Written Testimony of
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DELPHI

Thank you, Chairwoman Comstock, Ranking Member Lipinski, and Members of the Subcommittee on Research and Technology, for giving me the opportunity to testify today on behalf of Delphi.

My name is Jeff Owens, and I am Chief Technology Officer and Executive Vice President for Delphi Automotive. I am responsible for Delphi's innovation strategies as well as leading development of the company's advanced technologies.

As a leading global supplier of electronics and technologies for automotive, commercial vehicle and other market segments, 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 and Mississippi that employ approximately 5,000 people. Delphi's technology portfolio places us 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.

Like the Science Committee, Delphi has a long history of dedication to technological innovation. We have produced a long-line of innovative firsts dating back over a century. In 1911, Delphi produced the first electric starter; in 1936, the first in-dash radio, and the first integrated radio navigation system in 1994. In April of this year, Delphi performed the first autonomous vehicle cross-country drive.

Today I will give you an overview of the cross-country drive and discuss some of the lessons learned from the trip. I will discuss the technologies that made the trip possible, in particular active safety technology that is not only vital to the eventual success of autonomous vehicles but is available in the marketplace and saving lives today.

I will also discuss some of Delphi's and the Department of Transportation's current research priorities and actions the federal government could take to set the stage for autonomous vehicles in the future.

I will begin with a short video showing the cross-country drive and highlighting some of the Delphi technologies that made it possible.

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[1 minute video clip]

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 take-over if the car encountered a situation the vehicle could not clearly navigate on its own. It is a testament to the technology that we encountered very few such situations. Again, 99 percent of the drive required no additional driver input.

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 and vision systems**: Our vehicle uses a combination of short- and long-range radars—Electronically Scanning Radars (ESR) and Short Range Radars (SRR) in a 360^o configuration. The ESRs specialize in long-range sensing functions, such as adaptive cruise control and cross traffic detection.

- **Vision:** The vehicle is equipped with 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 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 systems become more complex and computing technologies become more capable and with much higher processing power, it enables re-architecting the vehicle. This creates a need for multi-domain control where the architecture can be optimized for control, functional safety and complex sensor fusion systems for automation.

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 with the hardware. Vehicle technology is increasingly software based and dependent. If you don't get the software right, the car will not function.

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.

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 couple of quick 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 tweak 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 drive -- 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, also known as Advanced Driver Assist Systems (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 accidents.

Need for broader adoption of active safety

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 accidents 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 accidents, 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% 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 autonomous cars of the future. A key element of broader penetration of active safety technologies in the US fleet is consumer awareness and demand.

How the government can help -- Modernize NCAP

The driving public is very interested in buying cars with improved safety features. There are numerous technologies currently available, but it is relatively difficult for consumers to decipher the value of various safety technologies. One of the best consumer tools to highlight these features is the New Car Assessment Program, or NCAP – which includes the 5-star rating system that appears on all new vehicle window stickers.

Unfortunately, NCAP is currently outdated and not structured to accommodate active safety vehicle options. That is why Delphi supports amending the NCAP to require the 5-star ratings system include active safety technology. These are mature technologies that have been on the road since 1999 and are ready to deploy in high volume, resulting in greater consumer awareness and choice, and a reduction in accidents and fatalities. While these technologies are currently in use, they are in relatively few vehicles. At the current rate of acceptance, it is estimated that active safety technologies will not significantly impact crash statistics for more than a decade.

Incorporating active safety into the NCAP 5-star rating system would help save lives on the nation's roadways. Focusing on Collision Imminent Braking (CIB) and Lane Departure Warning (LDW), at least for initial ratings, will help drive consumer awareness and choice as well as enable technology for future autonomous vehicles.

There is no need to mandate measures or choose technology winners and losers. The best path is to provide consumers with information in a form that they can use and to which the market will respond. And the sooner we provide these choices, the sooner we experience lower fatality rates on our nation's roadways.

Delphi participation with DOT research

Delphi participates in the Department of Transportation Intelligent Transportation System (ITS) program. Delphi is part of the Crash Avoidance Metrics Partnership (CAMP) along with GM, Ford, Mercedes-Benz, VW, Toyota, Nissan, Honda, Hyundai-Kia, and Continental. CAMP is a public-private consortium which conducts pre-competitive research on intelligent transportation technologies in vehicles. In May 2013, the Federal Highway Administration (FHWA) entered into a 5-year, $45 million cooperative agreement for "projects designed to enable the successful deployment of vehicle-to-infrastructure (V2I) crash avoidance and driver information applications in passenger vehicles."

The ITS program plays an important role in enhancing the government's ability to ground-truth 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, however, on needed analysis and research on 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 US 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 subcommittee today. Delphi looks forward to playing an important role in the road to autonomous 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.