

Written Testimony
of
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Introduction

Thank you, Senator Langerholc and members of the Committee for the opportunity to speak to you today on a topic so vital to the future of Pennsylvania.

My name is Raj Rajkumar. I speak to you as an academic researcher and educator who has devoted nearly two decades to advance technologies that improve transportation safety. I direct Mobility21, a National University Transportation Center sponsored by the US Department of Transportation. The Mobility21 team is led by Carnegie Mellon University and our team includes the University of Pennsylvania, the Community College of Allegheny County and the Ohio State University. This work has been at the frontier of autonomous vehicle technology working closely with both industry and government, including PennDOT, members of the General Assembly and local government officials. I was honored to be among the founding members of the Pennsylvania Autonomous Vehicle Policy Task Force. I also come with the perspective of an AV tester, having tested AVs on Pennsylvania roads safely since 2013, and am one of the original AV testers registered with PennDOT.

I also speak to you today as an entrepreneur and job creator who has built a company and experienced first-hand the potential of this technology to contribute to economic development and reduce vehicle crashes¹ in Pennsylvania. The AV software company, Ottomatika, I founded in 2013, was acquired in 2015 by Delphi, which then became Aptiv and is now Motional, helping to spark the growth of Hazelwood Green with over 100 employees. These workers join 3,000 others throughout the Pittsburgh region, most working at other CMU spin-outs or related firms. In addition to advancing AV technology, the breakthroughs from these firms help anchor over 100 robotics and AI firms in the region in markets ranging from logistics, smart infrastructure, agriculture, energy to health care.

¹ In 2020, there were 1,129 automotive fatalities in Pennsylvania.

This hearing comes at an inflection point requiring prompt and decisive action. Continued advances in connected and autonomous vehicle (CAV) technology will be vital to the future of Pennsylvania and the nation. CAV technologies are essential to end the scourge of **vehicle crashes** and to realize the full potential of smart transportation applications, accelerate the transition to electric vehicles and build the 21st century logistics system that will contribute to the competitiveness of our manufacturing base. CAVs will also provide a means of transportation and independence to differently-abled people, seniors and residents of rural and suburban areas without access to public transit. In fact, providing equitable transportation access to all is a primary goal of our Mobility21 National University Transportation Center at Carnegie Mellon University.

This moment in time demands a focused commitment to the paramount need for safety that is combined with a clear vision and policy framework that charts a well-defined path to deployment. My remarks will seek to speak to this challenge by touching on three key topics. First, I will highlight how integral Pennsylvania has been to the growth of this technology and industry, and how this past record of accomplishment helps inform the path forward. Secondly, I will briefly review the key technology trends and market segments that are defining the growth of CAV-related applications. Finally, I will outline some core principles and considerations to help secure Pennsylvania's continued leadership in this vital frontier of innovation and ensure that the benefits of these breakthroughs reach all regions of our state.

An Industry Born in Pennsylvania

The autonomous vehicle industry is truly a Pennsylvania industry – due in no small measure to the history of collaboration among the Commonwealth, academia and industry. Carnegie Mellon is a birthplace of autonomous vehicle technology, and its collaboration with the Commonwealth was essential for the earliest days of this work. The university traces its roots in this field to work undertaken to aid the clean-up of Reactor #2 at Three Mile Island in 1983. The development of an autonomous cart created to help navigate inside the radioactive reactor was the seedling of CMU's AV research and what is now a global industry with a potential market size of several trillion dollars per year².

My research is advancing what is now Carnegie Mellon's 16th-generation AV and the collaboration with the Commonwealth has continued to grow and advance this innovation frontier together.

In August 2013, just weeks before the public was aware about Google testing AVs on roads in California, I had the honor to host then-PennDOT Secretary Barry Schoch and Congressman Bill Shuster on a 33-mile autonomous ride from Cranberry Township to the Pittsburgh International Airport. The journey started from a community park with a 10-mph speed limit, included 11 traffic lights along Route 19 instrumented with Vehicle-to-Infrastructure (V2I) communication capabilities, traversed I-79S and I-376W requiring changing lanes at highway speeds, and finally ended at the PIT Departures terminal. This landmark ride was part of a conscious effort to make Cranberry Township one of the first communities in the world to pioneer the deployment and use of V2I technology.

² The Verge, "Intel predicts a \$7 trillion self-driving future", <https://www.theverge.com/2017/6/1/15725516/intel-7-trillion-dollar-self-driving-autonomous-cars>.

Funding provided by Pennsylvania Act 89 of 2013 was an important part of Pittsburgh's finalist proposal to the 2016 US DOT Smart City Challenge and the subsequent \$11 million US DOT Advanced Transportation Congestion Management Technology Deployment (ATCMTD) grant to develop the City of Pittsburgh's *Smart Spines* plan and expand its connected vehicle testbed. There have been many additional collaborations. As one example, a groundbreaking research study to prepare the state for emerging CAV technologies was carried out in 2014 by my colleague Chris Hendrickson with a report titled "Connected and Autonomous Vehicles Vision 2040". Mobility21 has had the privilege and honor of having the current PennDOT Secretary, Yasmin Grammian, and the former PennDOT Secretary Leslie Richards as members of its Advisory Council. Carnegie Mellon University has also had the opportunity to work closely with PennDOT on the PA AV Summits organized and hosted annually by PennDOT. The next chapter in this collaboration is work that I am just now beginning with PennDOT on a US DOT-funded project to demonstrate and evaluate the safe operation of CAVs in construction zones. The explicit goal of the project is to explore how to bring greater safety to our frontline construction and transportation workers. Too many construction zone workers are lost to drivers not paying attention to the road³. This project is part of the US DOT's Automated Driving System Demonstration Grants program, and is the largest of the funded efforts under the program.

A Look Ahead I: Pathways for the Future Growth of CAV-Related Technologies

We will need to draw upon the rich history of collaboration among government, academia and other stakeholders to ensure that the ongoing safe development of CAV technology continues to generate employment, opportunities and innovation in Pennsylvania.

The starting point is to focus on the scale and the scope of CAV technology. Self-driving technology involves a "stack" of integrated technology subsystems including computing hardware, sensing, vision and communication technologies. It also includes several inter-woven software layers with algorithmic and AI architectures that enable the processing of millions of data items per second.

The continued development of self-driving technology is dependent upon both separate and integrated advances in these layers of the stack. Self-driving applications are also dependent upon and contribute to advances in computing, software, networking and artificial intelligence in fields ranging from health care to manufacturing and warehouse logistics.

Self-driving vehicles are also part of a convergence of technologies that will transform transportation and the environment of Pennsylvania urban and rural communities. This convergence involves the synergy among breakthroughs in autonomous vehicle technology, electrification and connectivity. My research has demonstrated that CAV technology and the enhanced sensing, communication control capabilities it is enabling will be essential to support the scaling of electric vehicles as well as greener applications in rail and shipping.

Similarly, AV technology will be significantly enhanced by the deployment of 5G and follow-on generations of wireless technology, while also extending the reach of this technology to realize the potential for significant energy and efficiency improvements in the economy. The opportunity to integrate CAV technologies with smart grid, smart road infrastructure and smart building applications

³ According to [PennDOT data](#), in 2019, there were 1,754 work zone crashes, resulting in 16 fatalities. Since 1970, 89 PennDOT employees have died in the line of duty.

could be transformative in addressing the climate challenge and generating a wide range of emerging service industries. This necessitates that we continue to invest in and support pilot deployments of edge computing and Vehicle to Everything (V2X) technologies that enable self-driving vehicles to communicate with virtually all elements of the infrastructure around them.

Several distinct market and application segments are emerging. These segments include the following:

- Robotaxis: vehicles without any human operator, possibly without a steering wheel, gas and brake pedals – used to provide dedicated or shared rides;
- Passenger vehicles: individually-owned consumer vehicles that drive themselves in well-tested domains which become larger over time. Early-stage driver-assist features like lane keeping assist and blindzone alerts are already being introduced into passenger vehicles and this trend will continue—and save lives;
- Road-worthy delivery robots: vehicles that drive on public roads but carry only goods and no passengers for delivery;
- Personal delivery devices: vehicles that move at pedestrian speeds on sidewalks to deliver food and medicine within a community (neighborhood or campus);
- Long haul trucks: semitrailers that are a backbone of the nation’s economy and;
- Public Transit: vehicles that could be used in coordination with existing mass transportation.

The diversity of these market segments also highlights how central the technology will be to shaping the future of a comprehensive transportation system that can better meet the needs of individuals, communities and industry. It is expected that self-driving ground vehicles will fuse with autonomous system breakthroughs in drones to revolutionize agriculture as well as personal transportation, the shipment of goods and even health care services.

A Look Ahead II – Considerations for Ensuring Pennsylvania’s Continued Leadership

A recognition of this evolving web of innovation is the starting point for ensuring that Pennsylvania remains the world leader in the safe development of AV technology. Here are three core principles that could help inform such a strategy.

A. Build a Safety-First Strategy for Accelerating Testing and Creating a Clear Path to Deployment

Safety is paramount and cannot be compromised. Safety will be enhanced by creating clearer and more uniform approaches to AV testing. Such a framework needs to be flexible to incentivize and enhance industry investment within Pennsylvania in advances that address critical safety needs.

As the General Assembly has already demonstrated in action taken last year, this regulatory framework should not seek to create a one-size-fits-all approach for the various self-driving market segments. The regulatory approach should specifically take into account the distinct elements and nature of the different application areas.

This framework must also provide a clear and defined path to real-world testing and the conditions for driverless testing. Completely driverless testing permits can be obtained already in the states of Arizona, California, Michigan and Nevada. If Pennsylvania does not permit such operations, an industry

whose core technology was created within the Commonwealth will unfortunately but certainly migrate elsewhere. Not unlike other market dynamics over large emerging industries, states are competing to attract the leading companies along with their employees, investments, as well as the host of indirect and induced jobs that will be created. It will be important to both benchmark advances in other states and build collaborative partnerships within our Commonwealth that can assist in the safe scaling of testing and deployments.

One model for this approach is the nation's first multi-state connected and automated vehicle testbed, the *Smart Belt Coalition*⁴, launched by Pennsylvania, Ohio and Michigan. This coalition, originally proposed by Carnegie Mellon University, brings together transportation agencies, industry and academia to create coordinated demonstrations of key AV technologies. In November 2020, the Coalition hosted an automated truck platooning demonstration from Detroit to Pittsburgh to help inform the multi-jurisdictional policy needs for a national AV platform.

Direct collaboration with and support from the federal government to advance AV and smart community testbeds is another critical strategy whose timing is immediate and urgent. Proposals currently pending in the federal infrastructure package, the re-authorization of the FAST Act, President Biden's FY22 proposed budget and major science funding proposals will enable a major Pennsylvania effort on safety, automation, electrification and testbeds.

B. Continue to Invest in and Develop the Infrastructure that will Catalyze CAV Growth

The overarching goal of CAV technology is to improve safe and efficient mobility. The acceleration of EV adoption and smart community applications also depends on a strategy that recognizes CAV technology as a component of a broader information technology infrastructure. Strategies and policies to accelerate 5G deployment, improve edge-computing applications and Vehicle to Everything (V2X) capabilities will be essential. This integration will also help inform how CAV-related technologies can address other critical policy challenges including improving infrastructure monitoring and maintenance, creating broadband access opportunities for all citizens, enabling a smart grid infrastructure and lowering the cost of smart traffic signalization services. Just like Pennsylvania created the first superhighway in the nation, we now have the leadership opportunity to define national safety standards for AVs: these include how to design safe construction zones, make road objects more visible to human drivers and AVs, and how to enable the long transition from advanced driver assist technologies to driverless vehicles.

C. Take the Challenging Policy Issues Head On

Finally, the same foresight and boldness that Pennsylvania government leaders and innovators have brought to launch the CAV revolution for the world should be brought to addressing key challenges the full-scale deployment of this technology will bring. These challenges include impacts on the future of jobs and the skills needed as the nature of work in a broad array of industry segments evolves.

The introduction of self-driving technology is likely to transform the nature of jobs rather than eliminate occupations. Transit and truck drivers in particular do *much* more than driving, serving as concierges, helping hands and security personnel among other roles. It is likely that these roles will expand as autonomy is introduced into operations to reduce the count and severity of safety incidents. But these

⁴ https://www.paturnpike.com/pdfs/business/Smart_Belt_Coalition_Strategic_Plan_Aug_2017.pdf.

are not issues that can be “thrown over the transom” to be resolved after CAV deployment. Breakthroughs this transformative necessitate social innovation as well as technological advances.

Labor organizations should be engaged directly in university research advancing the frontier of CAV technology. Carnegie Mellon is in the early stages of designing a model for this collaboration with a project bringing together the perspectives of transit unions to the development of autonomous transit technology. These collaborations can help inform training as well as new job creation opportunities and bring the perspective of the worker—whose domain expertise on safety and operations is incredibly valuable—to the research enterprise.

Pennsylvania can be the national leader in advancing the re-skilling and education programs needed to ensure that this innovation frontier generates broad opportunities. Similarly, we must engage in pilot initiatives and programs to ensure that AV technology is not yet another contributor to widening the urban-rural opportunity gap. This requires exploring new models of collaboration and innovative applications for CAV-related technologies targeted to rural communities and economies.

Carnegie Mellon University is an integral part of efforts and collaborations with partners in Pittsburgh and across the Commonwealth including the Community College of Allegheny County’s Automotive Technician Training Program and the Pennsylvania Rural Robotics Initiative. These partnerships can serve as early models for action in both these areas. Without doubt, Pennsylvania can lead the nation in the policy and partnership innovations that can address these challenges.

Conclusion

I have had the honor of being among the first Pennsylvania licensed testers of AVs and CAVs and have engaged in testing not just in Pittsburgh but other regions⁵ of our great Commonwealth as well. This experience has deepened my strong belief in the potential of this technology to save lives and enhance the vitality of communities throughout Pennsylvania.

Yet, it is critical to note that this future of AV leadership within the Commonwealth is *not* a given. Pennsylvania’s technology and policy boldness and vision at the dawn of this innovation help inform the path forward. We must strive to establish and extend our continued leadership in the job and business growth and community impact that deployment of this technology will bring. There is strong and focused competition on AV technologies and deployment from not only other states in the nation but also international rivals like China. So, our leadership in the quest to grow jobs, businesses and communities that the deployment of this technology will bring is unfortunately not assured.

This hearing and your committed engagement and leadership represent a critical step in ensuring Pennsylvania’s ability to seize and shape the future. The time is now.

⁵ We have given CAV rides to the Governor of Pennsylvania, PennDOT Secretary, State Senators and Representatives in Harrisburg around the Capitol. We have also provided autonomous rides in Gettysburg to high-ranking police officers from multiple states. We also regularly provide AV demonstrations to dignitaries visiting Pittsburgh and Carnegie Mellon University.