

Testimony of Michael Mansuetti

President

Robert Bosch LLC



BOSCH

Driving Automotive Innovation and Federal Policies

Senate Committee on Commerce, Science and Transportation

United States Senate

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Background

In North America, the Bosch group of companies (“Bosch Group”) employ nearly 32,800 associates (with more than 18,000 in the U.S.) in more than 100 locations, as of December 31, 2016. In 2016, Bosch generated consolidated sales of \$13.7 billion in the U.S., Canada and Mexico.

The Bosch Group is a leading global supplier of technology and services. The global group of companies employ roughly 390,000 associates worldwide (as of December 31, 2016) and generated sales of \$80.9 billion in 2016. The operations are divided into four business sectors: Mobility Solutions, Industrial Technology, Consumer Goods, and Energy and Building Technology.

As leaders in IoT, Bosch offers innovative solutions for smart homes, smart cities, connected mobility, and connected industry. We use our expertise in sensor technology, software, and services, as well as our own IoT cloud, to offer customers connected, cross-domain solutions from a single source. Our strategic objective is to create solutions for a connected life, and to improve quality of life worldwide with products and services that are innovative and spark enthusiasm. In short, Bosch creates technology that is “Invented for life.” The Bosch Group comprises Robert Bosch GmbH and the roughly 440 affiliates in some 60 countries. Bosch’s global manufacturing, engineering, and sales network covers nearly every country in the world. The basis for Bosch’s future growth is its innovative strength. At 120 locations across the globe, Bosch employs 59,000 associates in research and development.

Chairman Thune, Ranking Member Nelson, members of the Committee, thank you for the opportunity to testify before you today.

My name is Mike Mansuetti and I am the President of Bosch North America.

Robert Bosch founded the company in 1886, when he opened the “Workshop for Precision Mechanics and Electrical Engineering” in Stuttgart, Germany. From its inception, the company has focused on the importance of the international market and Mr. Bosch established his first U.S. office in New York City in 1906. The Bosch companies in the United States have now grown to encompass more than 18,000 associates with 25 active manufacturing sites across the country and three dedicated Research and Development Centers (Pittsburgh, PA; Palo Alto, CA; and Cambridge, MA). We maintain a significant presence in Michigan, South Carolina, Illinois, Florida, Wisconsin, California, Kentucky, and Minnesota. Bosch concluded its 2016 fiscal year with \$13.7 billion in consolidated sales in North America. Bosch has four business sectors – Mobility Solutions, Industrial Technology, Consumer Goods, and Energy and Building Technology. Mobility Solutions is our largest sector, comprising approximately 60 percent of our business and representing 217,000 associates worldwide.

Bosch invested more than \$450 million in North America in 2016. In 2016, Bosch opened an expanded technical center in Plymouth, Michigan, and relocated its Research and Technology Center within Pittsburgh. Moving forward, Bosch will invest \$175 million in its Charleston, South Carolina plant to enhance its mobility solutions manufacturing activities at the facility. In December 2017, we were pleased to announce an additional \$152 million of capital investment for our Anderson, SC manufacturing location to accommodate the expansion of our automotive electronics business and to retain additional associates at that site.

The United States remains at the forefront of Bosch’s innovation efforts. We are actively testing Automated Vehicles in Michigan and in California, both on our own as a Tier One automotive supplier and in cooperation with our customers. In 2017, Bosch announced the creation of a new Center of Competence which will focus on Artificial Intelligence. Palo Alto, CA will serve as one of the three key global sites for these efforts. In support of our growth as an Internet of Things (IoT) company, Bosch founded the Chicago Connectory in May 2017. The Connectory serves as a community of entrepreneurially-minded innovators meant to foster cross-domain collaboration among corporate partners, startups and universities to drive the development of new

IoT technologies. The Connectory also provides cutting-edge technology, expert programming, and mentorship from leading experts in IoT. In addition, Bosch offers technical resources, a small prototyping space, as well as mentorship from teams and leaders on topics in manufacturing, software engineering and commercialization. Part of the objective of the Connectory is to revolutionize the way we envision new products within Bosch and bring them to market.

I appreciate the opportunity to appear before you today and to share Bosch's perspective on the transformation of the automotive industry. This hearing is taking place at a critical juncture in our history as an industry. We are witnessing a revolution in almost every aspect of the vehicle, ranging from the method in which we power our cars, to how we handle and transition control of the overall vehicle and to the role that the vehicle of the future will play in the lives of individuals. I would also highlight the growing connection between the vehicle and the other aspects of our daily lives. Bosch is developing new applications that will enable consumers to manage their home, to safely engage in activities such as working and relaxing in the vehicle and to achieve time, economic and environmental efficiencies by avoiding congestion on the roads. I also wish to take this opportunity to express our deep appreciation for the efforts of Chairman Thune, Senator Peters, Ranking Member Nelson and all of the Committee members in sponsoring and passing the AV START Act (S. 1885). Your leadership in this critical area is greatly appreciated by Bosch. The Committee staff took great care to consider the issues that are impacting automotive suppliers and to understand the complex role that we play as incubators and developers of Automated Driving Systems (ADS), software and related components. We wish to acknowledge their hard work over the past year.

Automated Driving and Driver Assistance Systems:

At Bosch, a driving motivation is safety. Above all, we see the potential for automated vehicles and for advanced driver assistance systems to dramatically decrease the numbers of vehicle-related injuries and fatalities, in the U.S. and across the globe. This is our primary driver as we seek to develop, refine and launch these new technologies into the market. We often speak of these advancements in a futuristic manner, but the reality is that automation is already providing tremendous benefits to vehicle drivers and occupants today. Bosch pioneered the active safety system Electronic Stability Control (ESC), also known as ESP, which is deployed in every new

passenger car sold in the U.S. In 2017, the National Highway Traffic Safety Administration (NHTSA) issued a report which found that more than 7,000 lives were saved by ESC during the 5 year period between 2011-2015¹. The technology works by monitoring driver intent and vehicle direction and by automatically applying braking force as needed to prevent a loss of control. Most drivers are not even aware of its support as its activation is reflected solely in the momentary illumination of an indicator light on the dashboard.

As noted above, Bosch is heavily engaged in AV development and testing in the United States. Making automated driving a reality calls for profound understanding of all vehicle systems. Bosch has this expertise, and manufactures most of the key components itself – including radar, video, and ultrasonic sensors, brake control systems, electrical power-steering units, display instruments, and connectivity solutions inside and outside the vehicle. Bosch has more than 3,000 engineers around the world working to make automated driving a reality.

We are using our decades-long experience to ensure the safety of our components and ADS. Automated driving will demand much more than just the fitment of more sensors and cameras, it will require a new vision for the electronic architecture and safety-critical functions of the vehicle. The most highly automated systems available in the market today are classified as SAE Level 2. While the system is able to execute both steering and acceleration/deceleration under certain circumstances, the human driver is responsible for monitoring the driving environment and function as the backup to the system.

In order to realize higher levels of automated driving, we will need redundancy in safety-critical systems such as braking and steering. Bosch is actively developing and bringing to market redundant braking solutions to support all levels of automation. This redundancy is obviously a critical element for SAE Levels 4 and 5, but it will also be important for SAE Level 3 vehicles where a human driver is still necessary, but safety-critical functions may be handled by the vehicle under certain traffic or environmental conditions.

We are enabling redundant braking by replacing the vacuum brake booster with an intelligent electro-mechanical booster, the iBooster. A conventional brake system

¹ DOT HS 812 391, March 2017, Estimating Lives Saved by Electronic Stability Control, 2011–2015

today comprises two actuators: a vacuum brake booster and ESC unit. In this system, in the unlikely situation that a failure occurs in the ESC unit, the human driver would act as the backup by depressing the brake pedal. The redundant brake system for automated driving is comprised of two actuators that are each able to decelerate the vehicle independent of the driver applying the brake pedal. Thus, even if a failure occurs in the brake system, either actuator (iBooster or ESC) is able to avoid wheel lock-up by modulating the brake pressure, which maintains the ability to steer during deceleration.

Redundant steering is also a key technology for automated driving and Bosch is leading in this area. In 2017, Bosch introduced its Electric Power Steering (EPS) system with fail-operational function. The system, which enables either a driver or automated driving system to make a safe stop in the rare case of a single failure, is a key requirement on the path to fully automated driving.

Bosch is forging new alliances, with both traditional partners and unique service providers, to address all of the key factors that will be necessary for automated driving. For example, in 2017, we announced a partnership with Daimler which will focus on Level 4 and Level 5 automated vehicles. In addition, on January 4, 2018, Bosch announced its intent to acquire a five percent stake in HERE Technologies, a global provider of digital mapping and location services. High-definition maps are a requirement for self-driving cars. These must be kept up-to-date with data from the vehicle's sensors and supplemented with real-time information on traffic conditions, congestion, construction sites, and accidents. Bosch's "road signature" uses information from the Bosch radar and video sensors in the vehicle to enrich and update high-definition maps. Consequently, Bosch and HERE are exploring opportunities to utilize road signature in the maintenance of HERE's map for automated vehicles. At the same time, Bosch will be continuing its work on the road signature with partners such as TomTom, AutoNavi, Baidu, NavInfo, and Increment P.

Bosch has built upon the foundational technology ESC, and our industry position as a leading manufacturer of micro-electro-mechanical systems (MEMS) and radar sensors, and mono- and stereo-vision cameras, to create a very broad portfolio of advanced crash avoidance systems that can help prevent an accident from occurring or minimize the severity of its impact. Our product list includes Automatic Emergency Braking, Lane Keeping Assist, Blind Spot Detection, Backover Avoidance Systems and

Pedestrian and Rear Auto Braking systems. Bosch's Corporate Research and Technology Center estimates that Automatic Emergency Braking (City and Inter Urban) could address 35 percent of the accidents in the U.S. while Lane Keeping Assist and Lane Departure Warning (coupled with ESC) could address another 20 percent.² These are not ideas or visions yet to be realized; these are systems that can offer tangible, real world and life savings benefits to drivers and occupants right now. This Committee, and Congress as a whole, helped to advance the development of these technologies by supporting and funding the NHTSA Data Modernization Project. Recognizing the critical need for more comprehensive and robust real-world data concerning the actual causes of crashes in the U.S., the House and Senate directed NHTSA in 2012³ to update its data collection efforts and provided funding to enable the incorporation of new collection sites, improved technology and enhanced data analysis. A deeper and more analytical understanding of the actual factors and aspects involved in real world crashes enables all of us to target those causes and to develop technology that provides a concrete benefit to consumers. This data is among the many elements that Bosch considers when determining where to invest its resources in creating future safety technologies.

Bosch commends the Committee for incorporating crash avoidance systems into the consumer education requirement that was approved as part of the AV START Act (S. 1885). We also wish to express our sincere appreciation to Senators Heller and Markey for the important work that they have done to call attention to crash avoidance technologies (Safety Through Informed Consumers Act of 2015⁴) and the need for their inclusion in the vehicle's star safety rating.

Bosch urges the Committee and NHTSA to re-energize and update the U.S. New Car Assessment Program (NCAP) or 5-star rating program. Highly automated vehicles will provide significant benefits and enable a new vision of mobility for millions of Americans; however, these vehicles may take years to reach high levels of market penetration. We project that conditionally automated Level 3 vehicles will be available to consumers this decade and Level 4 highly automated vehicles will be available in the beginning of the next decade. Since more than 37,400 individuals died in motor vehicle crashes in 2016, we must take immediate steps to help educate consumers on

² Bosch Corporate Research analysis based on NHTSA Traffic Safety Facts 2015, DOT HS 812 384

³ DOT HS 812 128, March 2015, NHTSA's Review of the National Automotive Sampling System: Report to Congress

⁴ S. 1535, the Safety Through Informed Consumers Act of 2015. This legislation was approved in 2015 as part of the Fixing America's Surface Transportation (FAST) Act.

the options that are available today. Consequently, we respectfully recommend that the Committee examine the potential to incorporate crash avoidance technologies into the overall vehicle rating. A prior proposal to update NCAP, issued by NHTSA in December 2015, included not only several positive changes that would have boosted consumer awareness of new active safety systems, but also raised concerns relative to the significant adjustments that would be required in connection to the vehicle crashworthiness rating. We ask the Committee to re-examine the crash avoidance portion of the proposal, which generated notable support from relevant stakeholders such as leading vehicle manufacturers, the National Safety Council (NSC), the National Transportation Safety Board (NTSB), and the Insurance Institute for Highway Safety (IIHS).

I wish to note that Bosch supports the Federal Guidance for Automated Vehicles, which was released in September 2017. We commend NHTSA and the U.S. Department of Transportation (DOT) for all of their efforts and wish to acknowledge the significant investment of time and resources on the part of DOT leadership and the staff at NHTSA to create this framework. Bosch understands and supports the objectives of NHTSA in urging the release of a Voluntary Safety Self-Assessment (VSSA). Indeed, our company intends to release its own VSSA.

Consumer Education:

Bosch is also cognizant of the tremendous need to conduct outreach to consumers and to engage in an active debate as to the benefits of these technologies, the manner in which the driver will be able to interact with them and to the proper expectations associated with such innovations.

Bosch's position on the need for improved consumer education is well known. We have urged NHTSA and the U.S. Department of Transportation for many years to include crash avoidance systems as a key component of the vehicle 5-star rating and to provide additional information to consumers through the Monroney Label.

Bosch strongly concurs with U.S. Transportation Secretary Chao that consumer education and awareness are critical enablers to the future success and adoption of ADS. In order to bolster public understanding, Bosch has launched the Bosch Automated Mobility Academy to educate members of the public on how automated mobility can improve their quality of life and to explain how various advanced

technologies and functions will make the fully automated future possible. The Academy also provides information on driver assistance technologies that provide safety and comfort benefits today and will serve as the building blocks to higher levels of automation.

You may access the Bosch Automated Mobility Academy at:

<http://www.bosch-mobility-solutions.us/us/highlights/automated-mobility/amc/>

In addition to the Academy, Bosch remains committed to increasing consumer awareness through its partners and through demonstrations and presentations at dedicated industry and government events.

Cybersecurity:

The topic of cybersecurity is tightly intertwined with the emergence of increasingly automated and connected vehicles and it is a priority for Bosch. Again, I commend the Members of this Committee and your staff for working so diligently to address this critical and complex issue. Bosch has been working for several years to develop robust and comprehensive solutions for our customers. Bosch strongly supports a layered approach to vehicle cybersecurity. We have espoused this principle in the development of our own products and in our engagement with customers.

We are addressing our customers' requirements in two ways: (1) developing systems and technologies that can address risks based on the electronic architecture of current vehicles, and (2) investing in future solutions that will be interwoven into the vehicle design from the ground up. Our current cybersecurity product portfolio ranges from security embedded in the hardware of our electronic products to sophisticated mechanisms which serve as a "wall" between external connectors to the vehicle and the safety-critical systems that govern the steering, braking and other functionalities.

Also, with the Bosch group of companies we have the leading team of security specialists in the automotive sector, ESCRYPT. It is an industry leader in securing over the air (OTA) updates of firmware and software, which are carried out in a similar manner as smartphone software updates. Users select a function on their smartphone or the infotainment system. The information is sent to the Cloud, which functions like an app store to provide the software and to start downloading it straight into the vehicle. Further, security updates can be distributed by such an infrastructure. Data transfer

runs securely in the background while the car is being driven – and importantly the updates are only made when conditions are secure. According to Gartner Inc., 250 million cars around the world will be connected by 2020⁵, so this topic will continue to remain at the forefront as the industry advances.

In the future, Bosch sees the focus of automotive cybersecurity as intrusion detection and prevention. Bosch and ESCRYPT are actively developing components and systems to support OEMs in developing vehicles that are safe and secure. ESCRYPT's Intrusion Detection Prevention System enables continuous monitoring of attacks in the field and timely detection of attacks. The information is conveyed to a backend office through the cloud, enabling analysis by security analysts and forensic experts who can then develop an appropriate response. This could include a roll-out of countermeasures via security updates for the entire fleet in order to remedy the vulnerability.

Understanding the importance of industry cooperation and engagement in addressing potential threats and developing best practices, Bosch joined the Automotive Information Sharing and Analysis Center (Auto-ISAC) in 2016 and one of our associates presently serves as the Chair of the Supplier Affinity Group within the ISAC.

Bosch understands that the Committee has expressed interest in the topic of coordinated disclosure. Bosch has already established a process to enable effective communication with other Bosch entities and external parties, including researchers. In 2016, a Product Security Incident Response Team (Bosch PSIRT) was created to serve as the central point of contact for external security researchers, partners or customers to report security information related to Bosch products. The PSIRT interface provides a clear and accessible means for external parties to communicate and ensures that all submissions will be reviewed and considered. This mechanism enables an assessment of the validity of vulnerability notifications and allows for a quick and appropriate action. The Bosch PSIRT webpage further includes a list of existing Security Advisories.⁶

⁵ "Gartner Says By 2020, a Quarter Billion Connected Vehicles Will Enable New In-Vehicle Services and Automated Driving Capabilities," (Jan. 26, 2015). Press Release: <https://www.gartner.com/newsroom/id/2970017>

⁶ Bosch Product Security Incident Response Team website: <https://psirt.bosch.com/index.html>
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In addition, acknowledging security as an important element of the product-development process is a necessary step to ensure that security capabilities are properly implemented and that considered relative to all aspects of the vehicle life-cycle. Bosch has developed a security engineering process that is followed for all warranted present and future product development.

I also wish to note the importance of industry standards and of the active engagement by standard setting bodies across the world to develop appropriate standards in this area and, eventually, to harmonize their approach where possible. Bosch believes the industry standards will play a critical role in framing the future adoption and use of the technology. We are supporting these efforts and utilizing the recommended practices. For example, Bosch is actively participating in the ISO-SAE 21434 Road Vehicles Cybersecurity Engineering standardization process, which addresses the means of handling security topics in automotive product engineering.

Securing automobiles is a complex issue that requires both a comprehensive, strategic approach and a long-term commitment. We are devoted to developing tools and offering consulting to help the U.S. automotive industry with this important issue.

Artificial Intelligence:

Bosch is advancing artificial intelligence. At the Bosch Connected World 2017 conference in Berlin, Bosch presented an onboard computer for automated vehicles. Thanks to artificial intelligence (AI), the computer can apply machine learning methods. The AI onboard computer is expected to guide self-driving cars through even complex traffic situations, or ones that are new to the car. Bosch's AI onboard computer can also recognize pedestrians or cyclists.

Bosch is also actively seeking ways to utilize AI to improve our existing products and operations, including in manufacturing where AI can scrutinize the effectiveness of our production so that products can be manufactured more quickly while maintaining exceptional levels of precision and quality. AI also has the potential to make our lives easier in many areas, whether its intelligent cars finding parking spaces, having the room temperature automatically adjusted to our needs, or protecting our homes against break-ins. We wish to acknowledge the leadership of Senator Cantwell, Senator Markey and Senator Young in introducing the

Fundamentally Understanding the Usability and Realistic Evolution of Artificial Intelligence Act of 2017 – or the “FUTURE of Artificial Intelligence Act.”

Powertrain:

Amongst the most dramatic challenges facing all of us in the industry is the design of the powertrain that will be needed for the future. Although much of the focus of the automated vehicle debate has been on the safety aspects and the engineering requirements, such as redundancy, fail-safe operational modes and human machine interface (HMI) needed to bring this objective to fruition, the reality is that automated vehicles will also change the needs of the powertrain.

Bosch is investing in the future by continuing to innovate new technologies that boost performance and efficiency and by investing in the many systems and advancements that we will be demanded by electric vehicles. At the North American International Auto Show (NAIAS) in Detroit last week, we featured our electric axle drive and our second generation 48-volt system (which provides improvements in fuel economy and performance). Bosch takes the challenge of the move to electric propulsion by offering a complete electric drive that is cost-attractive, performance based and helps saving battery capacity due to its very high system efficiency. The Bosch eAxle platform is designed to support the full range of passenger car and commercial vehicle segments.

Smart Cities:

In assessing the landscape before us, Bosch also sees a shift in how consumers utilize their vehicles and the options that they expect in terms of mobility. One of the most notable challenges that we are facing as a global society is congestion and the difficulty associated with traffic management in our large cities. Urban traffic is predicted to triple by 2050. In the U.S., the average individual spends more than 40 hours a year stuck in traffic, wasting more than \$120 billion in time and fuel. In order to prepare for the mobility scenario of the future, we have launched several smart city projects in countries around the world. Today, half of Bosch’s 14 smart city projects include urban mobility solutions such as connected parking, automated driving, fleet management, multimodal transport, electromobility, and vehicle connectivity (V2X and DSRC). After a successful pilot phase, Bosch intends to launch community-based parking in several U.S. cities this year. In places such as

L.A., Miami, and Boston, the company will make real-time information about on-street parking available to car manufacturers. Drivers will be able to see on their navigation systems where there's a free space and drive directly to it. We have also announced a collaboration with Daimler to bring self-driving SAE Level 4 and Level 5 vehicles to city streets by the start of the next decade. This will open up new horizons in particular for people with limited mobility.

The Workforce of the Future:

As we look forward to these advances and leaps within the industry, we cannot fail to address the demand for trained workers to fulfill the millions of jobs that will be needed to fuel the industry's transformation. Of Bosch's 390,000 associates worldwide, more than 20,000 are software engineers, nearly 20 percent of whom are working exclusively on the IoT.

Bosch recognizes the need to build and shape the manufacturing workforce for the future. As is the case with many of our partners in the industry, we encounter challenges in finding the right candidates for our open jobs and positions. Our strategy encompasses inspiring young minds and helping to generate an interest in science, technology, engineering and math ("STEM") and careers in manufacturing. The strategy includes hands-on training for students who are enrolled in technical colleges and universities.

Our investment also extends to our current associates. We provide access to a broad variety of training programs and skill-building initiatives to all of our team members. Bosch maintains several apprenticeship programs at its manufacturing facilities in the U.S. These programs enable students to receive hands-on training and gain valuable experience while working at a Bosch site. For example, the Bosch Rexroth plant in Fountain Inn, SC currently operates four U.S. Department of Labor-registered apprenticeship initiatives.

Many of the participants of the apprenticeship programs transition to a Skilled Associate position with Bosch at the conclusion of their training. Bosch Rexroth has an active partnership with the Greenville, SC Technical College. In March 2016, the Bosch Community Fund (BCF) provided \$62,500 to the Greenville Tech Foundation in order to establish a hydraulics simulation lab at the Greenville Technical College Center for Manufacturing Innovation.

In addition to providing grants to support apprenticeship programs, the BCF also provides grants to fund educational programs focused on STEM, as well as manufacturing professional development for teachers. Last October the BCF awarded 7 grants totaling over \$86,000 in the Owatonna, Minnesota community to support organizations and initiatives that provide students with robotics courses, career preparedness classes and manufacturing workshops. By investing in lab improvements, teacher training and enhancements in STEM and engineering curricula, the BCF is able to impact students' lives in the community and help to prepare the next generation for the workforce of the future. Since 2014, the BCF has awarded more than \$308,000 to schools and organizations in the Owatonna area, and the BCF is engaged in many similar efforts across the country.

Bosch also supports both A World in Motion (AWIM) and First Robotics initiatives. Led by the Society of Automotive Engineers (SAE), AWIM works with children in kindergarten through 8th grade to bring science, technology, engineering and math education to life. Bosch volunteers work directly with children to complete challenges as a means to inspire them and build interest in STEM topics. Today, Bosch employees participating in AWIM are volunteering in nearly 80 classrooms located near seven Bosch North American facilities to bring STEM education to life. This not only gives us the opportunity to get involved in our communities, but also helps us develop our future scientists and engineers. The Bosch Community Fund also provides support to AWIM. Under the aegis of the First Robotics program, Bosch opens its doors to high school students and they are invited to work with Bosch engineers to design and build a robotic solution.

Conclusion:

Thank you again for the opportunity to speak before the Committee. Bosch looks forward to continuing to work with each of you and with the Committee in the future. We would be pleased to provide additional technical information on any of these topics.

I welcome any questions you may have.