TESTIMONY

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Before the

House Committee on Transportation and Infrastructure

Subcommittee on Highways and Transit

November 19, 2013

Autonomous Driving Technologies: On the Road to Reality

Thank you Chairman Shuster, Ranking Member Rahall, Chairman Petri, and Ranking Member Holmes Norton for convening this important hearing and for your pioneering leadership in supporting innovations that have the potential to bring cost-effective improvements to highway safety and efficiency. I am honored to share my views as a researcher working with my colleagues at Carnegie Mellon University and the University of Pennsylvania who are part of our joint U.S. DOT National University Transportation Center (UTC) for Safety, which is dedicated to the invention and adoption of technologies that aim at the ultimate goal of zero traffic fatalities. Our work is also supported by the Hillman Foundation based in Pittsburgh.

Our center, Technologies for Safe and Efficient Transportation, or T-SET, focuses on not only developing technologies to improve safety, but also deploying them. We are proud to have over 40 partners in an active consortium, whose goal is to accelerate the transfer of technologies from our research lab to commercial use in the transportation sector. Our work is also supported by the National Science Foundation through the Cyber-Physical Systems (CPS) program. "Cyber-physical systems" utilize the cyber capabilities of computing and communications to monitor and control aspects of the physical world. Autonomous vehicles represent a classical example of cyber-physical systems, where sensors obtain information about the rapid changes in the immediate environment, computers communicate among themselves to process the information in real-time, and send commands to actuators that steer, brake and apply the throttle. All these operations have to be carried out safely, reliably, securely and cost-effectively. The fundamental scientific building blocks of cyber-physical systems have broad applicability to many other domains including smart grids, aerospace, manufacturing, process control, healthcare, medical devices, agriculture, and all modes of transportation including transit.

This hearing is very timely because there is tremendous excitement building around autonomous vehicle capability not only in industry and academia, but in the minds of the traffic-weary traveling public.

Rapid advances in technologies are bringing the promise of autonomous driving within sight. Such a fundamental and historic transformation in transportation would arguably be rivaled only by the introduction of the automobile at the turn of the last century.

Today, we can undoubtedly envision a future of driving that is dramatically safer, more energy-efficient, more sustainable, more productive and, of particular interest in our major cities like Washington D.C., less congested.

Autonomous driving technologies can also contribute to completely new transportation paradigms that can generate significant cost savings for American taxpayers. Vehicles can travel closer to each other, utilizing available roads better and traveling at uniform, and therefore faster, speeds. Finally, these technologies are also contributing to a new wave of innovation led by our automotive industry, which can contribute to growth across the entire U.S. economy and create new jobs. This in turn will keep the nation as the global leader in intelligent transportation systems.

It is essential that we move forward with a clear vision of the future we seek to invent and build. While autonomous technologies are a catalyst to fundamentally transforming transportation, the well-being of our fellow citizens should always be at the center of this vision. This underlying principle, I believe, should guide both technology and policy development.

My testimony will focus mainly on the technologies and their promise. I wish to emphasize the critical importance of fostering a comprehensive approach to technology development. Specifically, my testimony will highlight the importance of continued investment in basic research to address significant technical challenges that remain in the way of achieving fully autonomous vehicle travel. It will also touch upon the need to integrate technology and policy development in order to accelerate innovation and adoption.

Mr. Chairman, the grim statistics that call out for the pursuit of technologies to make our vehicles and roads safer are well known to the members of this Committee, but they are worth re-capping to underscore the urgency of this need and the fundamental reason we are here today.

More than 1.2 million people die globally each year as a result of traffic accidents. These accidents are the number one cause of death of individuals between 10 and 24 years of age. The economic cost of these accidents is estimated to be about 518 billion dollars per year. However, the staggering loss due to the suffering of those left behind as well as the lost contribution to society of those whose lives ended prematurely is incalculable.

The average American spends one work-week per year stuck in traffic delays. The European Union estimates that traffic delays cost the continent 80 billion euros per year in lost productivity. The loss of independence faced by aging and disabled people who can no longer drive, as well as the burden placed on their families, is also significant and merits special mention.

Autonomous driving is a realistic and near-term prospective solution to these challenges. Indeed, as Chairman Shuster recently showed through his willingness to experience CMU's driverless vehicle firsthand on a 33-mile ride on September 4 in Pittsburgh, autonomous vehicles have already arrived in the sense that they have been shown to be feasible and practical in real-world, unconstrained street and highway traffic conditions. We are very grateful for his leadership as well as that of the Members here today in recognizing the importance of this emerging technology.

An autonomous vehicle is really the convergence of a host of technologies. It is a system built on breakthroughs in sensing and actuator technologies, and continuing improvements in computing and communications. Put another way, autonomous driving is an emerging and welcome result of the rich foundation of federal investments in basic research in engineering, computer science and robotics. However, it is also built upon steady and continuous innovations incrementally deployed by the automotive industry to harness advanced driver assist systems for safety and driver comfort. For example, adaptive cruise control systems and lane departure warning systems leverage advances in sensing, computer vision and distributed real-time processing. These cutting-edge technologies exist in some commercially available cars today.

The seminal turning point in the pursuit of the grand vision of autonomous driving was the Urban Grand Challenge sponsored by the Defense Advanced Research Projects Agency within DoD. The DARPA Urban Challenge, won by a team from Carnegie Mellon University in 2007, demonstrated the potential of autonomous driving in an urban setting. However, that Challenge, featuring heavily-instrumented experimental prototype vehicles, featured no pedestrians, only limited traffic, constant and uninterrupted access to GPS services, and only daytime driving in clear weather conditions.

Bringing autonomous driving into reality requires continued fundamental research to address the challenges presented by poor weather, non-ideal road surfaces, different lighting conditions, fixed and moving obstacles--- from fallen trees to darting children, and the need for redundancy to ensure safe recovery from any failure of sensors, actuators, computers or communications networks. Fundamental advances must also be made in the capability to verify and validate the correct and secure operations of autonomous driving systems. While extensive testing will always be needed, a countless number of possibilities can be encountered on the roads. Technologies to model and verify operations under all possible conditions will allow the public to gain confidence in the reliability of autonomous driving systems. Research into prognostics to locate problems before they lead to vehicle failures would significantly enhance the reliable day-to-day operations of large fleets of autonomous vehicles. Since intruders and other malicious attackers can potentially cause major damage, core research challenges in enforcing the security and privacy of these cyber-physical autonomous systems must also be addressed.

These are just some of the technical challenges I referred to earlier.

Besides addressing these fundamental scientific challenges and technology gaps with active support from General Motors, the National Science Foundation and the US Department of Transportation, we at Carnegie Mellon University have been working to improve the aesthetics of the autonomous vehicle in order to create a product that consumers will actually want to purchase. We envision a future where autonomous driving capabilities dramatically reduce accidents, improve productivity, enhance the quality of life for the elderly and the physically disadvantaged, reduce pollution, improve gas mileage and decrease material costs—all without abrogating the role of the automobile in American life.

One pivotal research thrust that will accelerate the safety and reliability of autonomous driving capabilities involves connected vehicle (V2V) technologies. The US Department of Transportation has rightly placed heavy emphasis on connected vehicles, which enable automobiles to communicate with one another and with the infrastructure. The accurate and reliable operation of autonomous vehicles will be significantly improved by the seamless integration of automation and connected vehicles. Vehicle-to-infrastructure (referred to as V2I) integrates sensing and robotic systems to enable communications between the vehicle and the fixed infrastructure through which it must navigate. V2I and V2V together will lead to dramatic improvements in safety and noticeable reductions in congestion.

Carnegie Mellon has developed a 1.8 mile test-bed with 11 instrumented traffic lights along a highway in the township of Cranberry, 20 miles north of Pittsburgh. In the next year, a larger test-bed will be developed near the Carnegie Mellon campus to further extend these capabilities.

V2I and V2V systems can provide benefits that extend beyond accident avoidance. These systems can remarkably enhance real-time signalization—reducing travel time, fuel consumption and pollution. And we have only just begun to imagine the future possibilities. For example, researchers at Carnegie Mellon are exploring opportunities for V2V systems to be used by bicyclists and pedestrians. Similarly, the Big Data opportunities created by vehicles which can talk to each other and the infrastructure will yield innovations in mobility analytics to identify and resolve traffic bottlenecks, to help emergency responders and to better integrate different modes of transportation including transit. Finally, research at Carnegie Mellon University is also exploring advances in sensing and computations to create more accurate and detailed bridge and highway monitoring capabilities at a small fraction of the cost of current systems.

While all of this technology holds great promise for dramatically improving roadway safety and efficiency, the following are some considerations for policymakers.

First, we should exercise caution in rushing to deploy technologies before ensuring that they can be fully trusted. For the foreseeable future, a human must continue to sit in the driver's seat even if the vehicle is driving itself. The role of the human would be to act as a monitor who takes over control when appropriate. To re-state, we should not expect that, in the next few years, automobiles will drive themselves without a human in the loop. Rather, these technologies will continue to advance in discrete steps with a licensed driver in the driver's seat. Only sometime during the 2020s will a fully autonomous system that does not require a human to be in the driver's seat become feasible.

Secondly, we must recognize that the pace of advances and adoption will be predicated strongly on the level of support for continued research. There is enormous global economic opportunity in the future of autonomy in the transportation sector. Ensuring that the US remains at the leading edge of this massive economic opportunity will require serious R&D investments in both basic research and applied test-beds linking industry, universities, companies and communities. This model of collaboration has been at the heart of our work with the University of Pennsylvania, the Pennsylvania Department of

Transportation and our community partners in Pittsburgh and Philadelphia. These models are also at the heart of the vision that the Department of Transportation, the Research and Innovative Technology Administration (RITA) and the National Science Foundation have been aggressively encouraging and pursuing.

Thirdly, we must ensure that policy and regulatory innovations evolve along with the technology. V2I and V2V communications may also require new models of multi-governmental coordination on signaling and infrastructure investments. Wireless spectrum allocated to vehicular communications will save lives and property, and any spectrum sharing that is envisioned must not take- away from the safety benefits of these communications. In other cases, the policy agenda may require bringing together regulatory and policy communities that have traditionally acted separately. For example, if vehicles do not crash, they can be lighter and offer better mileage. If vehicle traffic flows better, emissions and fuel consumption drop. We should also engage the auto safety and environmental policy communities, because the implications for new pathways to realizing national goals via non-regulatory means are profound.

Fourthly, we must ensure that adequate privacy and cyber-physical security safeguards are developed and integrated.

Finally, I would add that these challenges should not deter policymakers from pursuing the goal of autonomous vehicles because this technology holds tremendous promise to reduce highway spending. I anticipate that we will see major positive impact on highway spending in the 2030-40 timeframe with investments we make in developing autonomous vehicle technology today.

In closing, I would like to thank the Members of this Committee for the opportunity to speak to you today on an area of research that for me has developed into a consuming passion. It is my hope that, over the next couple of decades, our nation will be able to look back at this moment with pride as one in which our policy leaders joined together to work toward a vision that profoundly transformed our economy and our lives.