL DIGGS, ESQ.
Director of Government Affairs,
National Federation of the Blind.

STATEMENT FROM SECURING AMERICA'S FUTURE ENERGY (SAFE)

About Securing America's Future Energy

Securing America's Future Energy (SAFE) has been leading efforts to improve U.S. energy security for economic and national security reasons for over a decade, led by retired four-star military officials and leading business CEOs on its Energy Security Leadership Council. SAFE's policies include increasing domestic production of oil and gas while breaking oil's monopoly over the transportation sector, which accounts for over 70 percent of all oil consumption in America. Last year, SAFE formed an Autonomous Vehicle Task Force—comprised of business, technology and policy leaders—to advise it on the transformation currently underway in the transportation sector and had actively started working in this space. SAFE recently testified at the California DMV hearings and is also completing a National Strategy with specific recommendations on autonomy for our CEOs and military leaders to be issued on May 19.

Autonomous transportation could bring about the most dramatic transformation in society in the last 100 years. This shift could deliver unprecedented benefits by unleashing trillions of previously non-productive hours, addressing the dramatic un-

derutilization inherent to the current vehicle ownership model, significantly curbing the more than one million traffic fatalities annually worldwide [1], providing mobility and freedom to the disabled and elderly, and securing dramatic reductions in oil demand through efficiency and fuel diversification. It is the goal of SAFE to make sure that we are cognizant of the national interest as opposed of the interest of one company or industry over another, and to not allow incumbents to slow the advancement of critical technology down through regulatory mechanisms in the guise of safety or for other reasons.

Benefits of technology

Key benefits of autonomous vehicles will include:

Energy Security: Studies, including our own internal modeling, demonstrate the potential for autonomous vehicles to reduce petroleum dependency. Autonomous vehicles will allow more efficient operation, reduce congestion, and will encourage the economic and technological case for Advanced Fuel Vehicles. Morgan Stanley estimated that U.S. fuel savings would be $150 billion annually before even taking into consideration fuel economy improvements.

Safety: Preliminary data shows that even as effective advanced safety technologies become more prevalent and reliable, motor vehicle related accidents rose over 8 percent in 2015. The total social and economic cost of vehicle crashes is estimated to be over $800 billion per year. Autonomous vehicles have the potential to avoid or mitigate many, if not most, of the 93 percent of crashes which are caused by human error.

Mobility Access: By 2050, the number of Americans older than 65 will approach 90 million, more than double today's number. Studies show that as Americans enter their 70s and 80s, their travel is sharply reduced in large part due to age-related infirmities. Autonomous vehicles can provide mobility, independence and dignity, to older Americans, and better integrate them into the economy.

Similarly, the disabilities community could be transformed through better access to mobility. According to the U.S. Census Bureau, the labor force participation rate for individuals with an ambulatory disability is only 25 percent, compared to 75 percent for the broader population.

Harvard economists have found that access to efficient, quick, and reliable transportation significantly improves the odds of individuals lifting themselves out of poverty.

Current technology status

While it has long been possible to automate some of a vehicle's function (*e.g.,* cruise control), the last few years have seen an increasing focus on the potential to deploy highly automated vehicles to the public. New entrants to this space who are outside the auto industry have been particularly influential. Google began to work in this space in 2009 and of January 2016, the company has tested more than 1.4 million autonomous miles.

Traditional automotive companies sense a competitive threat have not ignored this important trend. By now, most have now announced autonomous vehicle development activities, although they differ in whether they are aiming for "full automation" where the driver is rendered unnecessary, or using autonomous vehicles as a "backup driver" to improve safety. Some automakers are experimenting with new business models such as carsharing and other mobility on-demand services, while others believe that personal vehicle ownership will remain the near-exclusive paradigm for most Americans for decades to come.

SAFE Activities in this space

Regulatory Process: SAFE's Autonomous Vehicle Initiative advocates for policy framework which does not impede with the deployment of autonomous vehicles and that the regulatory process is reformed so that it can respond quickly to an increasingly changing technology environment.

SAFE and several representatives of the Autonomous Vehicle Task Force participated in a workshop with the California DMV on regulations for the deployment of autonomous vehicles. SAFE, in conjunction with its Task Force and a network of external experts, is engaging California and offering resources for the creation of deployment regulations.

Communications: SAFE has been educating the public and activating a broad range of constituents through a coordinated media campaign on autonomous vehicles. Articles written by or quoting SAFE affiliated experts include

[1] *http://www.who.int/gho/road__safety/mortality/traffic__deaths__number/en/*

- SAFE Announcement: "SAFE Launches Autonomous Vehicle Task Force to Advance U.S. Economic and National Security"
- Detroit News: "Self-driving cars put the 'auto' in automobile" (opinion by Mike Granoff, SAFE Autonomous Vehicle Task Force member)
- USA Today: "Toyota, new task force could boost non-gas options" (news), also appeared in Detroit Free Press here
- Detroit News: "Group launches task force to speed driverless cars" (news)
- Green Car Congress: "SAFE launches Autonomous Vehicle Task Force" (news)
- The Hill: "Regulators: Don't Slam the Brakes on Driverless Cars" (opinion by Robbie Diamond)
- SAFE Reaction: "Autonomous Vehicle Task Force: Latest California Regulation for Driverless Cars Will Stalemate Progress, Send Innovation Elsewhere"
- SAFE Reaction: "SAFE CEO: DOT Regulations for Autonomous Vehicles Should Leave a Wide Berth for Innovation, Improvements in Efficiency and Safety"
- Cleantechnica: "Do Driverless Cars Need Drivers?" (opinion by Rutt Bridges, SAFE Autonomous Vehicle Task Force member)

Coalition Building: SAFE is organizing both industry players and broader stakeholders to create consensus positions around autonomous vehicles. SAFE is organizing stakeholder groups and business interests who are potentially impacted by autonomous vehicle deployment.

SAFE Positions

Don't Let Regulations Stifle the Technology: SAFE is actively promoting this message in response to California proposed autonomous vehicle regulations, which is an example of steps governments should not take. Government should allow the deployment of fully autonomous cars so long as they are demonstrably safe and the private sector is willing to deploy them.

Government Role: The government's role is important but should be limited to ensure that policies advance, not impede innovation and progress of these technologies. Policies will be important to ensure that adoption is carried out smoothly and safely.

There is a need for some government spending to create a regulatory framework and speed adoption, but not a major, multi-billion dollar spend. The private sector is capable of investing in development of the technology and there are strong incentives for it to do so.

Energy Security and other social benefits: Market-based mechanisms should encourage the use of autonomous vehicles to achieve social benefits such as increased mobility for older Americans, Americans with disabilities, and lower-income Americans. Primarily among those benefits is the energy security benefits of autonomous vehicles. Autonomy has the potential expedite the end of oil dependence.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN THUNE TO DR. CHRIS URMSON

Question 1. At the hearing, we discussed a number of potential benefits and opportunities offered by autonomous vehicles, including increased safety, mobility, and efficiency. How do you think transportation and mobility will change in the future? Will the design, operation, and ownership of cars change? How will the regulatory and legal environment need to adapt to those changes?

Answer. We would like to transform mobility for everyone. From the very earliest days of the self-driving car project, we've wanted to realize the full potential of this technology to help as many people as we can—such as helping senior citizens get to doctor's appointments, or helping people who have health conditions that make driving difficult. We think fully self-driving cars could open up opportunities for new and interesting models in which people have access to a vehicle rather than owning a vehicle, but it's still too early to know how that would work or make any firm decisions. However, the regulatory environment will need to evolve to accommodate the safety innovations necessary to safely operate fully self-driving cars in the U.S. Current regulatory authority is insufficient to keep pace with safety technologies being developed by vehicle manufacturers and technology innovators. Among those technologies are adaptive beam headlights, side mirror-replacing sensors, and new automated systems necessary for fully self-driving cars. New and amended automotive safety standards take years to finalize through NHTSA rulemaking. Existing authority concerning "general exemptions" (49 USC 30113) provides some leeway for development and field evaluation of innovative features but its limitations on dura-

tion (two years) and vehicle numbers (2,500 in any 12-month period) do not provide for full deployment. 49 USC 30114 ("special exemptions") is limited to research, investigations, demonstrations, training, competitive racing events, show, or display. The recently enacted section 49 USC 30112(b)(10) permits introduction of vehicles into commerce that do not comply with the FMVSS "solely for the purposes of testing or evaluation." As we discussed during the hearing, we would propose giving the Secretary of Transportation new authority to permit implementation of innovative safety technologies in motor vehicles. The Secretary (likely acting through NHTSA by delegation) could grant such approval only after public notice and comment and only upon a determination that the terms of the approval and any accompanying conditions would ensure safety at least as well as relevant Federal Motor Vehicle Safety Standards (FMVSS). The result would supplement existing NHTSA authorities, to expedite the safe introduction of life-saving vehicle technologies.

Question 2. Self-driving cars are likely to increase mobility, especially for those that are currently unable to drive. In developing such technologies, how does your company work to increase accessibility and incorporate the needs of people with disabilities, so that the technology and interfaces can be used independently?

Answer. During our development, we have found it very important to include the feedback and experiences of people with disabilities—such as Steve Mahan, who works for the Santa Clara Valley Blind Center, and has tested every generation of our technology—from our Prius vehicles to our latest prototypes. We believe there is more work to be done in collaboration with the disability community to ensure that certain needs can be designed into the technology and interfaces as it becomes ready for broader testing and deployment.

Question 3. In response to my question at the hearing about timing for the availability of autonomous vehicles in the marketplace, GM's witness expressed that GM expects to deploy vehicles in the next couple of years, depending on how the technology develops and the criteria established by regulators. When do you think these cars will be ready and available in the marketplace?

Answer. We're currently testing our vehicles in four cities: Mountain View, Austin, Kirkland, and Phoenix; we have a few on the streets of Mountain View and Austin now. In this current phase of the project, we're studying how these communities perceive and interact with us, and we're continuing to smooth out the vehicles' behavior to make them feel more natural to people inside and around them. We also want to uncover challenges that are unique to a fully self-driving vehicle—e.g., where it should stop if it can't stop at its exact destination due to construction or congestion. The next step for us will be running pilot programs with our prototypes to learn more about what people would like to do with vehicles like this, though we don't have any specific timelines to share right now. As I described during the hearing, my oldest son is currently twelve years old, and my team's goal is to ensure that he won't have to obtain his driver's license several years from now.

Question 4. While self-driving cars have the potential to save many lives, advanced computing and electronics may also create new concerns. Can you elaborate on what steps your company is taking to make sure it stays ahead of cyber vulnerabilities and other safety issues with these new technologies and connectivity?

Answer. Google has a world-class team dedicated to making our technology secure, which includes measures to protect the cars from being hacked. All our communication to and from the car is over an encrypted and authenticated channel. Data that is stored in the car itself is encrypted such that even if the vehicles are compromised, there would be no readable data aboard them. The hard drive that stores the information is regularly removed from the car and wiped clean so that the car never has large volumes of data in it. We're also constantly testing and scrutinizing the security of Google's systems—including our self-driving cars. Within Google, we have a team of engineers whose job is to try and break into our products, so we're able to continuously improve and evolve the security of our systems.

Question 5. There are clearly benefits of driver assistance technologies, many of which are available today. Do you think driver assistance technologies can evolve to fully autonomous cars? Or will we see a mix of vehicles on the road?

Answer. Many people assume that, over time, incremental improvements in driver assist technologies—things like automated parking, or automatic braking in stop-and-go traffic—are going to ultimately lead to fully self-driving cars. That isn't going to happen. It's impossible to keep adding assistive technology around the driver and someday end up in a place where a driver isn't necessary. It's not a continuum—it's a chasm—and that chasm is the difference between incremental benefits for society and a society that can shake itself free of many of the environmental, lifestyle, and safety burdens that our dependence on the automobile has unwittingly imposed on us. Getting to fully self-driving has important implications for how you design

both the hardware and the software. If you think about how a typical automobile works, it's entirely built around having a human present and able to operate it safely. If you're going to have a vehicle that doesn't rely on having a fully alert and responsive human, you'll need to build extra systems in, like steering and braking. You may end up disrupting the normal way all the vehicle's systems function. Despite this, we recognize that the industry is continuing to develop and deploy driver assistance technologies in the market today, and expect that such vehicles would share the road with both standard human-operated cars and fully self-driving cars.

Question 6. How supportive has NHTSA been of your efforts to develop and get autonomous vehicles on the road? How can a public-private partnership be helpful in developing and deploying these technologies?

Answer. NHTSA's has rightly recognized the need to take quick action to help ensure that the United States is able to stay in the forefront of the development, testing, and safe deployment of this technology. The Department of Transportation has also recognized the safety, environmental and accessibility benefits of self-driving cars. Secretary Foxx has committed to quickly working with the states to remove regulatory roadblocks that would prevent self-driving cars on U.S. roads, when the technology is ready. This is why we support NHTSA's goal of working *"with the ITS–JPO to lead multiple pilot deployments of Level 4 automated light duty and heavy duty vehicles researching different approaches to automation in different places"* and *"developing new public-private partnership models for deployment"* to *"generate data and experience about how to effectively encourage, regulate and legislate around this technology."*[1]

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. STEVE DAINES TO DR. CHRIS URMSON

Question 1. Dr. Urmson, first thing on Google's self-driving website states: "Navigating city streets. We've taught our cars to navigate through many complicated scenarios on city streets." In Montana, we have gravel roads, wildlife, towns without stop lights, roads that aren't mapped. What effort has Google taken to ensure functionality in rural environments?

Answer. We recognize that rural communities have a significant demand for new mobility options. For example, 79 percent of seniors age 65 and older in the U.S. live in car dependent suburbs or rural communities. This is why it is is so important that learn how different communities perceive and interact with self-driving cars—we want to get more experience testing our cars in new locations with different driving environments, traffic patterns, and road conditions. Since the Senate Commerce Committee hearing, we've added Phoenix to our mix of diverse communities including Mountain View, Austin, and Kirkland. The greater Phoenix area also offers the opportunity to test our cars and sensors in desert conditions, with extreme temperatures and dust in the air.

Question 2. A portion of the 5 GHz frequency band is dedicated solely to automotive short-range communications. In 1999 the FCC said allocating this spectrum would foster innovation. Over the last 17 years this spectrum has been left inaccessible by consumers. Since its inception, Google has innovated in many sectors and utilized a variety of frequencies. Considering usable spectrum is finite, what efforts are Google taking to share with other industries?

Answer. Google has long advocated more intensive, dynamic spectrum sharing as a way to meet the growing data demands of 21st century broadband users. For example, Google was an early supporter of allowing opportunistic wireless use of the television broadcast bands, and in support of that efforts, it operates a television white spaces database to enable wireless devices to make non-interfering use broadcast spectrum. Google has also advocated more intensive sharing between governmental and civilian users, and is developing a Spectrum Access System to facilitate sharing between military radar, satellite users, fixed wireless broadband providers, and new fixed and mobile wireless users in the 3.5 GHz band.

Question 3. In order for autonomous vehicles to become an everyday reality, an unprecedented amount of data will be necessary. Individual cars will collect much of this data. What data will Google be accumulating? Will Google be selling or sharing this data with 3rd parties?

Answer. The cars process data in real time to be able to make sense of the surroundings and to help them drive safely. Radar is used to detect and avoid large

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[1] FY 2017 Budget Estimates—NHTSA *<http://www.nhtsa.gov/staticfiles/administration/pdf/Budgets/FY2017-NHTSA_CBJ_FINAL_02_2016.pdf>*

moving objects such as other vehicles, lasers are used to detect and avoid pedestrians. Driving cameras are used to detect and recognize traffic lights, stop signs and emergency vehicles. While we're proving this technology out, we save this information to run simulations to complement the driving the cars do in the real world. The data collected by our vehicles is for testing and learning purposes.

Question 4. Consumers are justifiably concerned about the privacy of their data. In the FAST Act, the Committee included the Driver Privacy Act, establishing privacy protections for vehicle data recorders. Will Google make it clear personal data is owned by the individual?

Answer. Google's prototype vehicles do not include traditional vehicle event data recorders, since they were not designed to store accident crash data linked to human operation of a vehicle, for which the privacy protections under the FAST Act were designed. We also agree with the findings of the Senate Commerce Committee in S. Rept. 114–147—DRIVER PRIVACY ACT OF 2015, that *"S. 766 would use the definition of EDR in section 563.5 of title 49 of the Code of Federal Regulations. In this context the Committee contemplates that the term should not be interpreted as to burden unnecessarily the development and dissemination of advanced vehicle safety technologies, including autonomous vehicles. In the latter respect, the Committee contemplates that the EDR would be discrete from any devices and functions used for the operation of such vehicles."* Our vehicles are only being used for testing by our engineering team right now. When we begin any pilot tests, we will make it clear to users how any personal information will be used, and we plan to notify users before such personal information is used for any purpose other than getting them from point A to point B in our vehicle.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO DR. CHRIS URMSON

Question 1. In her written testimony, Dr. Cummings stated that "the self-driving car community is woefully deficient in its testing and evaluation programs (or at least in the dissemination of their test plans and data)" and that companies should commit to "principled, evidence-based tests and evaluations." How would you respond to these concerns? Do you believe that the self-driving car community, including your company, is testing rigorously enough? If so, should there be greater dissemination and transparency of test plans and data?

Answer. As we develop our self-driving car, we're constantly testing, analyzing and evaluating how our software performs. We do this on our test track, in the real world (1.5 million miles to date), and in our simulator (more than 3 million miles a day). Ultimately, a self-driving car's readiness for the public can't be boiled down to a single number, but we can accumulate a portfolio of metrics for our system that are useful to watch over time.

One metric we're watching closely as an important indicator of our progress is the rate of what we call "simulated contacts." These are situations in which, when we replayed a real-world situation in our simulator, we determined that our vehicle would likely have made contact with another object if our test driver hadn't taken over driving. We have many other metrics and methodologies that will be useful for establishing our safety record over time. On our test track, we run tests that are designed to give us extra practice with rare or out-of-the-ordinary situations. And our simulator generates thousands of virtual testing scenarios for us; it executes dozens of variations on situations we've encountered in the real world by adjusting parameters such as the position and speed of our vehicle and of other road users around us. This helps us test how our car would have performed under slightly different circumstances—valuable preparation for a public road environment in which fractions of seconds can be of critical importance.

In addition to the testing that is done on public roads, our simulator and on our private track, there is another important element to understanding that we are ready for operation. This is the completion of a functional safety analysis. This process is used to identify the ways in which the car can fail and and create a safety risk. The identified causes are then mitigated to reduce or eliminate the risk associated with the various failure modes. This analysis is supplemental to the various testing that is done and further strengthens our confidence regarding public road deployment.

Thanks to all this testing and analysis, we can develop confidence in our abilities in various environments. Throughout these processes, it has proved extremely valuable for us to publish information on how far we've traveled, new capabilities we've added, and any accident encountered. We make this information available through monthly reports on our website at *https://www.google.com/selfdrivingcar/reports/*

Question 2. As you may know, NHTSA is working on new guidance to states, policymakers, and companies on self-driving vehicles. Do you believe that NHTSA has sufficient expertise, in terms of staffing and resources, to guide the development of autonomous vehicles?

Answer. There are significant areas of technical expertise within NHTSA today, supporting a range of advanced automotive safety technologies, including self-driving cars, which exceed those available at the state levels. However, we believe that additional staffing and resources would help accelerate the efforts that NHTSA is undertaking in this area going forward.

Question 3. Specifically, what, if any, additional authorities should Congress consider providing NHTSA to allow for safe deployment of autonomous vehicles?

Answer. We strongly support NHTSA's goals and believe that Congressional action is needed to keep pace with safety technologies being developed by vehicle manufacturers and technology innovators, including fully self-driving cars. To achieve this goal, we propose that Congress move swiftly to provide the Secretary of Transportation with new authority to approve life-saving safety innovations. This new authority would permit the deployment of innovative safety technologies that meet or exceed the level of safety required by existing Federal standards, while ensuring a prompt and transparent process.

Questions 3a. Should Congress provide authority to an agency, such as the Federal Trade Commission, to issue privacy and data security rules for autonomous vehicles?

Answer. We do not believe that the Federal Trade Commission has requested this type of authority but the agency has repeatedly publicly outlined how its current authority encompasses the privacy of new technologies. In an October 2014 filing with NHTSA on the V2V ANPRM, the FTC stated that, "the Commission's primary source of legal authority in the privacy area has been Section 5 of the FTC Act, which empowers the Commission to take action against deceptive or unfair commercial practices." "To date, the FTC has brought more than fifty cases against businesses that allegedly failed to maintain reasonable security." "In addition to enforcing the law, the FTC has distributed millions of copies of educational materials for consumers and businesses to improve their understanding of ongoing threats to security and privacy. On the policy front, the Commission regularly holds seminars and workshops to examine the implications of new technologies and business models on consumer privacy."

Response to Written Question Submitted by Hon. Edward Markey to Dr. Chris Urmson

Question. Mr. Urmson, would Google support mandatory cybersecurity and privacy standards for autonomous vehicles?

Answer. Cybersecurity and privacy must be front of mind for those working on this technology. We believe that it will be critical for the automotive and technology industries to apply existing industry cybersecurity and privacy standards from the technology sector to self-driving cars to ensure the security and privacy of both the vehicles and their passengers. For example, all our communication to and from the car is over an encrypted and authenticated channel. In addition, data that is stored in the car itself will be encrypted such that even if the vehicles were compromised, there would be no readable data aboard them. The same security practice is used in Google's Data Centers today, to prevent data from being accessed even if a system is compromised (*e.g.,* (see *Google Transparency Report on E-mail Encryption in Transit*).

Response to Written Questions Submitted by Hon. Gary Peters to Dr. Chris Urmson

Question 1. The need to protect connected vehicles from cybersecurity threats presents an opportunity for the auto industry to partner with security researchers to ensure the robust safety of these technologies. Can you describe the value of the "bug bounty" programs your companies offer to security researchers and hackers to share vulnerability information with your company?

Answer. Since 2010, Google's Security Reward Programs have been a cornerstone of our relationship with the security community. Part of this relationship involves providing cash rewards for quality security research that identifies security vulnerabilities in products that we provide or proactive security improvements to select products. Google currently offers the following security reward programs: Google

Vulnerability Reward Program (VRP), Patch Reward Program, Vulnerability Research Grants, Chrome Reward Program, Android Reward Program. We've now paid more than $4,000,000 in rewards to security researchers since 2010 across all of our reward programs, with rewards ranging from $100 to $20,000 for each vulnerability disclosed based on the severity. These programs have been successful because of two core beliefs:

- Security researchers should be rewarded for helping us protect Google's users.
- Researchers help us understand how to make Google safer by discovering, disclosing, and helping fix vulnerabilities at a scale that's difficult to replicate by any other means.

In 2015, Google added the Vulnerability Research Grants program to proactively identify bugs beyond the areas of research normally supported by our vulnerability rewards. These are up-front awards that we will provide to researchers before they ever submit a bug. We publish different types of vulnerabilities, products and services for which we want to support research beyond our normal vulnerability rewards. We then award grants immediately before research begins, with no strings attached. Researchers then pursue the research they applied for, as usual, and are still eligible for regular rewards for the bugs they discover.

Question 1a. Are these programs an effective way to engage the security and privacy communities?

Answer. Yes, these security vulnerability reward programs have helped Google identify thousands of vulnerabilities across numerous product areas since 2010. In addition, they continue to foster a crucial relationship between Google and the security research community in identifying current and future vulnerabilities. The programs also incentivize researchers to disclose vulnerabilities to Google first, to allow adequate time for repairing it, before it is publicly disclosed and puts users at risk.

Question 2. What data does your company collect from cars, and how are you storing it on your own systems?

Answer. Our self driving vehicles currently use a number of sensors to help understand their surroundings and arrive safely at their destination. This information is crucial to maintaining and improving road safety. The vehicles use this information in real time to do things like navigate, obey traffic rules, and avoid hazards. This information also powers simulations used by our engineering team to test the self-driving software, which improves the safety and passenger experience of the vehicles, and are stored in Google's state-of-the-art Data Centers. Security is part of our data centers' DNA. We build custom servers exclusively for our data centers, never selling or distributing them externally. We've also designed them so they don't include unnecessary hardware or software—reducing the number of potential vulnerabilities. We also have robust disaster recovery measures in place. For example, in the event of a fire or any other disruption, we shift data access automatically and seamlessly to another data center so that our users can keep working, uninterrupted. Our emergency backup generators continue to power our data centers even in the event of a power failure. At the data centers themselves, we have access controls, guards, video surveillance, and perimeter fencing to physically protect the sites at all times.

Question 3. How is that data being protected from privacy and from cyber threats?

Answer. We have a world-class team dedicated to making our technology secure, which includes measures to protect the cars from being hacked. All our communication to and from the car is over an encrypted and authenticated channel. Data that is stored in the car itself is encrypted such that even if the vehicles are compromised, there would be no readable data aboard them. The hard drive that stores the information is regularly removed from each car and wiped clean so that the car never has large volumes of data onboard.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO MICHAEL F. ABLESON

Question 1. In her written testimony, Dr. Cummings stated that "the self-driving car community is woefully deficient in its testing and evaluation programs (or at least in the dissemination of their test plans and data)" and that companies should commit to "principled, evidence-based tests and evaluations." How would you respond to these concerns? Do you believe that the self-driving car community, including your company, is testing rigorously enough? If so, should there be greater dissemination and transparency of test plans and data?

Answer. At GM we are working diligently to test this technology. We regularly partner with outside experts and the academic community. We also undertake significant testing at our dedicated Milford Proving Grounds facility.

We have state of the art simulation testing capabilities and are building an Autonomous Driving Simulation Lab and a Driver in the Loop Simulator Lab at the Milford Proving Ground, which will be in use in 2016. The Autonomous Driving Simulation Lab will provide capability to simulate autonomous driving dynamics over a wide variety of conditions. The full motion Driver in the Loop Simulator will enable us to rigorously develop the vehicles systems, optimize safety and ensure passenger comfort. Our partnership with Virginia Tech University has also enabled us to test and model tire performance which will be used in the Autonomous Simulators as well as regularly test vehicles on the Virginia Smart Road and in the SoVa Motion Labs.

In addition, we believe that controlled ride-sharing projects, such as those we are planning with Lyft provide us with a safe testing platform for automated vehicles. We also believe transparency surrounding testing and data are important, and we are exploring ways to further this objective to increase consumer confidence. We are also regularly engaged with NHTSA in connection with its automated vehicle efforts, which includes testing and data considerations.

Question 2. As you may know, NHTSA is working on new guidance to states, policymakers, and companies on self-driving vehicles. Do you believe that NHTSA has sufficient expertise, in terms of staffing and resources, to guide the development of autonomous vehicles?

Answer. We cannot speak to NHTSA's staffing and resources but we are extremely encouraged by NHTSA's actions taken to date. This technology is changing rapidly and all involved parties will have to continue to adapt to these changes.

Question 3. Specifically, what, if any, additional authorities should Congress consider providing NHTSA to allow for safe deployment of autonomous vehicles?

Answer. We believe NHTSA is taking the correct steps within the parameters of its authority. As noted in my testimony, we will continue to work with NHTSA to find creative ways to advance automated technology in real world controlled projects to accelerate learning about the technology and how it performs. As we learn through real world projects, we will have better information to determine if additional legal authority is needed going forward.

Questions 3a. Should Congress provide authority to an agency, such as the Federal Trade Commission, to issue privacy and data security rules for autonomous vehicles?

Answer. GM's commitment to data privacy and security is unwavering and we appreciate any effort aimed toward increasing privacy and security. We do not believe, however, that a single binding set of rules or a particular set of practices apply in all contexts. The best approach will vary depending upon circumstances, and automakers must be free to choose the solution that best fits both the needs of the product and the demands of automotive safety and innovation. We also believe that existing authority already exists through Federal and state consumer protections statutes to protect consumers of autonomous vehicles.

Question 4. At the hearing, many of us on the Committee couldn't help but be reminded of the hearings that took place two years ago in that very room. In that case, the defect in the ignition switches wasn't something related to software or LIDAR or anything approaching the technological complexity of what's required in a self-driving car. In fact, the deadly problem in GM's ignition switches was really just a simple nuts-and-bolts mechanical problem.

Question 4a. Could you walk us through what your company does in terms of spotting and reporting potential safety issues as your company develop autonomous vehicle technologies?

Answer. GM utilizes a number of processes in an attempt to detect potential safety issues in GM vehicles, including data analytics and GM's Speak Up for Safety program. GM's Emerging Issue Identification process, along with the Safety and Field Investigations (SFI) process, help identify and analyze potential safety issues and conduct specific investigations as appropriate. Where a cybersecurity issue is identified that may impact vehicle safety, the issue is brought into the SFI process. GM routinely communicates with NHTSA regarding issues currently under investigation by GM and the results of GM's investigation and decision-making processes. In addition, we periodically meet with NHTSA and review cybersecurity issues that might be of interest. These processes apply to all vehicles, including those with autonomous technologies.

Question 4b. What internal processes are now in place to prevent personnel from covering up defects?

Answer. Please see the Answer to 4a above.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. GARY PETERS TO MICHAEL F. ABLESON

Question 1. The need to protect connected vehicles from cybersecurity threats presents an opportunity for the auto industry to partner with security researchers to ensure the robust safety of these technologies.

Question 1a. Can you describe the value of the "bug bounty" programs your companies offer to security researchers and hackers to share vulnerability information with your company?

Answer. GM finds great value in working with the security research community. We welcome their input; we have, in fact, as of April 12, thanked 68 hackers, through our website, *https://hackerone.com/gm* for their contribution to GM's Security Vulnerability Disclosure Program.

Question 1b. Are these programs an effective way to engage the security and privacy communities?

Answer. General Motors has established strong relationships with many security researchers, various consortiums and other third-party cybersecurity experts. These relationships are implemented through contractual security-focused arrangements, contractual vulnerability testing and solution engagements and mutual collaboration agreements. In addition, General Motors engages with the cybersecurity research community through regular attendance at research community conventions and meetings. Also, General Motors employees play leading roles in SAE and other standard setting organizations that are actively engaged with the research community. GM's Security Vulnerability Disclosure Program is a way to allow researchers who may not be already working with GM to communicate to GM if they know of vulnerabilities in GM products.

Question 2. How does your company ensure that the supply chains are protected from cyber threats?

Answer. We utilize our requirements as pre-sourcing cybersecurity qualifications for suppliers for relevant components. Our cybersecurity organization interacts with suppliers throughout the development process conducting, among other activities, design reviews, code scan reviews, supplier security testing results reviews, security and penetration testing (conducted by General Motors and external experts) and final cybersecurity sign off. We also have contracts requiring our suppliers to meet our requirements, with rights to conduct audits and reviews. We are also working towards a supplier training program on topics including GM's cybersecurity requirements and best practices.

Question 3. How does the Auto-ISAC assist in ensuring that cyber threat information is efficiently exchanged across the industry, including suppliers and manufacturers?

Answer. The Auto ISAC can facilitate cyber threat information exchange across the industry through its information sharing portal. Since its inception, the ISAC has accomplished the following:

- 100+ intelligence reports published
- 10 public speaking events organized
- 428 intelligence sources developed
- 40 vehicle hacking tools tracked
- 130+ active users on the portal
- 18+ Board of Directors and Standing Committee meetings held
- 9 portal training sessions (in both English and Japanese)
- 30+ mentions in the press

The Auto ISAC has also identified and reported more than 14 vulnerabilities, provided by both Auto-ISAC members and other cyber intelligence sources.

Question 4. What data does your company collect from cars, and how are you storing it on your own systems?

Answer. The type of information generated by vehicles can vary by make, model, model year, as well as individual customer use of a vehicle and its features and services. In general terms, GM vehicles generate raw data regarding system status and operation through on-board computers or electronic control units within the ve-

hicle. The majority of this data is not transmitted outside the vehicle or retained permanently in the vehicle's systems. Data that is transmitted off-board the vehicle through the OnStar system is encrypted during transit into our back office systems, where the data is stored with appropriate data protection safeguards in place.

OnStar is GM's primary mechanism for collection of vehicle data. OnStar's Privacy Statement delineates three categories of data collected (*https://www.onstar.com/privacy*). These categories are defined as Vehicle-Related Information (examples include odometer, oil life remaining, tire pressure, diagnostic data and information about vehicle collisions); Driving Information (examples include geolocation, speed, safety belt usage, and other similar information about how the vehicle is used); and Account Information (examples include contact and billing information and information about how customers use certain OnStar services and its website).

Question 5. How is that data being protected from privacy and from cyber threats?

Answer. General Motors continues to devote substantial resources and effort to protect vehicles from cybersecurity threats and to maintain data privacy practices that promote security, transparency, choice, and integrity. We are taking a multi-layered approach to in-vehicle cybersecurity and are designing many vehicle systems so they can be updated with enhanced security measures as potential threats evolve. For example:

- We were the first auto manufacturer to create an integrated and dedicated global organization focused on minimizing the risks of unauthorized access to vehicles and customer data. Jeff Massimilla, our Chief Product Cybersecurity Officer, has responsibility for the end to end cybersecurity of our vehicles and reports on a regular basis to our CEO and Board of Directors.
- We have collaborated with experts in the defense and aerospace industries, government organizations, academia and industry consortiums on best practices and key lessons.
- We are also in full support of the recently formed Auto Information Sharing and Analysis Center (Auto ISAC), which will identify trends and common cyber threats and focus the industry's ongoing efforts to safeguard vehicle electronic systems and networks. Jeff Massimilla is the Vice Chairman of the Auto ISAC Executive Committee.
- GM has launched a Security Vulnerability Disclosure Program through which security researchers who are not already working with us that find security bugs or vulnerabilities related to our products or services can inform GM via a security website portal.

We strive to ensure that our customers are aware of what data we might collect and how it could be used. The user terms and privacy statements implemented across our customer-facing channels are designed to provide customers with clear, meaningful, descriptions of our data policies and practices. We also publish our policies in order for consumers to make informed choices about our products and services. It is also our practice to obtain opt-in consent for any services that may fall outside those described in the OnStar User Terms and Privacy Statement. Once OnStar services are activated, a customer may subsequently cancel the services at any time, however, cancelling core services means that vehicle connectivity will no longer be available.

Question 6. As the software and operating systems of GM vehicles offer increasing automated functionality, it is possible that liability will swing towards the manufacturers.

Question 6a. Do you expect automakers to assume more liability at higher costs?

Answer. One of the great promises of automated functionality is the potential improvement in driving safety by the reduction of driver error as a factor in the number and severity of accidents. At present, it is difficult to estimate the impact of increasing automated functionality on the norms of liability, given the nascent state of the technology, the large and growing car park of conventional vehicles, and the role of autonomous in ride-sharing platforms versus individualized driving, all of which can influence the approach to autonomous vehicle liability by the tort bar and OEMs.

Question 6b. How could you see this potential shift affecting suppliers and consumers?

Answer. Please see above.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN THUNE TO GLEN W. DE VOS

Question 1. At the hearing, we discussed a number of potential benefits and opportunities offered by autonomous vehicles, including increased safety, mobility, and efficiency. How do you think transportation and mobility will change in the future? Will the design, operation, and ownership of cars change? How will the regulatory and legal environment need to adapt to those changes?

Answer. Autonomous vehicles are expected to significantly revolutionize the driving experience. First, safety will be dramatically increased. Today's commercially available active safety features, also known as Advanced Driver Assistance Systems (ADAS), alone will reduce annual driving deaths in the U.S. by one-third or more than 10,000 lives a year once adopted throughout the fleet. Full automation has the promise to go even further, making most auto crashes and injuries a thing of the past. The reduction in accidents will also significantly lessen road congestion, which crashes greatly exacerbate. Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication, together known as V2X, will further help with congestion as better information flow from infrastructure to vehicles can, not only allow cars to reroute to the least congested road, but also allow for better traffic management practices, such as better traffic light timing. These technological advances will allow cars to operate more efficiently and with fewer impediments. In addition, fuel economy will improve since reducing both idling and the start/stop of most daily commutes saves fuel. All of this can happen in advance of full automation.

Full automation can produce even more remarkable changes. Road design, for example, can be simplified since many of the current road design features are intended to address drivers' limitations. From roundabouts replacing clover leafs, to platooning vehicles allowing for faster speeds and fewer lanes on the highway, automated vehicles could have a profound impact on the built infrastructure, reducing cost, and saving energy.

It remains to be seen how car ownership patterns change. Automated vehicles make it easier to foresee a future in urban areas where fewer residents own their own cars, instead relying on fleets of driverless vehicles as shared personal transportation devices. Automated vehicles could also allow people with disabilities, including age-related ailments, to safely drive—restoring freedom of mobility to millions—and therefore expand the ranks of car owners.

It will be important for the industry and regulators to work together to adapt to these changes. The first area where the Department of Transportation (DOT) and National Highway Traffic Safety Administration (NHTSA) can work with the industry is through implementation of the STICRs Act. The STICRs Act will speed consumer adoption of ADAS by updating the 5-star safety rating system. Safety conscious consumers want to buy cars that are highly rated and the inclusion of active safety in the 5-star rating will have an almost immediate impact on consumer adoption of these life-saving technologies. Greater adoption of ADAS will not only save lives now but will set the stage for greater consumer acceptance of full automation in the future.

It is also important to develop a uniform set of policies and regulations pertaining to automated driving. Currently, many states are establishing their own regulations in this space. It will be important to have national policies, not 50 potentially varying state-level policies, that are flexible enough to allow for the roll-out of automated vehicles for fleets, the movement of goods and services, and individual consumers.

Question 2. Self-driving cars are likely to increase mobility, especially for those that are currently unable to drive. In developing such technologies, how does your company work to increase accessibility and incorporate the needs of people with disabilities, so that the technology and interfaces can be used independently?

Answer. Fully automated driving will revolutionize the driving population. It will provide more mobility and driving opportunities to people who are currently unable to drive due to disabilities.

In the immediate future, ADAS has the potential to help people who may be discouraged from driving. Technologies such as automatic emergency braking will create a safer environment for drivers with potentially slower reflexes or who do not have as much driving experience, such as the elderly or new young drivers. The cocoon of safety that is created by ADAS will increase confidence among drivers and encourage more independent vehicle use.

Question 2a. In response to my question at the hearing about timing for the availability of autonomous vehicles in the marketplace, GM's witness expressed that GM expects to deploy vehicles in the next couple of years, depending on how the tech-

nology develops and the criteria established by regulators. When do you think these cars will be ready and available in the marketplace?

Answer. Despite the success of our cross-country drive and our demonstration of urban driving at CES 2016, significant challenges remain in moving automated driving from concept to reality and finally to commercialization. The availability of automated cars in the marketplace will also depend on regulatory activity and mass consumer adoption—which is difficult to predict. Technological advances and strong consumer demand could result in fully automated cars entering the consumer marketplace in the next decade. Several automobile manufacturers have already announced automated vehicle launches for as early as 2020 and Delphi is helping lead the way. Delphi V2V technology is scheduled to be introduced on the 2017 Cadillac CTS later this year. Volvo and others began offering automated functions like automatic emergency braking and traffic jam assist in 2014. V2V and V2I will also play an important role in providing information about the environment in which the vehicle is driving. These technologies are important foundations for automated vehicles and will help save lives before fully automated vehicles are deployed.

Question 3. While self-driving cars have the potential to save many lives, advanced computing and electronics may also create new concerns. Can you elaborate on what steps your company is taking to make sure it stays ahead of cyber vulnerabilities and other safety issues with these new technologies and connectivity?

Answer. Delphi takes cybersecurity and safety very seriously. Making sure that our products are safe and secure has always been a priority for Delphi. Accordingly, Delphi was the first Tier 1 supplier to join the Automotive Information Sharing and Analysis Center (Auto-ISAC) to further improve cybersecurity threat awareness and coordination across the industry. The Auto-ISAC provides a forum for information exchange among entities in the automotive industry for the purpose of sharing trusted and timely information about existing or potential cyber-related threats and vulnerabilities in light duty on-road passenger vehicle electronics and associated networks.

Additionally, Delphi is in the midst of creating a state-of-the-art R&D cybersecurity lab to verify new tools and technology and process security incidents when they occur.

Delphi works with a number of international organizations, government agencies and companies to ensure a coordinated approach to the safety and security of interconnected vehicles—including the National Institute of Standards and Technology (NIST) and Society of Automotive Engineers (SAE). We have also worked with Original Equipment Manufacturers (OEMs) to ensure that the products we engineer meet OEM specifications, and leverage open-source and industry accepted information security protocols.

Delphi has also taken an aggressive internal approach to ensure that our products are secure. In 2014, we appointed a central cybersecurity director to ensure a uniform and comprehensive corporate wide approach to cybersecurity. We also have a dedicated team of engineers and IT professionals who provide oversight in the area of cybersecurity and connected vehicles from supply to delivery and aftermarket. Additionally, a steering committee meets regularly to provide appropriate guidance with respect to policies, procedures, and standards.

We also strategically engineer safety into technology. For example, Engine Control Units or ECUs are developed with a secure boot and programming functionality so only valid and trusted programs and software are executed. A vehicle's wireless connectivity is also protected using industry encryption standards to protect the vehicle network and the user's privacy.

Question 4. There are clearly benefits of driver assistance technologies, many of which are available today. Do you think driver assistance technologies can evolve to fully autonomous cars? Or will we see a mix of vehicles on the roads? How will the STICRS Act, enacted into law as part of the FAST Act, help to speed the deployment of such technologies?

Answer. The STICRs Act will greatly speed the adoption of life-saving active safety technology. There are technologies that are available in the marketplace today, such as automatic emergency braking, blind spot detection and lane departure warning which can have an immediate safety impact. Before STICRs, ADAS was not mandated as part of the New Car Assessment Program's (NCAP) 5-star safety rating. The 5-star rating is an important factor in driving consumer demand. Safety conscious consumers want to buy cars that are highly rated. Including active safety in the 5-star rating will give consumers a clearer picture of which vehicles are the safest to own and increase demand for active safety technology.

ADAS will be a crucial aspect as we move towards fully automated cars. Over time, automated driving will likely evolve from ADAS. Technologies that are avail-

able in the market today will provide a foundation for automated driving. In addition, as a March 2016 AAA survey of drivers illustrated, only one in five drivers today trust "self-driving" cars. Increased consumer adoption of ADAS will speed consumer acceptance of fully automated vehicles. The same survey found that ADAS technology is already desired by sixty percent of the driving public.

Question 5. While driver assistance technologies may serve as the building blocks for self-driving cars of the future, there are some concerns that, if we have cars that handle nearly all driving situations, human drivers might get complacent and not pay attention and take control of the car when they need to. What is Delphi doing to address those concerns?

Answer. With respect to driver engagement, there are two technology systems that we implemented in our driverless car to help address the issue.

A. Driver Monitoring: Delphi's automated driving platforms are equipped with state-of-the-art driver state sensing systems, which allow the vehicle to monitor the availability of the driver in situations where a takeover may be necessary. If the driver is found to be unavailable, the vehicle is capable of coming to a stop until it is safe to proceed.

B. Drive-by-wire system: The drive-by-wire system featured in Delphi's automated driving platforms is implemented in a manner that preserves the function of the production vehicle's steering and drivetrain. When manually operated, the vehicle drives exactly as a production vehicle would. When auto mode is engaged, the automated system uses the same vehicle input interfaces as a human driver, which allows passengers to directly see and feel how the vehicle is behaving. The automated driving system is completely separable from the stock system, which allows the driver to instantaneously assume full control of the vehicle at any time.

Question 6. How supportive has NHTSA been of your efforts to develop and get autonomous vehicles on the road? How can a public-private partnership be helpful in developing and deploying these technologies?

Answer. In December of 2015, NHTSA announced the creation of new 5-star safety rating systems that would include ADAS. The new ratings will include three 5-star ratings: crashworthiness, crash avoidance, and pedestrian protection. The announcement follows passage of the STICRs Act and will increase consumer demand for active safety technology, a building block for automated vehicles. The timeline set by the STICRs Act is to promulgate a rule within one year. It is critical that this timeline does not slip.

Additionally, the Obama Administration's announcement of a ten-year, $4 billion effort to "accelerate the development and adoption of safe vehicle automation through real-world pilot projects" through the programs authorized by the FAST Act demonstrates broad support for moving the U.S. to an automated future. These pilots should be a useful public-private partnership. For example, DOT's Smart Cities initiative will be helpful in driving development of intelligent transportation systems on a city-wide basis that no single company or local government could accomplish on its own.

Response to Written Questions Submitted by Hon. Bill Nelson to Glen W. De Vos

Question 1. In her written testimony, Dr. Cummings stated that "the self-driving car community is woefully deficient in its testing and evaluation programs (or at least in the dissemination of their test plans and data)" and that companies should commit to "principled, evidence-based tests and evaluations." How would you respond to these concerns? Do you believe that the self-driving car community, including your company, is testing rigorously enough? If so, should there be greater dissemination and transparency of test plans and data?

Answer. Delphi is committed to ensuring that all of our products are safe and reliable. Our technologies go through a rigorous testing process to guarantee that they are safe and will perform to the specifications set by our customers. In addition to the substantial and continuous testing Delphi performs in the development and manufacture of its existing ADAS product line, Delphi conducted the first cross-country automated drive last year. During the test drive, the car was in autonomous mode 99 percent of the time. This drive allowed us to collect nearly three terabytes of data that will be instrumental in improving automated driving technologies. Delphi will continue to be at the forefront of developing, testing and evaluating the component technologies that are saving lives today, and that will allow for automated vehicles in the future. We look forward to continuing to work with DOT and

NHTSA to improve and evolve the testing and evaluation programs and protocols on these critical safety features.

Question 2. As you may know, NHTSA is working on new guidance to states, policymakers, and companies on self-driving vehicles. Do you believe that NHTSA has sufficient expertise, in terms of staffing and resources, to guide the development of autonomous vehicles?

Answer. Delphi has a strong working relationship with NHTSA and has been pleased with NHTSA's recent steps on updating NCAP to include ADAS, and its outreach to industry on the future of automated vehicles. In addition to its talented staff, continued collaboration with the automotive industry will help NHTSA access some of the specialized expertise it requires to make informed decisions about the future of automated vehicles.

Question 3. Specifically, what, if any, additional authorities should Congress consider providing NHTSA to allow for safe deployment of autonomous vehicles?

Answer. NHTSA currently has broad authorities in the regulation of vehicle safety. Congress has proven in the past that additional legislative action can have a beneficial impact on vehicular safety, specifically as it relates to automation technologies. Congress's passage of the FAST Act which included the STICRs bill gave NHTSA the mandate to quickly update its NCAP 5-star rating system to include ADAS technologies. This new legislative requirement was a significant step towards driving consumer adoption of ADAS technologies which will save thousands of lives annually, and is a critical step on the road to consumer acceptance of full automation.

There are a number of areas in which NHTSA and DOT need to continue to be active. One is in the V2V roll-out. DOT needs to have sufficient authority to ensure that through a collaborative process with industry, V2V and V2I can rollout in a timely and coordinated fashion. V2V will be a major safety improvement not only for new cars but, through the after-market, existing vehicles. The Federal Government will be a driver of this adoption, through infrastructure spending as well as through the designation and protection of the necessary spectrum.

Another area that could benefit from NHTSA's expertise is the reconciling of the multiple state rules governing automated driving. A balkanized 50-state framework will increase the cost and slow the roll-out of automated vehicles. A collaborative process involving NHTSA and the companies that are developing the marketing of automated and semi-automated technologies that helps drive national rules of the road makes more sense than 50 state solutions.

Questions 3a. Should Congress provide authority to an agency, such as the Federal Trade Commission, to issue privacy and data security rules for autonomous vehicles?

Answer. With respect to privacy, as a Tier 1 supplier, Delphi builds to the standards requested by our OEM customers. Delphi only keeps and stores data associated with its own test vehicles, unless data storage is a product feature that is disclosed and agreed to by customers. For our aftermarket offering, *Delphi Connect,* Delphi stores data associated with end customer vehicles. This attribute, however, is an essential product feature and is clearly disclosed to customers in our terms of service for *Delphi Connect.* Delphi's experience and practices do not inform the question of whether additional regulatory authority in this space is needed or advisable.

With respect to cybersecurity, it is clear that expanded collaboration and information sharing among and between the companies responsible for building automated systems, as well as with relevant agencies of the Federal Government, is critical. It is for this reason that Delphi was the first Tier 1 supplier to join the Automotive Information Sharing and Analysis Center (Auto-ISAC). There is a long list of agencies that either currently are or would like to collaborate with the automotive sector on cybersecurity. They include the National Institute of Standards and Technology (NIST), DOT (including NHTSA), and the Department of Homeland Security, as well as others with cyber security and research expertise in the field. Delphi believes that strong internal controls, adoption and implementation of best practices and collaboration and information sharing between and among the industry and with government agencies are key to developing and maintaining cybersecurity in automated vehicles. At this time, it is unclear if expanding FTC's regulatory authority would improve the cybersecurity of automated vehicles.

Question 4. At the hearing, many of us on the Committee couldn't help but be reminded of the hearings that took place two years ago in that very room. In that case, the defect in the ignition switches wasn't something related to software or LIDAR or anything approaching the technological complexity of what's required in a self-driving car. In fact, the deadly problem in GM's ignition switches was really just a simple nuts-and-bolts mechanical problem.

Question 4a. Could you walk us through what your company does in terms of spotting and reporting potential safety issues as your company develop autonomous vehicle technologies?

Answer. Delphi is committed to making cars safer. Delphi's business is built around the megatrends of *Safe, Green, Connected,* and as these megatrends converge and become more integrated, we work to remain uniquely positioned to bring full-system solutions to our customers. We have a robust and market leading development and manufacturing process that ensures the highest quality standards are achieved in all our products.

All of our technologies are commercialized following a rigorous development process which includes—but is not limited to—component qualification, simulation, verification, environmental validation, functional testing, FMEA, Functional Safety ($ISO_2$6262) compliance, and fleet testing. Systems are verified at both the sensor level (bench, chamber, real world usage profile) per functional test plans with derived performance requirements and at the vehicle feature level using functional test plans that evaluate true positive and false positive performance on test track and in real world environments. The false positive performance requirements are generated from a functional safety case and typically require very large amounts of real world data collection to ensure that the vehicle performs properly under all conditions and in all environments. This testing always includes environments where issues had been identified during the development of prior systems. All performance issues identified are resolved using structured problem solving in a "test/develop countermeasure/re-simulate process.

Question 4b. What internal processes are now in place to prevent personnel from covering up defects?

Answer. Delphi has conducted a thorough review of its policies and procedures related to safety. We believe our policies and practices are robust, are being improved and will continue to improve.

Delphi's chief technology officer meets routinely with the company's global engineering team to reinforce the importance of raising concerns and providing feedback to our customers. Additionally, the chief technology officer personally reinforces with the company's global engineering team the importance of promptly raising concerns so that they can be handled.

We have strengthened our procedures to promptly communicate safety concerns to our senior management team. Also, we have strong document retention policies in place and our critical engineering documents are stored digitally. We continuously improve our processes and procedures to increase vehicle safety.

We have enhanced monitoring of safety issues that arise during product development, so that we can ensure they are identified and addressed early in the process.

Response to Written Questions Submitted by Hon. Gary Peters to Glen W. De Vos

Question 1. How does your company ensure that the supply chains are protected from cyber threats?

Answer. Delphi takes cybersecurity and safety very seriously. Delphi will qualify the integrity and operation of new software and ICs that will be used for our cybersecure product designs. This will be accomplished through collaboration and cooperation with dedicated suppliers during the development phase, followed by testing in our lab during product development.

Making sure that our products are safe and secure has always been a priority for Delphi. Accordingly, Delphi was the first Tier 1 supplier to join the Automotive Information Sharing and Analysis Center (Auto-ISAC) to further improve cybersecurity threat awareness and coordination across the industry. The Auto-ISAC provides a forum for information exchange among entities in the automotive industry for the purpose of sharing trusted and timely information about existing or potential cyber-related threats and vulnerabilities in light duty on-road passenger vehicle electronics and associated networks.

Delphi works with a number of international organizations, government agencies and companies to ensure a coordinated approach to the safety and security of interconnected vehicles including the National Institute of Standards and Technology (NIST) and Society of Automotive Engineers (SAE). We have also worked with Original Equipment Manufacturers (OEMs) to ensure that the products we engineer meet OEM specifications, and leverage open source and industry accepted information security protocols.

Delphi has also taken an aggressive internal approach to ensure that our products are secure. In 2014 we appointed a central cybersecurity director to ensure a uni-

form and comprehensive corporate wide approach to cybersecurity, and we have a dedicated team of engineers and IT professionals to provide oversight in the area of cybersecurity and connected vehicles from supply to delivery and aftermarket. Additionally, a steering committee meets regularly to provide appropriate guidance with respect to policies, procedures, and standards.

Question 2. What data does your company collect from cars, and how are you storing it on your own systems?

Answer. Delphi only keeps and stores data associated with its test vehicles. We collect a broad array of data from the sensors associated our automated vehicles. The data is both stored on-board and outside the vehicle. These are Delphi owned vehicles. Delphi does not store data from consumer owned vehicle unless data storage is a product feature that is disclosed and agreed to by customers. For our aftermarket offering, *Delphi Connect,* Delphi stores data associated with end customer vehicles. This attribute, however, is an essential product feature and is clearly disclosed to customers in our terms of service for *Delphi Connect.*

Question 3. How is that data being protected from privacy and cyber threats?

Answer. As noted in *Question 1,* Delphi takes protection from privacy and cyber threats very seriously. Delphi has developed its Engine Control Units, or ECUs, with secure boot and programming functionality, so only valid and trusted programs and software are executed. The wireless connectivity is protected using industry encryption standards to protect the vehicle and user's privacy, including security to authenticate and gain access (WiFi protected access 2 or WPA2). We also leverage Bluetooth to connect a user's personal devices, but ensure that the connection is via Secure Simple Pairing (or SSP) which allows for encryption of data between linked devices, thus providing additional security.

Delphi has a history of working to improve cybersecurity across the automotive sector. Delphi has, on multiple occasions, hosted the SAE International/Battelle CyberAuto Challenge. The challenge entails a 5-day workshop where teams of students and professionals, including automotive engineers, government engineers, and "white hat" hackers, work on production vehicles to find real solutions to the challenges posed by cybersecurity in automobiles. Teams work to identify automotive cybersecurity trends and develop talent in a new technical discipline in this high tech space.

Response to Written Questions Submitted by Hon. John Thune to Joseph Okpaku

Question 1. At the hearing, we discussed a number of potential benefits and opportunities offered by autonomous vehicles, including increased safety, mobility, and efficiency. How do you think transportation and mobility will change in the future? Will the design, operation, and ownership of cars change? How will the regulatory and legal environment need to adopt to those changes?

Answer. The notion of car ownership is already changing at a rapid pace. As I stated in my testimony, according to a study by the University of Michigan, in 2014 only 24 percent of sixteen year olds obtained a driver's license. In 1983, that figure was 46 percent. Additionally, as millennials age and gain more market buying power, it is more likely that they will spend money on access to services, likely through a smartphone, rather than spending on full ownership of a good or service.

Today, we are a nation driven by innovation, creativity, and positive transformation, all of which are shared core elements in our emerging digital economy. Lyft's co-founders John Zimmer and Logan Green have undertaken the formidable goal of filling the 80 percent of empty seats in cars on the road, and providing a true alternative to car ownership. With rapid urbanization comes increased traffic congestion, a detriment that continues to strain our economy, infrastructure, and environment. Lyft's vision is that through a mobile ridesharing platform, we will be able to take more cars off the road and complement existing public transit options. Lyft believes that this vision can only be achieved through collaborating and partnering with government, to ensure there are regulations in place to protect consumers and allow for competition.

Now, three and half years after Lyft launched, smart regulations have been enacted in over 30 states across the country. As the digital economy continues to grow, and broadband and spectrum issues become even more important with the advent of self-driving cars, there will be new opportunities that lie ahead for government and industry. Lyft sees similar parallels to the developing autonomous vehicle industry, and would caution not to overly regulate too quickly. Thoughtful and unburdensome regulations need to be developed to allow for innovation, promote fair competition, and provide set safety standards. Lyft looks forward to working with

Congress, states, and NHTSA as autonomous testing continues, and thoughtful regulations develop.

Question 2. Self-driving cars are likely to increase mobility, especially for those that are currently unable to drive. In developing such technologies, how does your company work to increase accessibility and incorporate the needs of people with disabilities, so that the technology and interfaces can be used independently?

Answer. Lyft has long been on a mission to reconnect people and their communities through better transportation options. We're making sure that people who need rides most are able to easily get them. Over the last few years Lyft has been committed to helping people with disabilities through rideshare, and we anticipate that this shift to autonomous vehicles will only continue to improve mobility options for all.

Lyft has partnerships with a broad range of accessibility/disabilities groups from across the country, including the National Federation of the Blind and the National Down Syndrome Society. These partnerships are based on the notion that, among other things, having a safe, reliable, on-demand, and cashless form of transportation has been transformative for people with disabilities. These partners have helped us think through improvements to the Lyft platform and policy developments, as well as how to best engage and educate our community. As we move into the new autonomous vehicle mobility space, we look forward to continuing to work with our partners on ensuring that our platform provides an inclusive service that benefits everyone in our community.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. DEAN HELLER TO JOSEPH OKPAKU

Question 1. Given that seniors in Nevada represent 13 percent of our state's population, expanding seniors' mobility is of great concern to me. I know many of the populations that could benefit the most from ride sharing and ultimately on-demand autonomous vehicles are the very people who either can't afford or struggle to use technologies, like smart phones, that are needed to actually request a vehicle.

Last August, my office held a roundtable in Reno with seniors, Federal agencies, health care providers, community leaders, and others who are concerned about the health and well-being of Nevada's senior citizens.

The Nevada legislature had recently passed legislation clearing the way for ride share companies like Lyft and Uber to operate in the state, so I heard directly from a constituent with her interest in your services, but she doesn't own a cell phone. Another constituent said he only had a flip phone so he could call his family during emergencies.

I think on-demand autonomous vehicles could be a major benefit for the elderly. It could help seniors get to their doctor's appointment, run errands like getting groceries, or simply ensure they maintain their independence even though it might not be safe for them to drive.

What can we do to make sure these types of technologies are more available to elderly populations?

Answer. Lyft has been dedicated to increasing mobility options by providing safe, affordable, and reliable rides. For seniors, many of whom no longer have a driver's license and have limited mobility options, Lyft has provided them with an on-demand service that can get them to medical appointments and restore their freedom and independence.

Every year almost 3.6 million Americans miss or delay medical care because they lack appropriate transportation to their appointments. However, more than a quarter of Americans 65 years and older do not own smartphones, so that segment of the population had not been able to access the traditional Lyft platform. To address this issue, Lyft was excited to announce a digital dispatch partnership with National MedTrans Network that would allow for seniors or caretakers to call for a Lyft ride through their phone or a desktop computer. Through this kind of partnership we're already fulfilling 2,500 rides per week in New York City alone. Across the country, Lyft has transported nearly 100,000 people through our partnerships with healthcare organizations. Lyft has lowered ETAs by 80 percent, and reduced the average cost of non-emergency medical transportation by an average of 20 percent, providing dramatic reductions in wait times and missed physician appointments.

As we shift into the autonomous space, access to more mobility options will only increase for our senior populations and their caregivers. We look forward to working with communities to best serve their needs in innovative and impactful ways.

Question 2. Likewise, I think on-demand autonomous vehicles could have major benefits for our veterans. In the Pahrump, NV area, the VA was providing taxi cab vouchers to get veterans to their appointments. However, cab access in that area was limited.

Has Lyft done any work with veteran service organizations or the VA to develop strategies to improve veteran mobility?

Answer. Lyft has been proud to work with veteran's communities across the country. Last November, in honor of Veterans Day, Lyft teamed up with First Lady Michelle Obama's Joining Forces initiative to provide free transportation to former military men and women who lack a way to get to job interviews.

Since then we have been developing partnerships with local Veteran Service Organizations (VSOs) and the National Coalition for Homeless Veterans to continue to help provide transportation options to homeless veterans going to job interviews.

As we shift toward autonomous vehicles, Lyft's goal is to deploy this new technology and service for all communities at all income levels. We look forward to continuing to work with VSOs to ensure that our heroes have access to reliable transportation options.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. STEVE DAINES TO JOSEPH OKPAKU

Question. Mr. Okpaku, last year, Montana enacted a law permitting ride-sharing companies to operate. Uber begin registering drivers in January. Lyft does not yet have a presence. How will autonomous vehicles enable Lyft and other transit providers to expand services to rural communities?

Answer. Lyft commends Montana for its great work in enacting legislation at the State level that permits ride-sharing companies to provide safe, affordable rides throughout the State. Lyft looks forward to opportunities to develop a rider and driver market-base in the state. The advent and deployment of autonomous vehicles will bring many benefits to consumers across various communities, both urban and rural. The anticipated benefits of autonomous vehicles such as better, more efficient vehicle utilization rates and a reduction in the frequency and severity of vehicle incidents, will all help drive down the cost of providing a shared mobility ridesharing platform that integrates autonomous vehicle technology. While the focus of such platform is likely to be in in urban markets at first, the anticipated cost savings of such a platform will make investment in expanding such platform to all communities, including rural communities, more likely. Lyft looks forward to working with you as these technologies continue to develop.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO JOSEPH OKPAKU

Question 1. In her written testimony, Dr. Cummings stated that "the self-driving car community is woefully deficient in its testing and evaluation programs (or at least in the dissemination of their test plans and data)" and that companies should commit to "principled, evidence-based tests and evaluations." How would you respond to these concerns? Do you believe that the self-driving car community, including your company, is testing rigorously enough? If so, should there be greater dissemination and transparency of test plans and data?

Answer. At Lyft, safety has always been the cornerstone of our business model, and it will continue to be the foundation for our evolution into the autonomous vehicle space. We fully agree with Dr. Cummings' statement that "principled, evidence-based tests and evaluations are needed." Lyft announced its partnership with GM in January 2016 to, among other things, grow an autonomous vehicle on-demand network. This joint partnership will leverage GM's deep knowledge of autonomous technology and Lyft's capabilities in providing a broad choice of ride-sharing services to consumers. Lyft will not be manufacturing the actual autonomous hardware that is subject to the testing referenced by Dr. Cummings. Our role is to remain focused on consumer networks and providing a safe, established, and affordable means by which to build consumer support, awareness, and comfort with self-driving cars.

Lyft will continue to work with GM and regulators to ensure that each vehicle that any of our passengers enters is one that is safe, reliable, and secure. This includes ensuring that any autonomous vehicle that integrates with the Lyft platform has undergone and passed a rigorous testing and validation process. While we disagree with Dr. Cummings' statement that "the self-driving car community is woefully deficient in its testing and evaluation programs," we are always supportive of a more open dialogue about transparency and seeking the right balance between

sharing of information, protection of consumer privacy, and safeguarding proprietary business information.

Question 2. As you may know, NHTSA is working on new guidance to states, policymakers, and companies on self-driving vehicles. Do you believe that NHTSA has sufficient expertise, in terms of staffing and resources, to guide the development of autonomous vehicles?

Answer. Similar to the Transportation Network Companies (TNCs) in the rideshare industry, there is no regulatory precedent for the new autonomous vehicle industry. Thoughtful and targeted regulations need to be developed to allow for innovation, fair competition, and adequate safety standards.

Lyft looks forward to working with NHTSA on its guidance to be released in the summer of 2016. To date, Lyft has not engaged directly with NHTSA on its proposed guidance, but Lyft commends NHTSA for its foresight to engage in this discussion at this time and for the thoughtful and open manner in which it has undertaken this task. Given that we believe the forthcoming guidance is only the first step in the development of sound, uniform policy regarding autonomous vehicles, Lyft would support increased funding to NHTSA to further build and strengthen its staff and core competencies with regard to autonomous vehicles.

Question 3. Specifically, what, if any, additional authorities should Congress consider providing NHTSA to allow for safe deployment of autonomous vehicles?

Answer. Lyft does not have insight into any additional authorities that NHTSA may need at this time, and would defer to the agency to express its needs to Congress.

Question 3a. Should Congress provide authority to an agency, such as the Federal Trade Commission, to issue privacy and data security rules for autonomous vehicles?

Answer. We do not believe that Congress should, at this time, provide additional authority to issue privacy and data security rules specifically for autonomous vehicles. We anticipate AV technology will evolve quickly, whereas by its nature the regulatory and rule-making process is comparatively slow. Even well intentioned regulations or rules issued now to protect against data security or privacy threats could quickly become obsolete.

However, Lyft would welcome an opportunity to partner with NHTSA, DOT, FTC or other appropriate agencies to develop industry standards that address data security and privacy concerns without unduly burdening new and promising technology and business models relating to autonomous vehicles. In this regard, it should be noted that the FTC already believes it has the general authority to safeguard against privacy and data security violations. See generally, *https://www.ftc.gov/news-events/media-resources/protecting-consumer-privacy,* stating:

> "The FTC has been the chief Federal agency on privacy policy and enforcement since the 1970s, when it began enforcing one of the first Federal privacy laws—the Fair Credit Reporting Act. Since then, rapid changes in technology have raised new privacy challenges, but the FTC's overall approach has been consistent: The agency uses law enforcement, policy initiatives, and consumer and business education to protect consumers' personal information and ensure that they have the confidence to take advantage of the many benefits of the ever-changing marketplace."

Given the FTC's involvement in privacy enforcement, we have confidence that the Commission can and will use their existing authority to address improper conduct relating to data security and privacy in connection with autonomous vehicles.

Response to Written Questions Submitted by Hon. Gary Peters to Joseph Okpaku

Question 1. What data does your company collect from cars, and how are you storing it on your own systems?

Answer. Lyft currently neither owns nor operates cars, and therefore collects no data from cars. During the driver onboarding process, Lyft collects general identifying information regarding vehicles, such as the make, model and year of vehicles, which is required to comply with regulatory obligations in jurisdictions where it operates. Lyft also collects evidence of compliance with local vehicle inspection requirements.

Question 2. How is that data being protected from privacy and from cyber threats?

Answer. Lyft maintains an information security program to prevent unauthorized access, destruction, modification, transfer or disruption of Lyft systems and infra-

structure that store, host, process, or dispose of the data we collect to operate the Lyft service. Lyft's security engineering team is primarily responsible for the Lyft information security program and works closely with the engineering, IT, and legal teams to handle cross-functional security projects and issues. The information security program is designed to prevent, detect, and respond to security incidents that may compromise data confidentiality, integrity, and accessibility, including but not limited to, unauthorized computer or network access, compromised systems or credentials, malware attacks such as viruses, Trojan horses, and worms, password cracking, denial of service, network spoofing, phishing, social engineering, non-malicious employee misuse or error, and lost or stolen digital devices.

Lyft is hosted entirely on a third party cloud infrastructure, which is standard across the technology industry, and provides a strong security foundation and physical security controls. The cloud infrastructure has achieved numerous compliance certifications, including ISO 27001 and SOC 2. Internally, Lyft implements and maintains measures to prevent and detect security vulnerabilities prior to any security incident. These measures include network access controls and segmentation, network monitoring technologies to detect and investigate anomalous activity, automated configuration management tools, monitoring and identification of security vulnerabilities. Lyft also places strong limitations on employee and machine access to the cloud infrastructure, limits employee access to applications and data (including customer data) on an as-needed basis, subjects employees to a responsible data usage policy, uses single-user accounts, strong authentication mechanisms, and does not collect or store payment card data. Furthermore, the security team is involved in all stages of software development process and all changes to Lyft applications and infrastructure are subject to approval through this process.

Lyft's information security program is also designed to address and respond to security vulnerabilities and data incidents, should they occur. Our information security program includes a privacy and data security reporting policy, an incident response team, and an incident response plan that clearly establishes policies and procedures to identify, assess, investigate, escalate, and respond to security vulnerabilities and incidents. Upon identification of a potential security vulnerability, the security team mitigates and resolves the issue in a timely manner according to the severity of the vulnerability and its likelihood of exploitation. Lyft also conducts regular backups for disaster and incident response purposes and captures and retains log data for debugging, monitoring, and responding to incidents. Finally, Lyft seeks to limit security incidents by training employees on our responsible data use and handling policy, basic security awareness to prevent social engineering, phishing and other network attacks, and escalation policies.

Question 3. As the software and operating systems of GM vehicles offer increasing automated functionality, it is possible that liability will swing towards the manufacturers.

Question 3a. Do you expect automakers to assume more liability at higher costs?

Answer. We agree that this is an important question, but it is probably too early for anyone to predict how litigation risk and liability will shift. However, as safety experts and industry leaders acknowledge, autonomous vehicles will significantly reduce the number of accidents leading to injuries and fatalities on our Nation's streets and highways. Thus, even if manufacturers and operators of autonomous vehicles wind up taking on a higher proportion of litigation risk—risk that in essence is being shifted from drivers—the inherent safety of this technology will reduce litigation and overall exposure to liability. We are confident that our court system, our common law jurisprudence and our insurance markets have sufficient flexibility to evolve along with autonomous vehicle technology, and look forward to working with Congress to ensure that it does so in a fair and efficient way.

Question 3b. How could you see this potential shift affecting suppliers and consumers?

Answer. Please see above.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. BILL NELSON TO DR. MARY CUMMINGS

Question. In light of the concerns you raised about the inherent limitations of human-automation interaction, would you say that Google is taking the better path by developing completely self-driving cars instead of the many other companies that are developing and commercializing numerous semiautonomous features as stepping stones to fully self-driving cars?

Answer. There is no one "right path" in terms of developing self-driving cars. Because of known issues with human inattention and propensity for distraction,

Google X is moving towards a fully autonomous car. This could be a good path but it assumes that the technology is mature enough to function in all weather conditions, under all driving scenarios including low probability events, and in mixed vehicle settings, *i.e.,* where human drivers of widely varying abilities still command vehicles that have no advanced technology on them. If the technology is not mature enough (which it will eventually be but is not currently), then these vehicles should only operate in limited environments with significant safety controls in place.

Other companies are choosing the "optionally-operated" concept where the technology provides driver assistance. While more achievable in the near-term, driver assist is also not a perfect technology in that most systems require humans to pay attention under dynamic conditions, which is not likely in the typical driving population. However, this stepping stone approach allows manufacturers to introduce incremental functionalities in limited releases that can be assessed and modified. But because of the need to still include the human in the loop in some capacity, manufacturers of these partially capable systems need to pay much more attention to the human-technology interaction aspects of their designs, which few companies are doing.