PREPARED STATEMENT FOR THE RECORD OF

INTEL CORPORATION

For the

UNITED STATES SENATE COMMITTEE ON

COMMERCE, SCIENCE & TRANSPORTATION

SUBCOMMITTEE ON SURFACE TRANSPORTATION AND

MERCHANT MARINE INFRASTRUCTURE, SAFETY AND SECURITY

Hearing On

HOW THE INTERNET OF THINGS CAN BRING

U.S. TRANSPORTATION AND INFRASTRUCTURE INTO THE 21ST CENTURY

June 28, 2016

The Internet of Things and America's Transportation Future

Intel Corporation (Intel) respectfully submits this statement for the record in conjunction with the Senate Commerce, Science & Transportation Committee, Surface Transportation and Merchant Marine Infrastructure, Safety and Security Subcommittee, hearing on "How the Internet of Things (IoT) Can Bring U.S. Transportation and Infrastructure into the 21st Century." Our statement focuses on the opportunity to unleash the enormous potential of the IoT to enable vastly improved transportation safety, mobility and efficiency – and, in doing so, seize a leadership opportunity for the U.S. by ensuring that the nation's intelligent transportation technology evolves at the forefront of innovation.

Witness: Doug Davis is the Senior Vice President and General Manager of Intel's worldwide IoT Group (IOTG). Doug has been an Intel employee for 32 years, and began his career as a product engineer in the company's Military and Special Products Division. Over the last decade, Doug has run Intel's worldwide Embedded and Communications Group, managed wafer factory operations, and now leads the IoT Group. This organization is responsible for the company's IoT strategy and solutions – consisting of hardware, software, security and services across a wide range of market segments, including transportation, manufacturing, healthcare, retail, smart home, smart buildings and smart cities. For more than 30 years, Intel has made significant investments, driven exciting innovations, led standards activities, and supported what has evolved to become the IoT. At Intel, we like to say that the IoT is an overnight transformation thirty years in the making.

BACKGROUND

The Internet of Things. At its simplest, the IoT is: "Things" (devices) securely connected through a network to the cloud (datacenter), from which data can be shared and analyzed to create value (solve problems). The IoT enables us to connect "things" like phones, appliances, machinery and cars to the Internet, share and analyze the data generated by these things, and extract meaningful insights that create new opportunities and solve problems. These opportunities are extensive and exciting with the ability to transform entire industries and our lives for the better. The IoT encompasses two major segments: Consumer IoT and Industrial IoT. The "Consumer IoT" connects devices like game consoles, smart TVs, household appliances, wearables and smart phones. The "Industrial IoT" connects devices in industrial environments like factory equipment, security cameras, medical devices and digital signs.

Transportation is one of the most promising sectors for the IoT. By converting vast amounts of data into meaningful and actionable intelligence, the IoT can help solve many of modern society's automotive safety, transportation efficiency, mobility, and infrastructure challenges. The IoT is rapidly enabling innovations like connected cars, "smart" fleet management, intelligent transportation infrastructure and, of course, self-driving (autonomous) cars. Notably, almost half of Americans aspire to live in a driverless city where cars, buses, and trains operate intelligently and automatically without people driving them, and over one-third expect a driverless city by 2024.[1] A policy framework that harnesses the full potential of these transformational IoT opportunities in the automotive and transportation sector is critical to U.S. economic leadership and productivity in the 21st century.

Intel Leadership in IoT Transportation. As an IoT leader, Intel is committed to driving innovation across all market sectors, with a significant focus on IoT transportation. We are collaborating with policymakers, automakers, suppliers, academia, and cities worldwide – utilizing the IoT to accelerate innovation. Intel is collaborating with our automotive industry partners and governments that seek to not only reimagine the car, but also restructure the idea of transportation as a whole.

To realize the full potential of this new vision, industry must undertake the appropriate and comprehensive testing to ensure that all systems operate flawlessly. Consequently, Intel is building Centers of Excellence (CoEs) to road test autonomous vehicles in our home states of Arizona, California, Oregon and California, as well as Germany.[2] Working with the automotive industry, our CoEs will enable improvements in AV development by gathering data needed to build the machine learning models that will provide the intelligence for these vehicles. We're focusing on what it will take to realize safe, secure, fully autonomous driving, and for vehicles to reliably communicate with each other and the world around them. We are exploring how valuable data can bring new services to market and how smart human-machine interfaces can make autonomous driving intuitive and enjoyable.

For example, we are partnering with automakers to enable platforms with fundamental advanced driver assist features like lane-keeping assistance, collision warning, and automated parking assist,[3] which are early capabilities on the path to self-driving cars.[4] We also are helping businesses use IoT technology to optimize fleet management and freight transport, using real-time data analytics to make drivers safer and more efficient while reducing fuel consumption. We are also partnering with city governments to deliver cutting-edge IoT transportation infrastructure solutions like intelligent traffic management (using advanced data analytics to enable integrated transportation coordination, emergency traffic response, and congestion reduction)[5] and enhanced public transportation experiences (using real-time interactive digital signage to make multi-modal transit easier and more

[1] *The Vote Is In*, Intel Corp. (Feb. 2014), http://newsroom.intel.com/community/intel_newsroom/blog/2014/02/10/the-vote-is-in-citizens-support-smart-cities-with-driverless-cars-public-service-drones-and-surroundings-that-sense-activities.

[2] Intel Labs: http://www.intel.eu/content/www/eu/en/research/intel-labs-europe.html

[3] ADAS Demo: http://www.intel.com/content/www/us/en/automotive/advanced-driver-assistance-systems-video.html

[4] *Self-Driving Car Technology and Computing Requirements*, Intel Corp. http://www.intel.com/content/www/us/en/automotive/driving-safety-advanced-driver-assistance-systems-self-driving-technology-paper.html.

[5] Intelligent Traffic Management: https://www.youtube.com/watch?v=M0ZN8El6lfY

engaging for citizens).[6]

Intel's Vision for IoT in Transportation. Intel's vision for the future of transportation is one of zero accidents, mobility for all, environmental sustainability, reduced congestion, increased efficiency and *innovation that evolves at the pace of technology to ensure U.S. global leadership*. We are making large investments[7] to enable a future of autonomous vehicles with highly advanced sensors; connected cars using advanced cellular technology like 5G (5th generation cellular) for real-time vehicle-to-vehicle (V2V) collision avoidance; powerful in-vehicle computing capabilities to deliver driver strategy and trajectory computing and self-driving capabilities; and secure, high-speed, ultra-reliable communications with advanced data centers in the cloud. All of this will be driven by the IoT and will transform our lives and economies for the better.

With the advent of new business models like transportation-as-a-service and the growth of the car sharing economy, the transportation sector is poised to make the leap from technologies and business models grounded in the 20th Century to exciting and empowering technologies firmly anchored in the 21st Century. To successfully compete in the forward-looking global economy, U.S. policymakers must enable a transportation ecosystem that is safe, secure, flexible and interoperable. Global leadership will accrue to those markets that address these goals in the most efficient manner possible.

The challenges for the stakeholder industries are numerous. For example, industry must profitably transition from its current legacy business models to business models that focus less on the human as a "driver." Technology industry suppliers also must pivot to intelligently utilize increasing amounts of data, while addressing the needs of two vastly different generations of consumers — baby boomers who want to maintain mobility and millennials who are challenging the status quo of vehicle ownership. We must adapt as new technologies become the foundation of our transportation ecosystem.

Of particular importance to the stakeholder industries will be how the U.S. government addresses some of the key foundational technologies that will serve as the core architecture for future capabilities. Most significantly, policymakers should be aware that it is widely expected that 5G cellular (the rapidly emerging successor to today's 4G) will be a foundational technology for the IoT overall and critical to the success of IoT in transportation. For the U.S. to lead in the global IoT transportation future, it is vital that the nation's transportation strategy recognizes the global marketplace direction and enormous global industry investment in 5G – and that the U.S. pragmatically invest its own limited federal resources in 5G to keep pace with the transportation industry worldwide.

So what do we mean by 5G, how does it impact the transportation sector specifically, and why does it matter so much? Advanced cellular communications such as next generation 5G technology offer

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[6] Real-Time Interactive Transit Displays: http://www.intel.com/content/www/us/en/intelligent-systems/tech-today/transportation-digital-signage-video.html.

[7] *Intel Bulking Up Safety and Security of Self-Driving Car Efforts*, Fortune (April 2016) ("Intel Self-Driving Car investments"), http://fortune.com/2016/04/05/intel-self-driving-car/.

uniquely superior characteristics that are critical for V2V real-time collision avoidance: very low latency (especially in dense vehicle environments),[8] ultra-high reliability, consistent safety prioritization,[9] very high speeds, advanced security, and cost effectiveness to enable scale – and therefore *many more saved lives*. This next generation of cellular also will have the backing of huge global private industry investment and strong consumer demand which propels technologies to the forefront and enables them to evolve at the pace of innovation, which will be key for the long term evolution of IoT solutions.

Evidence of the global race to secure leadership in this space is everywhere and should be viewed by U.S. policymakers as both a wakeup call as well as a challenge to move intelligently and swiftly. Leading examples include 5G deployments that are underway for the 2018 FIFA World Cup in Russia[10] and the 2018 Winter Olympics in PyeongChang, South Korea,[11] followed by the 2020 Summer Olympics in Tokyo, Japan.[12] Moreover, *5G transportation use cases – and specifically V2V safety real-time collision avoidance – already have been demonstrated* in major countries, with more following suit this year. For example, Japanese mobile operator NTT DOCOMO (along with Nokia, Samsung, Ericsson, Fujitsu and Huawei) successfully conducted 5G vehicle trials in actual-use environments in 2015.[13] Also in 2015, Deutsche Telecom (along with Continental, Fraunhofer ESK, and Nokia) successfully demonstrated "near-5G" communication between vehicles via the cellular LTE network on the 'Autobahn A9 motorway testbed' in Germany.[14] And Korean mobile operator KT plans to conduct early 5G trials and commercialization between 2016 and 2018.[15] Clearly, the race is on and it's a crowded field.

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[8] *Letter Report: Review of the Status of the Dedicated Short-Range Communications Technology and Applications [Draft] Report to Congress*, TRB at 5-6 (April 2015), http://onlinepubs.trb.org/onlinepubs/reports/DSRC_April_28_2015.pdf.

[9] 5G provides reliable safety prioritization by optimally managing both the communication channel and the prioritization of safety information through the network, while supporting a highly scalable broadcast mechanism for vehicles.

[10] *Huawei to introduce 5G networks for 2018 FIFA World Cup* (Nov. 2014), http://www.trustedreviews.com/news/huawei-to-introduce-5g-networks-for-2018-fifa-world-cup.

[11] *PyeongChang 2108, the "5G Olympics"* Korea Info. Soc. (April 2016), http://www.koreainformationsociety.com/2016/04/pyeongchang-2018-5g-olympics.html.

[12] *Nokia, NTT DoCoMo prepare for 5G ahead of 2020 launch*, Reuters (2015), http://www.reuters.com/article/us-telecoms-mwc-ntt-docomo-idUSKBN0LY0FD20150302

[13] *DOCOMO Successfully Conducts 5G Trials in Actual-use Environments (2015)*, https://www.nttdocomo.co.jp/english/info/media_center/pr/2015/1126_00.html.

[14] *Continental, Deutsche Telekom, Fraunhofer ESK, and Nokia Networks Showcase First Safety Applications at "digital A9 motorway test bed* (2015): "https://www.telekom.com/media/company/293064

[15] *SK Telecom announces the foundation of 5G Open Trial Specification Alliance with NTTDOCOMO, Verizon and KT* (2016): http://www.sktelecom.com/en/press/detail.do?idx=1156

WHY CONGRESS SHOULD CARE: THE SOCIETAL AND ECONOMIC IMPACT OF IOT IN TRANSPORTATION

So why should policymakers care and why should they spend so much time making sure the benefits are realized in a way that enables technology in the U.S. to keep pace with global marketplace innovation? The potential impact of IoT technology to address important societal and economic challenges in the automotive and transportation sector is remarkable, compelling and exciting. The benefits that will flow from broad deployment of IoT technology in transportation is what energizes our team at Intel, and we are optimistic that enthusiasm will be contagious here in Congress.

The following is a summary of some of the many benefits of smart utilization of the IoT that have been identified for the transportation ecosystem:

Safety and Economic Savings. Improved vehicle safety is, and will remain, the consistent top priority and foundation for Intel's IoT transportation efforts. The statistics with respect to preventable automobile accidents are devastating. Every year, more than 30,000 people in the U.S. die from preventable automobile accidents,[16] and human error is the primary reason for over 90 percent of US crashes.[17] An EU study found that distracted and drowsy driving were responsible for 13 percent of traffic deaths in 2014.[18] These accidents take an enormous emotional and physical toll on the driving public and their loved ones, at a cost of approximately 300,000 lives each decade in the U.S. and a cost of $190 billion each year in healthcare costs associated with accidents.[19]

Self-driving vehicles – where the vehicle senses its environment and navigates without human input – are widely expected to dramatically reduce crashes:

If only 10 percent of vehicles were self-driving:

- US traffic deaths could decrease by 1,100; and
- save almost $38 billion per year.

If 90 percent of vehicles were self-driving:

- traffic deaths could decrease by 21,700; and

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[16] *Mortality – Motor Vehicle Traffic Deaths*, CDC, http://www.cdc.gov/nchs/fastats/injury.htm (site last visited June 26, 2016).

[17] *Driverless cars could reduce traffic fatalities by up to 90%*, says report, Science Alert ("Science Alert"), http://www.sciencealert.com/driverless-cars-could-reduce-traffic-fatalities-by-up-to-90-says-report; *National Motor Vehicle Crash Causation Survey*, U.S. Dept. of Transportation, at 25 (2008), http://wwwnrd.nhtsa.dot.gov/pubs/811059.pdf.

[18] Autonomous cars – game-changers for safety?, FANCI (Jan. 2016), http://fanci-project.eu/autonomous-vehicles-changer/

[19] Science Alert.

- save $447 billion per year.[20]

And, when 100 percent of vehicles are self-driving, the US could save $1.3 trillion per year.[21]

McKinsey similarly projects that autonomous vehicles could drastically reduce accidents, including reducing the lethality of vehicle crashes in the U.S. from second to ninth amongst accident types. They estimate that this would reduce the annual cost of roadway crashes in the U.S. from $212 billion to $22 billion – a cost savings of nearly 90 percent per year.[22]

Efficiency and Productivity. According to the United States Census Bureau, the average American commute to work is 25.4 minutes, and Americans spend 157 hours per person each year traveling on the nation's roads and highways.[23] Moreover, the average American commuter spends 38 hours per year stuck in traffic, which collectively causes urban Americans to travel 5.5 billion more hours and purchase an extra 2.9 billion gallons of fuel; the cost to the US economy of this wasted time and fuel is $121 billion per year.[24] IoT technologies like self-driving vehicles (where citizens can engage in productive activity while in transit) and more intelligent transportation infrastructure (with better traffic management) could enable a far more productive and efficient U.S. citizenry.

And for making our lives better, autonomous vehicles could free as much as 50 minutes a day for users, who will be able to spend traveling time working, relaxing, or accessing entertainment. The time saved by commuters every day might add up globally to a mind-blowing one billion hours—equivalent to twice the time it took to build the Great Pyramid of Giza. It could also create a large pool of value, potentially generating global digital-media revenues of €5 billion (over $5.5 trillion USD) per year for every additional minute people spend on the mobile Internet while in a car.[50]

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[20] *Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations*, Eno Center for Transportation, at 8 (Oct. 2013), https://www.enotrans.org/wp-content/uploads/wpsc/downloadables/AV-paper.pdf.

[21] *The 'Internet of Things' Is Now Connecting the Real Economy*, Morgan Stanley (April 2014), http://www.technologyinvestor.com/wp-content/uploads/2014/09/internet-of-Things-2.pdf. Specifically, $488B savings from accident avoidance, $507B productivity gain from autonomous cars, $158B fuel savings, $138B productivity gain from congestion avoidance, and $11B fuel savings from congestion avoidance.

[22] *Ten ways autonomous driving could redefine the automotive world*, McKinsey & Co., (June 2015), http://www.mckinsey.com/industries/automotive-and-assembly/our-insights/ten-ways-autonomous-driving-could-redefine-the-automotive-world.

[23] *Commuting in the United States 2009*, US Census Bureau (Sept. 2011), https://www.census.gov/prod/2011pubs/acs-15.pdf

[24] *The American Commuter Spends 38 Hours a Year Stuck in Traffic*, The Atlantic (Feb. 2013), http://www.theatlantic.com/business/archive/2013/02/the-american-commuter-spends-38-hours-a-year-stuck-in-traffic/272905/. See also *The Massive Economic Benefits Of Self-Driving Cars,* Forbes (Nov. 2014) (estimating the savings could go up to $500B/year), http://www.forbes.com/sites/modeledbehavior/2014/11/08/the-massive-economic-benefits-of-self-driving-cars/#6bb4e79e68d9.

Reduced traffic congestion. Traffic congestion continues to have significant impacts on urban design, land usage, and overall time usage for travelers whether for work or pleasure. This issue is in large part based on the need for vehicle parking. In a recent study, the Transportation Alternatives group found that in one Brooklyn neighborhood, 64 percent of the local cars were on local roads merely because they were searching for a parking spot.[25] Autonomous vehicles would change that by self-parking themselves in less congested areas and therefore enable city planners and developers the flexibility to reshape and improve how we use land in cities. According to Rowe,[26] one of the most profound effects of driverless vehicles would be to drastically reduce the need for parking structures and surface lots, which today take up a third of land inside cities. Some of the garages and underground structures could be converted into storage spaces for urban dwellers who live in micro units, while the unneeded surface lots would be available for commercial or residential development or green space.

New mobility options for the disabled and elderly. Nearly 15 million people across the U.S., including 6 million disabled individuals, have challenges getting the transportation they need on a daily basis.[27] These individuals often become dependent on family members or must resort to costly modes of transportation in order to travel around their communities for business, medical and social activities. Autonomous vehicles – because they do not require a human driver – can open up better transportation and mobility options for these individuals. This will both increase their individual quality of life, as well as improve our overall society. Indeed, "without access to transportation, people with disabilities will not be part of society's economic environment and will continue to be alienated from the economic mainstream, thus causing a myriad of other problems, like homelessness and institutionalization."[28]

Revenue and Growth. The automotive and transportation industries will be among the first to see immediate growth from the IoT, with global IoT revenue from the transportation sector reaching $325 billion in 2018.[29] With almost nine percent of the US labor force employed in the transportation

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[25] *How Driverless Cars Could Turn Parking Lots into City Parks*, The Atlantic (Aug. 2015), http://www.theatlantic.com/technology/archive/2015/08/driverless-cars-robot-cabs-parking-traffic/400526/

[26] *Imagining the Driverless City*, Urban Land Magazine (Oct. 2015), http://urbanland.uli.org/infrastructure-transit/imagining-driverless-city/

[27] *Transportation Difficulties Keep over Half a Million Disabled at Home*, USDOT Bureau of Transportation Statistics (2003), http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/special_reports_and_issue_briefs/issue_briefs/number_03/html/entire.html.

[28] *Facts about Equity in Transportation for People with Disabilities*, The Leadership Conference on Civil and Human Rights (site last visited 6/25/16) http://www.civilrights.org/transportation/disability/facts.html.

[29] *Roundup of Internet of Things Forecasts And Market Estimates, 2015*, Forbes (citing IDC) (Dec. 2015), http://www.forbes.com/sites/louiscolumbus/2015/12/27/roundup-of-internet-of-things-forecasts-and-market-estimates-2015/2/#3060c5e34a10.

sector[30] and the US spending roughly $160 billion annually on highway infrastructure (about one-fourth funded by the federal government)[31] – America's share of this transportation IoT revenue (and cost savings from IoT technologies) could be significant.

Fuel savings and reduction in harmful emissions. Experts such as former GM executive Larry Burns, believe driverless trucks could reduce costs in the line-haul trucking industry by 40 percent. By switching from traditional car ownership models to a shared driverless model, the costs of car ownership (based on US modelling) could fall from $0.70 per mile to around $0.15 per mile - a 78% reduction.[32] Notably, the potential savings to the U.S. freight transportation industry alone – one of the most compelling use cases for self-driving vehicles – is estimated at $168 billion per year.[33]

First Responders. Another important benefit of mass adoption of autonomous vehicles could have a huge impact for first responders and thus the public at large. With access to driverless vehicles, emergency services could collaborate with analytics providers to improve response times and elevate the level of healthcare provided to residents while potentially lowering costs.[34]

GLOBAL TRENDS

But the US is not alone in wanting to realize those benefits. We see a number of initiatives globally that will shape the evolution of technologies, industrial capabilities, and environmental infrastructure for autonomous vehicles to become a mainstream capability that this Committee should note as it develops its own IoT transportation vision for the U.S. A review of what is being done globally must be an essential component of your deliberations and the following may help illuminate some of the key activities that merit attention.

Country Investments in Autonomous Vehicles. The race to an autonomous vehicle world is a global one. It is important for Congress to appreciate not only the amount of funding other countries are investing in IoT transportation, but most importantly the future proof technologies in which they are investing. In short, they are largely investing in AV technologies and 5G connectivity – both of which

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[30] *National Transportation Statistics*, U.S. Dept. of Transportation, Table 3-23 (July 2013), http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_03_23.html.

[31] *Statement of Joseph Kile,* Before the U.S. Senate Cmte. on Finance, The Highway Trust Fund and Paying for Highways (May 17, 2011), http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/121xx/doc12173/05-17-highwayfunding.pdf.

[32] Accenture Digital at 4.

[33] *Id*. Specifically, savings from labor ($70B), fuel efficiency ($35B), productivity ($27B), and accident savings ($36B).

[34] *"The new road to the future Realising the benefits of autonomous vehicles in Australia,"* Accenture Digital at 10 (2014) ("Accenture Digital"), https://www.accenture.com/t00010101T000000__w__/au-en/_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Local/en-gb/PDF_3/Accenture-Realising-Benefits-Autonomous-Vehicles-Australia.pdf

are widely expected to achieve rapid and widespread *voluntary* adoption worldwide. If America seeks to lead the world in IoT transportation, policymakers may find interesting the countries large and strategic investments that other countries are making to drive a successful IoT transportation future and keep pace with innovation for years to come.

- **China's** search giant, Baidu, has partnered with BMW and released a semi-autonomous vehicle prototype, and has tested their technologies on highways in China. The semi-autonomous vehicle is a modified 3-Series BMW that drove an 18.6-mile route around Beijing.[35]
- **Japan** is investing in a multimillion dollar research center, called the National Innovation Complex, opened at Nagoya University last year. A key project is to develop self-driving car technology.[36]
- **Germany's** Chancellor Merkel told carmakers that they should soon be able to test self-driving vehicles on German roads by promising to remove legal barriers.[18] The stretch on the A9 autobahn – which links Munich and Berlin – will give the industry the opportunity to "test and optimize new innovations in an adapted infrastructure that offers data connections and measuring tools.[19]
- **Sweden** is sponsoring a large-scale trial of 100 Volvo driverless cars to begin on the public roads of Gothenburg in 2017. This pilot is part of the Swedish government's vision of zero traffic fatalities, and will give insights into the technological challenges at the same time as receiving valuable feedback from real customers driving on public roads.[17]
- **Korea**. The Korean government has pledged 145.5 billion won ($127.7 million USD) to develop key technologies for self-driving cars in hopes of beating out global competitors, including leading IT companies, beginning in 2017.[37]
- **The UK** announced £20 million (over $27 million USD) of its £100 million Intelligent Mobility Fund will be invested in autonomous vehicle advancement, including current trials to test driverless cars on the streets of Bristol, Coventry and Milton Keynes, and Greenwich, and developing autonomous shuttles to carry visually-impaired passengers using advanced sensors and control systems.[38]

A review of what the auto industry has undertaken to date also is vital for your strategic planning.

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[35] *China's roadmap to self-driving cars*, Fortune (April 2016), http://fortune.com/2016/04/23/china-self-driving-cars/?iid=sr-link2; *Inside China's Plan to Beat America to the Self-Driving Car*, Wired (June 2016), https://www.wired.com/2016/06/chinas-plan-first-country-self-driving-cars/

[36] *Scania to test Ericsson 5G for V2X applications*, Safe Car News (May 2016), http://safecarnews.com/scania-to-test-ericsson-5g-for-v2x-applications-ma7311/

[37] *Gov't pledges 145.5 billion won for self-driving technology*, Korea Joon Gang Daily (April 2016), http://koreajoongangdaily.joins.com/news/article/Article.aspx?aid=3018172

[38] *Driverless car technology receives £20 million boost* (Feb. 2016), https://www.gov.uk/government/news/driverless-cars-technology-receives-20-million-boost; *Driverless cars to be tested on UK motorways in 2017*, Wired.uk (March 2016) http://www.wired.co.uk/article/budget-support-driverless-car-trials-uk-motorways-2017.

Again, we see advancements occurring worldwide:

Status of Autonomous Vehicles. Both traditional automakers and new automotive innovators are racing to deliver a self-driving vehicle world — largely predicting mainstream autonomous vehicles on market by or before 2020.[39]

Highly Autonomous Cars on Market Today

- **2015 Infiniti Q50S**: Intelligent Cruise Control, Predictive Forward Collision Warning, Forward Emergency Braking, Lane Departure Warning/Prevention, Active Lane Control
- **2015 Mercedes-Benz S65 AMG Coupe**: Distronic Plus with Steering Assist, Adaptive Brake Technology, Active Lane-Keeping Assist
- **2016 Tesla Model S P85D/P90D**: Autopilot, Autosteer, Auto Lane Change, Autopark, Traffic-Aware Cruise Control
- **2016 Volvo XC90 T6/T8 Hybrid**: Intellisafe Autopilot
- **2016 Honda Civic**: Semi-autonomous ADAS
- **2016 BMW 750i xDrive**: Driver Assistance Plus, Active Driving Assistant Plus

Near-Term Highly Autonomous Prototypes

- **Lexus GS 450h**: Intelligent Safety Concept
- **Faraday Future FFZERO1 EV Concept**: Self-driving, almost fully autonomous
- **Audi RS7**: Driving Concept Car
- **Acura RLX Sedan**: Self-Driving Prototype

Fully Autonomous Cars 2017-2021

- **Audi** expects its A8 to be capable of fully autonomous driving next year in 2017.[40]
- **Volvo** pledged no accidents in its cars by 2020 due to autonomous technology[41] and announced a 100-car public trial with Swedish authorities where *members of public* will be behind wheel.[42]

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[39] *Driverless car market: Gearing up to save lives, reduce costs, resource consumption* ("Self-Driving Forecast"), http://www.driverless-future.com/?page_id=384 (site last visited 6/22/16).

[40] *Next-gen Audi A8 drives better than you*, Motoring (Oct. 2014), http://www.motoring.com.au/next-gen-audi-a8-drives-better-than-you-46963/.

[41] *Volvo's 2020 pledge: No one will die in our cars*, CS Monitor/AP (Jan. 2016), http://www.csmonitor.com/Technology/2016/0121/Volvo-s-2020-pledge-No-one-will-die-in-our-cars

[42] *Volvo to test autonomous cars with ordinary drivers on public roads by 2017*, The Guardian (Feb. 2015),

- **Google** plans to have its driverless cars on the market no later than 2018.[43]
- **Tesla** Founder expects first fully autonomous Tesla vehicles by 2018.[44]
- **Baidu** expects a large number of self-driving cars on the road by 2019, with mass-production in full swing by 2021.[45]
- **Volkswagen** expects the first self-driving cars to appear on the market by 2019.[46]
- **Ford** CEO expects to have self-driving cars by 2020.[47] Similarly, **Changan** (Ford's partner in China) said a self-driving model should be on the market in 2-3 years, with the automaker spending 5 billion yuan ($773 million USD) to further the technology by 2020.[48]
- **Daimler**, the maker of Mercedes Benz, plans to have its driverless trucks ready by 2020.[49] **Uber** placed an order for 100,000 Mercedes self-driving sedans for its ride-sharing service by 2020.[50]
- **Nissan** will make fully autonomous vehicles available to the consumer by 2020.[51]
- **Toyota**, the maker of Lexus, plans to bring its first models capable of autonomous highway driving to the market by 2020.[52]

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https://www.theguardian.com/technology/2015/feb/24/volvo-test-autonomous-cars-ordinary-drivers-public-roads-by-2017

[43] *Sergey Brin on driverless car future*, Driverless Car Market Watch (Oct. 2012), http://www.driverless-future.com/?p=323

[44] *Elon Musk Says Tesla Vehicles Will Drive Themselves in Two Years*, Fortune (Dec. 2015), http://fortune.com/2015/12/21/elon-musk-interview/

[45] *China's Baidu Could Beat Google to Self-Driving Car with BMW*, The Guardian (June 2015), https://www.theguardian.com/technology/2015/jun/10/baidu-could-beat-google-self-driving-car-bmw.

[46] Self-Driving Forecast; see also *Die Zukunft nach dem Abgas-Skandal*, Focus Magazine (April 2016), http://www.focus.de/finanzen/news/wirtschaft-und-geld-die-zukunft-nach-dem-abgas-skandal_id_5457885.html

[47] *Ford's self-driving cars likely around 2020*, USA Today (Jan. 2016), http://www.usatoday.com/story/tech/2016/01/05/ford-reaffirms-multi-pronged-auto-tech-approach-ces/78301192/

[48] *Inside China's Plan to Beat America to the Self-Driving Car*, Wired (June 2016), https://www.wired.com/2016/06/chinas-plan-first-country-self-driving-cars/

[49] *Daimler tests autonomous big-rig convoy on public roads*, Road & Track (March 2016), http://www.roadandtrack.com/new-cars/car-technology/news/a28548/daimler-tests-autonomous-big-rig-convoy-on/

[50] *After considering Tesla, Uber reportedly placed an order with Mercedes for 100,000 self-driving cars*, Electrek (March 2016), http://electrek.co/2016/03/18/uber-order-mercedes-100000-autonomous-cars/.

[51] *Nissan's autonomous drive car*, Nissan USA (March 2014), http://www.nissanusa.com/blog/autonomous-drive-car

[52] *Toyota to launch first driverless car in 2020*, Wired UK (Oct 2015), http://www.wired.co.uk/article/toyota-highway-teammate-driverless-car-tokyo

- **GM** predicts that most industry participants now think that self-driving cars will be on the road by 2020 or sooner.[53]
- **BMW** CEO Harald Krueger said that BMW will launch a self-driving electric vehicle, the BMW iNext, in 2021.[54]

IOT AUTOMOTIVE TECHNOLOGIES

There also is good reason to review the fact that, within the transportation sector, there are two distinct yet often conflated technologies: the "connected car" and the "autonomous vehicle" (self-driving car). The first – with the rapid evolution to 5G cellular technology – may precede the second, but provides a great example of how technologies and capabilities rapidly advanced once the foundational capability for connecting cars was established. The same will likely hold true for autonomous vehicles once the foundational technologies are in place.

Connected car. The connected car has existed for many years with increasingly sophisticated capabilities. From the initial built-in cellular connectivity, the capabilities today include real-time navigation and traffic updates as well as internet web connectivity for on-board apps. In most countries, "connected car" is a broad term indicating that the vehicle is equipped with one or more technologies that enable Internet access – most often via a wireless network using advanced cellular (like 4G/LTE, 5G) and/or Wi-Fi technologies. A "connected car" shares internet access with other devices both inside as well as outside the vehicle, enabling passengers to access features including in-car entertainment, smartphone apps, navigation, roadside service and car diagnostics. (By contrast, USDOT tends to narrowly use the term "connected vehicle" to refer only to a vehicle with the agency's preferred V2V safety technology: Dedicated Short Range Communications or DSRC in the 5.9 GHz[55] spectrum band.) These solutions will rapidly evolve to use two-way Internet connectivity to communicate with not only other vehicles V2V but also infrastructure (V2I) and other "things" (V2X).

While this hearing is not intended to delve into spectrum policy, we would note that U.S. policymakers will ultimately need to address the path for various technologies. For example, nearly all studies projecting future marketplace penetration of connected vehicles are using the broader definition to reflect the projected pervasiveness of advanced cellular (5G), Wi-Fi, Bluetooth and satellite

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[53] *GM executive credits Silicon Valley for accelerating development of self-driving cars*, WSJ (May 2016), http://www.wsj.com/articles/gm-executive-credits-silicon-valley-for-accelerating-development-of-self-driving-cars-1462910491

[54] *BMW will launch the electric and autonomous iNext in 2021, new i8 in 2018 and not much in-between,* Elektrek (May 2016), http://electrek.co/2016/05/12/bmw-electric-autonomous-inext-2021/

[55] 5.9 GHz and 5G are entirely different things. 5.9 GHz is the embattled *spectrum band* in which DSRC technology would operate. Whereas 5G is a *cellular technology* (that operates in non-5.9 GHz spectrum bands).

communications – not DSRC.[56] For example, Gartner predicts that by 2020, there will be a quarter billion connected vehicles on the road.[57] This connected car market is projected to generate new services revenue from connected cars at approximately $40 billion annually by 2020.[58]

With 4G LTE now deployed in nearly every major market, the rapid evolution and market demand for cellular technologies like LTE-Advanced (LTE-A) and 5th generation cellular (5G), along with next generation Wi-Fi and Bluetooth, are driving this connected car innovation. These cellular technologies are the product of a competitive marketplace with significant and constantly evolving industry R&D, strong industry investment in wide-scale deployment, and very rapid and high marketplace adoption. If the U.S. seeks to capture a strong portion of this $40 billion per year connected car services market, it is imperative that the nation's policies and resources support public and private investment in these advanced cellular technologies, including testbeds for cellular V2V safety critical communications and real-time safety messaging and collision avoidance.

Autonomous vehicle (AV). As its name implies, the self-driving vehicle is capable of operating without a driver. It uses a complex array of tools to help it navigate real world conditions of day-to-day driving. For example, the Google self-driving car uses a mix of radar, LIDAR (measures distances by illuminating a target with laser light), HD cameras, advanced GPS and HD mapping to sense its environment and surroundings. *There is no DSRC connectivity in the Google car*; although it is widely expected that 5G connectivity will be added to many self-driving cars.

Autonomous cars also have the ability to make driving decisions based on complex analysis of data from these sensing elements. Self-driving cars also may have (but need not) Internet connectivity; for example, they may use 4G or 5G cellular communications as secondary source of information for V2V real-time collision avoidance, in addition to the on-board sensor-based systems which provide their primary source of data. In short, the vehicle is increasingly becoming smarter, more complex, processing more data and effectively becoming a "data center on wheels." Intel has been leading the industry in data center technology for decades and appreciates the importance of secure, efficient and reliable computing.

There are a number of technologies that are essential to the evolution of these solutions. Sensors have been and will continue to evolve rapidly. As noted, cameras and LIDAR as well as radar and ultrasound are used to help the car "see" what's around it. These sensors are being refined to be more purpose built for this specific application. Data from these sensors must then be integrated (sometimes called sensor fusion) at a first order to provide very fast initial indications of the environment. That data is then fed into very high performance computing platforms that can then process the data and make decisions about the control of the vehicle. The processing today is largely done according to algorithms

[56] *See, e.g.*, *Connected Car Report*, Gartner (2015), http://www.gartner.com/newsroom/id/2970017.

[57] *Id.*

[58] *Id.*

that have been refined based on environmental understanding and knowledge of driving decisions. Going forward though, these decisions will be made using sophisticated “machine learning” (ML) and “deep learning” (DL) technologies like vision-based object recognition which allows the vehicle to 'see' the objects in the environment around it - pedestrians, other cars, road signs, etc. These systems will gather data from vehicles on an on-going basis (called “scoring), send that data to the datacenter or cloud, continuously “learn” from what is happening from the fleet of vehicles on the road (called “training”), improve the driving model, and then send the improved model back down to the fleet. These systems must become well integrated end-to-end solutions that have persistent connectivity to the datacenter, and are able to evolve rapidly to meet the needs of more and more sophisticated transportation solutions.

In the last few years, there has been a remarkable acceleration in autonomous vehicle investment, innovation and testing around the world. Discussions of IoT innovations and autonomous vehicles have quickly migrated from niche engineering and auto industry websites to mainstream publications. Seemingly from out of the blue, the term “self-driving car” has entered into our everyday lexicon – with U.S. and global consumers of all ages *demanding* (and even *expecting*) sensor-based collision avoidance technologies like predictive collision warning, automatic breaking, parking assist and active lane control when purchasing new cars. A recent study by The Harford and MIT AgeLab found that, like younger generations, 76 percent of drivers age 50-69 purposefully seek out high-tech autonomous vehicle safety features.[59]

Moreover, the pace of autonomous vehicle investments and announcements around the globe have further accelerated in just the last 6 months. Over this time period, Intel has seen ship dates from our auto industry customers “pull in” (move up) by as much as 5 years, as these companies have come to fully realize that they must accelerate their technology innovation time-to-market or be left behind. Indeed, these self-driving technologies – which seemed like a far off “Jetsons” fantasy just five years ago – seem just around the corner today.

In order to turn this autonomous vision into a reality, the auto industry and transportation providers of the future must harness rapidly evolving technologies, collaborate with new partners like the high-tech industry, and embrace disruptive opportunities to innovate. This autonomous driving future will only continue to accelerate as technology advancements and the competitive marketplace further enable automakers to go to market with new autonomous vehicle innovations in an increasingly expedited manner to deliver on the vision of a zero accidents future.

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[59] *Looking Forward: Vehicle Technology Preferences Among Mature Drivers*, The Hartford Center for Mature Market Excellence® and MIT AgeLab (2016), http://extramile.thehartford.com/auto/vehicle-technology-preferences-mature-drivers.

POLICY RECOMMENDATIONS FOR A NATIONAL IOT TRANSPORTATION STRATEGY

Countries around the world are moving aggressively ahead on establishing national plans and blueprints with time-bound measurable goals, investing substantial funding in AV and 5G cellular V2V safety research and deployments, and launching PPPs to jumpstart these opportunities to quickly enable scale. As these other countries have recognized, a forward-looking IoT transportation strategy that will *keep pace with global innovation* is essential. It is critical for U.S. policymakers to enable a vibrant and state-of-the-art transportation system to ensure the nation's global competitiveness and economic stability in the 21st century. By adopting and implementing a National IoT Transportation Strategy for autonomous vehicles and 5G-enabled connected cars, the U.S. will be poised to secure a worldwide leadership position in this next evolution of transportation.

As a part of our larger U.S. National IoT Strategy (that would be developed pursuant to the new USDOC/NTIA IoT green paper process and the pending bipartisan DIGIT Act),[60] Intel recommends that the following principles drive our National IoT Transportation Strategy:

***Prioritize Safety and Security**.* Enhanced safety is vital to the success of America's IoT transportation future. Safety means (i) reducing the number and severity of crashes and (ii) protecting consumers and businesses from security breaches of the vast amount of data generated by their vehicles. With respect to crashes, self-driving vehicles will remove the risk of human error, and thus are widely expected to reduce US traffic deaths by tens of thousands per year, as discussed in detail above. With respect to security, future vehicles will generate a tremendous amount of "data exhaust" as they seamlessly connect to each other, infrastructure and consumer electronic devices and enable autonomous tasks.[61] For example, a self-driving car could generate as much as two petabytes of data per year.[62]

Security. Intel values security first and foremost. We believe that security is the foundation of IoT transportation and it is fundamental to Intel's roadmap planning. Our hardware and software are *being designed from the beginning to be secure*. This is important for trusted data exchange in the IoT, as data generated by devices (including vehicles) and infrastructure must be able to be shared among the cloud, the network, and intelligent devices for analysis. This enables users to aggregate, filter and share data from the edge of the network all the way to the cloud with robust protection. Data also must be accurate to be beneficial. Intel prioritizes the security, accuracy, privacy and integrity of data in all

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[60] *Developing Innovation and Growing the Internet of Things Act* (2016), https://www.fischer.senate.gov/public/_cache/files/03de7771-088b-45ac-8552-f82ddc0aa480/digit-2016---final-bill-for-filing.pdf.

[61] The Future of Intelligent Transportation: http://www.intel.com/content/www/us/en/automotive/experiencing-future-intelligent-transportation-video.html

[62] *A Self-Driving Car Will Create 1 GB of Data per Second*, SmartData Collective (July 2013) ("Smart Data"), http://www.smartdatacollective.com/bigdatastartups/135291/self-driving-cars-will-create-2-petabytes-data-what-are-big-data-opportunitie.

market sectors, and especially in the industrial (including transportation) domain where the safeguarding of critical infrastructure can be vital to economic and social stability.

Intel appreciates that we must deliver and evoke consumer and industry trust through these hardened security solutions to motivate adoption and participation in the IoT marketplace. We believe it is critical to integrate security into the hardware *and* software, from the smallest microcontroller (MCU) at the edge of the network to the most advanced server central processing unit (CPU) in the cloud and all gateways[63] and devices in between. These hardware- and software- level security capabilities create redundancies which prevent intrusions and enable a robust, secure, trusted IoT end-to-end solution.

Hardware. Intel's hardware provides transistor-level security *on the actual compute device itself*. By integrating security into the device itself from the outset (rather than layering it on top at a latter point in the design cycle with other, less secure external features), Intel's IoT solutions enable our customers to know the exact unique identity of every device on their network. This technology also has the capability for encrypting that unique identity to provide anonymity properties in addition to hardware enforced integrity. Because each compute device can have an immutable identification to enable secure provisioning, a non-approved device will not be allowed to access the network. The MCU or CPU itself will provide the "baked in" (irremovable, non-changeable) identity of the device, making the level of security significantly more robust.

On top of this immutable device identification, Intel's IoT solutions employ advanced hardware level security capabilities such as "whitelisting," which prevents harmful applications like viruses, control agents, and malware from ever being activated on the device. What this means is that, if the CPU ever "sees" an application that is not on its known good list ("whitelist") try to run on the device, it will automatically lock out that device and not allow it turn on. At other layers in IoT solutions, Intel also uses another advanced hardware security capability called "blacklisting," which blocks a defined list of known malware from entering the device and the network.

Software. In addition to the advanced hardware security capabilities in Intel's IoT solutions, Intel Security (formerly McAfee) integrates advanced security capabilities that provide robust software-level protection. This means that the software is continually monitoring the activity of its networked devices and looking for any abnormalities or possible threats. If the monitoring software identifies a threat, it proactively notifies users and/or automatically quarantines any devices on the network that could be at risk. By employing this combination of transistor-level security, along with advanced hardware and software level security, from devices on the edge of the network all the way to the data centers in the cloud, Intel protects IoT assets and information in ways few others can. We know that security is critical to protect the integrity of IoT solutions, so we will design it in from the outset.

We also must account for the distinct security challenges of autonomous and connected features, harnessing appropriate technical and policy strategies to mitigate risks and enable a safe, secure

[63] A gateway is a node on a network that serves as an entrance to another network.

vehicle that evokes trust from drivers and passengers on US highways. Autonomous vehicle solutions use local sensors and "intelligence" to provide a highly secure, self-contained, robust source of data. By contrast, a vehicle's "connected" features exchange data between two "things" – with the Internet, other cars, and infrastructure – potentially making this threat landscape more vulnerable. This is one of many reasons why it is exceedingly important that we look to advanced cellular technologies like today's 4G and the soon-to-arrive 5G for applications like V2V safety critical communications (vs. a system with multiple *known* vulnerabilities like USDOT's proposed DSRC Security Credential Management System).[64]

Encourage Innovation and Competition. Self-driving vehicle technology, connected cars, "smart" fleet management and intelligent transportation infrastructure have enormous potential to improve driving safety, mobility, energy use, and transportation efficiency – paving the way for U.S. smart cities of tomorrow. Innovation and market competition – in tandem with light-touch, adaptive, technology neutral, performance-based regulation – must drive our nation's policy framework and guidelines to enable the U.S. to lead the world in the automotive and transportation sector of the future.

As we know, regulation of technology, however well intended, will always lag marketplace innovation and often thwart innovation. This can be true even in areas of extreme importance such as building secure networks and technologies. In order to position the U.S. to lead the rest of the world in the globally competitive IoT transportation future, USDOT R&D funding should help enable and accelerate industry-driven investment. The agency should never seek to choose, mandate or direct the technologies which U.S. companies develop or in which they invest, nor should it put its thumb on the scale or try to drive a specific market outcome. Public policies that encourage innovation, competition, and market-driven investment are critical to enable U.S. leadership in IoT technologies like connected cars and self-driving vehicles to reach their full potential, realize maximum economic and safety benefits, and become widely available in a timely and globally competitive manner.

Promote technology neutrality. Pursuant to the *FAST Act*[65] Joint Explanatory Statement:[66] "The *FAST Act* ensures that [USDOT] programs are implemented and Intelligent Transportation Systems are deployed in a technology neutral manner. The Act promotes technology neutral policies that accelerate vehicle and transportation safety research, development and deployment by promoting innovation and competitive market-based outcomes, while using federal funds efficiently and

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[64] SCMS relies on sporadic connection between the vehicle and infrastructure to validate and revoke certificates initiated by the Certifying Authority. This sporadic connection can cause large delays in revoking security certificates and can erroneously permit non-secure and unauthenticated messages to be transmitted to/among vehicles. By contrast, cellular networks use mechanisms to robustly protect vehicles from cybersecurity incidents; persistent cellular connections help accelerate certificate update, distribution, and revocation, making certificate management much more effective, secure and reliable.

[65] *H.R. 22, Fixing America's Surface Transportation Act* (2015), https://www.congress.gov/114/bills/hr22/BILLS-114hr22enr.pdf.

[66] Joint Explanatory Statement of the Committee of the Conference at 10 (2015), http://transportation.house.gov/uploadedfiles/joint_explanatory_statement.pdf.

leveraging private sector investment across the automotive, transportation and technology sectors." As drafted by bicameral and bipartisan Members of Congress, this statement should serve as a constant guiding principle; it is critical that USDOT drive technology-neutral policies based on competitive market-based outcomes to ensure US consumers benefit from the life-saving capabilities of the most advanced technologies, which *stay apace with technology evolution* for decades to come.

It is imperative that the U.S. align our future transportation strategy with the realities and direction of the worldwide open, competitive marketplace and the areas of largest global investment. We must architect and adopt a leading-edge, future-proof strategy that invests primarily in AVs (self-driving cars) and 5G cellular technology starting with V2V real-time collision avoidance applications. However, USDOT is not promoting – or even seriously researching – advanced cellular technologies like 5G for V2V safety critical applications, which many industry experts believe will be the leading global V2V safety technology.[67] For the U.S. to stay apace our global competitors, Congress should direct USDOT to undertake a meaningful, technology-neutral cost-benefit analysis vs. DSRC[68] to ensure that US consumers are poised to reap the benefits of the best V2V safety technology(ies) that will *evolve at the pace of marketplace innovation* – and enable U.S. IoT transportation leadership now and in the future.

Most of the world is developing and testing AVs and 5G connectivity for real-time collision avoidance *independent of DSRC* (if they are testing DSRC at all). Let the technologies' capabilities determine marketplace winners and losers, rather than force industry investment in a technology (DSRC) chosen in 1999 before mobile broadband even existed – and that will put the U.S. behind other countries. Seventeen years later, we should be investing in the future (aligned with the greater global marketplace), rather than forcing U.S. investment in an old technology. If we invest the time now to do broader technology R&D and transition to a more future-proof strategy, policymakers will be ensuring that U.S. consumers have the benefit of the best collision avoidance technolology(ies) that *will evolve at the pace of innovation*. Without this, we risk thwarting U.S. global leadership and, more importantly, the potential to save more American lives.

DSRC has been slow to develop (in testing phase for nearly two decades) and is not poised to evolve at the pace of innovation because the marketplace is unlikely to see the global industry support or voluntary widespread market demand that would enable economies of scale. Also, unlike 5G, which industry is evolving from existing 4G networks and infrastructure, DSRC will require entirely new infrastructure at massive taxpayer expense for years to come; the cost of building and deploying new

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[67] *See, e.g., DSRC Confronts a Battle for relevance at ITS World Congress (2014)*: https://www.strategyanalytics.com/access-services/automotive/powertrain-body-chassis-and-safety/reports/report-detail/dsrc-confronts-a-battle-for-relevance-at-its-world-congress?Related#.Vwgur_krJD8

[68] It is critical that the nation's limited funding be invested in 5G and AVs *independent of* DSRC, as AVs and 5G connectivity operate independently of (and without need for) DSRC. Yet, USDOT investment in AVs and cellular to date primarily have encouraged a DSRC aspect to the test bed or project. Despite many comments by high-tech industry advocating advanced cellular/5G for V2V safety and questioning a DSRC mandate in the agency's 2014 V2V ANPRM, USDOT still has not funded any advanced cellular testbeds for V2V safety communications that would enable a head-to-head comparison with DSRC.

infrastructure for DSRC and covering all necessary rural and urban areas is estimated to be approximately $3,000/mile.[69] For these reasons, innovations like next generation cellular 5G are developed, tested, built out and commercialized at a far faster pace than DSRC – and will continue to evolve on pace with innovation. In the end, the losers will be U.S. consumers deprived of the best cellular V2V safety technologies that evolve on pace with a competitive marketplace.

***Encourage Open Platforms**.* Open IoT technology platforms are critical to the ability of U.S. companies to compete globally because they ensure cross-industry support and agreement. Open platforms allow multiple manufacturers to "plug in" their technologies, while proprietary platforms only allow use of a single manufacturer's proprietary technology. This encourages developers to create solutions that span from car to cloud in a simple way. Government should encourage industry to collaborate on open platforms for autonomous and connected vehicles.

Open platforms are necessary to accelerate and maximize innovation across the increasingly broadening automotive and transportation industries and enable economies of scale. For example, Intel is widely deploying "state of the art" autonomous reference platforms that are open, standards-based and scalable to support safe and secure computing both in the vehicle and the connected data center. This enables other stakeholders and innovators to contribute core technology including platform software, machine learning algorithms and data collected from vehicle sensors to enable a safe and secure driving experience.

***Support Open Standards and Consortia Efforts**.* Global standards and consortia efforts are critical to maintain the long term viability of technology advancements. They enable a commercialization path that is scalable, interoperable and reusable across a variety of use case deployments, vendors and sectors. Accordingly, a certain level of standardization and interoperability is vital to the successful commercialization of self-driving vehicles, connected cars, "smart" fleet management and the intelligent transportation ecosystem. Industry-led voluntary global standards can accelerate adoption, drive competition, and enable cost-effective introduction of new technologies, while providing a clearer technology evolution path that stimulates investment.

Industry is in the best position to lead development of technological standards and solutions to address global transportation ecosystem opportunities and challenges to enable self-driving vehicles, connected vehicles, "smart" fleet management and intelligent transportation systems. *Policymakers should refrain from mandating specific technologies, standards, or protocols* and, instead, let the marketplace determine technology winners and losers. Government should encourage industry to collaborate in global, open-participation standardization efforts to develop technological best practices and standards, and it should participate in the development of standards where there is a government interest and encourage the use of commercially available solutions to enable the benefits of these new technologies to become reality sooner.

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[69] *5G-PPP Automotive White Paper* (Oct. 2015).

***Invest in Public-Private Partnerships**.* The tech industry is critical to the future of US transportation policy dialogue. A vehicle is an increasingly complex data center on wheels, requiring evermore high-powered processors and internet connectivity – with self-driving cars expected to process at 1 GB of data per second.[70] As part of a National IoT Transportation Strategy, policymakers should encourage Public-Private Partnerships (PPPs) to launch and scale globally competitive transportation test beds. These testbeds are necessary to accelerate deployment of technologies such as 5G which is critical to U.S. leadership in V2V safety-critical and V2X communications and machine learning which is critical to autonomous driving.

Government and industry collaboration can be one of our nation's best assets to accelerate the adoption of world-class transportation systems. Viable PPPs between government and the auto and tech industries must entail logical investments for both government and industry, as well as ensure scalability of automotive innovations and sustainability of transportation infrastructure in the long term. Using public and private resources to facilitate US research leadership, and governance for in 5G connectivity and autonomous driving, while leveraging existing industry standards and investments, will accelerate our future toward self-driving vehicles, connected cars, "smart" fleet management, and intelligent transportation infrastructure.

Intel recommends that policymakers encourage PPPs in the following areas that are critical to the success of safe and secure autonomous and connected vehicles:

- *Trusted Data and Secure Compute* - Fully autonomous driving will require the processing capabilities of a "mini data center on wheels." A self-driving car will require up to 40 Teraflops of computer graphics processing speed, which is the equivalent to 20 HD TVs inside each vehicle. Compare: A Play Station 4 uses only 1.84 Teraflops. Along with this enormous computing power, every data exchange to and from the vehicle must be trusted, safe and secure. As discussed above, powerful computing with integrated security is Intel's core competency, and what our data center customers have required for decades.

- *5G Connectivity* – As discussed at the outset, soon-to-be launched 5G – boasts superior key performance indicators for vehicle connectivity use cases, especially V2V safety-critical applications. To align the Industry, Intel is driving standards workgroups in 3GPP and the Wi-Fi Alliance to influence new standards, converge protocols and demonstrate functionally safe and secure safety-critical use cases. Intel and our partners around the world in the academic, auto and technology industries are working collaboratively to drive robust, open, secure and scalable 5G standards for V2V safety-critical communications.

- *Security as a Foundation* – Intel has long touted security as a foundation for the IoT. Securing connected vehicles and the supporting infrastructure is foundational to keeping passengers

[70] Smart Data.

safe and secure and requires an end-to-end system (vehicle to cloud) approach. Not only must every vehicle be safeguarded against cyber threats, but every device connected to the vehicle and the personal information available via these devices, must also be kept private as it moves between the vehicle, connected devices, connected infrastructure, and the cloud. Intel formed the Automotive Security Review Board[71] to help align the tech and automotive industries and cybersecurity experts on guidelines and best practices to make vehicles secure.

- *Machine Learning* - The fully autonomous vehicle must become the ultimate learning machine. It will be relied upon to make smarter and safer decisions than even the most skilled human driver. Intel has been investing in companies with expertise in functional safety[72] and doing foundational research in Deep Learning for many years and is working to ensure that our products both in the vehicle and in the data center are capable of bringing the intelligence needed for the vehicle to sense and adapt.

- *Open, Standards-Based Platforms* - Intel is working with fellow tech and auto industry leaders to define industry standards to accelerate autonomous driving deployments and create economies of scale that enable rapid marketplace adoption. This will enable industry leaders to contribute core technology including platform software, machine learning algorithms and data collected from vehicle sensors to enable a safe and secure driving experience.

CONCLUSION

Intel appreciates the opportunity to share our perspective on the enormous opportunity of the IoT in the transportation sector. We look forward to working with this Committee and other policymakers to develop a strategy for U.S. leadership in the next evolution of transportation – one that is poised to evolve at the pace of innovation.

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[71] *Intel commits to mitigating automotive cyber security risks*, Intel Corp. (Sept. 2015), https://newsroom.intel.com/news-releases/intel-commits-to-mitigating-automotive-cybersecurity-risks/.

[72] *Intel Acquires Yogitech to Strengthen its Internet of Things Group*, Venture Capital Post (April 2016), http://www.vcpost.com/articles/119131/20160407/intel-yogitech-altera-corp-autonomous-vehicles.htm