Before the

FEDERAL COMMUNICATIONS COMMISSION

Washington, DC 20554

In the Matter of	)	
	)	
Petition For Waiver to Allow Deployment of	)	ET Docket No._____
Intelligent Transportation System Cellular	)	
Vehicle to Everything (C-V2X) Technology	)	
	)	

5GAA PETITION FOR WAIVER

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EXECUTIVE SUMMARY

At the dawn of the 5G revolution, the 5G Automotive Association ("5GAA") – a rapidly growing global association that brings together many of the world's major automotive, technology and telecommunications companies – requests that the Commission grant a waiver, subject to the conditions proposed in Appendix D attached hereto, of footnote NG160 to Section 2.106 of the Commission's rules to allow for the deployment of Cellular Vehicle-to-Everything technology, better known as C-V2X, in a 20 MHz channel located in the upper edge of the 5.850-5.925 GHz ("5.9 GHz") band (5905-5925 MHz). As supported by the attached 5GAA test report, C-V2X represents a significant advancement in connected vehicle technology and is the first step towards leveraging 5G to increase road safety and to maximize the myriad other benefits of connected vehicles on America's roads.

Built upon earlier efforts to develop Intelligent Transportation System ("ITS") services and leveraging advancements in cellular technologies, first 4G and ultimately 5G, C-V2X is a modern, standards-based connected-vehicle communications technology. C-V2X enables direct, peer-to-peer mode communications between vehicles themselves ("V2V"), vehicles and vulnerable persons such as pedestrians and cyclists ("V2P"), and vehicles and transportation infrastructure ("V2I"), as well as communications between vehicles and mobile networks ("V2N"). These communications can help enable important improvements in safety, traffic efficiency, mobility, and energy efficiency on America's roads.

Congress, the U.S. Department of Transportation ("DOT"), and the Commission have acknowledged for decades the life-saving and societal benefits enabled by ITS services. Today, the need for ITS services persists. Indeed, the DOT and the National Highway Traffic Safety Administration ("NHTSA"), the nation's expert agency in traffic safety, repeatedly have stressed in recent years the importance of ITS services in the 5.9 GHz band for improving safety.

Unfortunately, widespread implementation of C-V2X technology in the United States is not feasible today. The Commission's current rules for the 5.9 GHz band – adopted well before the development of C-V2X – restrict ITS operations to those that use the Dedicated Short Range Communications ("DSRC") standard.

The consequences of this restriction are significant. Recent testing performed by 5GAA members demonstrates that C-V2X peer-to-peer mode consistently outperforms DSRC in several key areas. These performance advantages, which include enhanced reliability over an extended communication range, better non-line-of-sight performance, and greater resiliency, can – both individually and as a complement to existing radar- and camera-based systems – provide vehicles and drivers with an earlier, more complete picture of the surrounding road environment.

C-V2X's performance advantages over DSRC are particularly important in non-line-of-sight scenarios (e.g., around corners, through large trucks, etc.). Because current and near-term in-vehicle camera and sensor-based technologies experience limitations in non-line-of-sight scenarios, C-V2X's performance advantage over DSRC thus may allow vehicles to perceive and provide earlier warnings of threats hidden from view. As NHTSA has acknowledged, such V2V warnings are particularly useful near intersections and in highway passing and braking scenarios.

The performance advantages of C-V2X peer-to-peer mode are further augmented by C-V2X's V2N mode communications. V2N mode communications play an important complementary role to peer-to-peer mode communications by, among other things, providing the ability to offload less time-sensitive V2V, V2I, and V2P communications to a cellular network during times of peak congestion.

C-V2X is also designed with an upgrade path to 5G. Over the next several years, C-V2X will unlock the power of 5G technologies, driving further improvements in performance, introducing new capabilities to connected vehicles and infrastructure, and extending the number of use cases for C-V2X. For example, 5G C-V2X is expected to complement and augment advanced driving applications that enhance semi-automated or fully-automated driving features by coordinating the behaviors of vehicles.

To expedite the availability of C-V2X services, 5GAA is requesting a waiver of the Commission's rules to deploy C-V2X in the 5.905-5.925 GHz portion of the ITS band. Good cause exists for the issuance of the requested waiver under the conditions proposed herein. First, grant of the requested waiver is in the public interest because it will expedite the widespread availability of ITS services in the 5.9 GHz band. Not only is C-V2X deployment expected to enable important safety benefits, but it also will enable other important public interest benefits, including improvements in traffic efficiency, productivity, mobility, and the conservation of fossil fuels. In addition, grant of the waiver will allow Americans to have access to the same modern safety technologies that are currently available or will soon be in other parts of the world. Finally, because C-V2X can be deployed in a cost-efficient manner, a waiver grant likely will enable consumers to benefit from ITS technology on an expedited timeframe.

Second, rather than undermine the underlying purpose of the rules, the waiver would advance the Commission's objectives for allocating the 5.9 GHz band for short-range ITS services. The waiver grant will enable the deployment of C-V2X technology, which will help improve vehicular safety and travel. Moreover, a waiver is not expected to disturb existing commercial DSRC operations. Finally, other non-DSRC users of the band will not be negatively affected by a waiver grant, as the conditions proposed herein impose substantially similar technical and service requirements on C-V2X operations as those that are currently required by the Commission's rules for DSRC operations.

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5GAA Petition For Waiver

I. Introduction

Pursuant to Section 1.3 of the Federal Communications Commission's ("FCC" or "Commission") rules, the 5G – Automobile Association ("5GAA")[1] respectfully requests that the Commission grant a blanket waiver, with conditions, of footnote NG160 to Section 2.106 of the Commission's rules[2] to allow for the deployment of Cellular Vehicle-to-Everything technology, better known as C-V2X, in the 5.905-5.925 GHz range of the 5.850-5.925 GHz ("5.9 GHz")

[1] 5GAA is a global cross-industry organization of companies from the automotive, technology and telecommunications industries working together to develop end-to-end connectivity solutions for intelligent transportation, future mobility systems and smart cities. *See* 5GAA, www.5gaa.org (last visited Nov. 19, 2018). Created in 2016 by eight founding members, 5GAA's membership has expanded rapidly and now includes over 100 companies. *See* Appendix A for a complete member list. In the past two years, 5GAA and its members have demonstrated the capabilities of C-V2X across the globe. *See* Press Release, 5GAA, *5GAA, BMW Group, Ford and Groupe PSA Exhibit First European Demonstration of C-V2X Direct Communication Interoperability Between Multiple Automakers* (July 11, 2018), http://5gaa.org/news/5gaa-bmw-group-ford-and-groupe-psa-exhibit-first-european-demonstration-of-c-v2x-direct-communication-interoperability-between-multiple-automakers; Press Release, 5GAA, *5GAA, Audi, Ford and Qualcomm Showcase C-V2X Direct Communications Interoperability to Improve Road Safety* (Apr. 26, 2018), http://5gaa.org/news/5gaa-audi-ford-and-qualcomm-showcase-c-v2x-direct-communications-interoperability-to-improve-road-safety-2; Press Release, 5GAA, *5GAA participates in Testbed Visit in Shanghai* (Nov. 16, 2017), http://5gaa.org/news/5gaa-participates-in-testbed-visit-in-shanghai; Press Release, 5GAA, *5GAA joins 3GPP* (Apr. 27, 2018), http://5gaa.org/news/5gaa-joins-3gpp; GSMA, *Cellular Vehicle-to-Everything (C-V2X) Enabling Intelligent Transport* (rel. Jan. 2, 2018), https://www.gsma.com/iot/wp-content/uploads/2017/12/C-2VX-Enabling-Intelligent-Transport_2.pdf.

[2] 47 C.F.R. § 2.106, NG160 ("In the 5850–5925 MHz band, the use of the non-Federal government mobile service is limited to Dedicated Short Range Communications operating in the Intelligent Transportation System radio service.").

band. In addition to the instant petition for waiver ("Waiver Request"),[3] 5GAA plans to file a complementary petition for rulemaking in the near future requesting that the Commission initiate a proceeding to modify its rules for the 5.9 GHz band to provide stakeholders the flexibility to take the evolutionary leap forward in connected vehicle technologies. This Waiver Request is narrowly tailored to allow for the immediate deployment of C-V2X during the pendency of the Commission's broader proceeding. As further discussed herein, a grant of the Waiver Request would serve the public interest by expediting the availability of C-V2X technology that holds the potential to improve safety, traffic efficiency, mobility, and energy efficiency on America's roads and would further, rather than undermine, the underlying objectives for allocating the 5.9 GHz band for ITS services.

II. The Current Rules Prohibit Use of C-V2X in the 5.9 GHz Band

Built upon earlier Intelligent Transportation System ("ITS") efforts and recent advancements in cellular technologies, C-V2X is a modern standards-based communications system that represents an evolution in connected vehicle technology and the first step towards leveraging 5G to increase safety and to maximize the myriad other benefits of connected vehicles on America's roads. Already incorporated into standards set by the 3rd Generation Partnership Project ("3GPP"),[4] C-V2X empowers direct communications between vehicles ("V2V"), between vehicles and pedestrians, cyclists and other vulnerable persons ("V2P"), and between vehicles and transportation infrastructure ("V2I"), as well as communications between vehicles and mobile networks ("V2N").

[3] This Waiver Request reflects the views of 5GAA, and does not necessarily reflect the views or positions of each of the individual members of 5GAA.

[4] 3GPP is the world's preeminent standards body for cellular technologies.

C-V2X offers capabilities unrivaled by other ITS technologies. In extensive comparative benchmark testing conducted by members of 5GAA, C-V2X consistently outperformed radio operations based on the IEEE 802.11p standard, commonly referred to as Dedicated Short Range Communications ("DSRC"),[5] in a number of key areas.[6] These performance advantages, which include superior reliability over a much greater communications range, better non-line-of-sight performance, and greater resiliency, can – both individually and as a complement to in-vehicle camera and sensor-based technologies – provide vehicles and drivers with an earlier, more complete picture of the surrounding road environment.

C-V2X also offers an evolution path to 5G. Chairman Pai has recognized the potential of 5G-enabled ITS:

> Imagine a world where everything that can be connected will be connected – where driverless cars talk to smart transportation networks…. That's a snapshot of what the 5G world will look like.[7]

C-V2X technology's evolution path to 5G promises to bring this vision to ITS, addressing America's road safety and connected mobility needs with applications such as connected and automated driving, ubiquitous access to services, and integration into smart city and intelligent transportation applications.

[5] Over the course of the better part of the last two decades, the DSRC service has been conflated with the IEEE 802.11p standard, which in turn is based on the ASTM E2213-03 standard. The Commission's rules define the DSRC service broadly, but limit operations within the DSRC service to radios compliant with the ASTM E2213-03 standard. *Compare* 47 C.F.R. § 90.371 (defining DSRC service) *with* 47 C.F.R. §§ 90.379, 95.3189 (limiting operations to radios compliant with the ASTM E2213-03 standard). This Petition uses the term "DSRC" to refer to technology based on the IEEE 802.11p standard or the ASTM E2213-03 standard.

[6] *See* 5GAA Test Report at Appendix B.

[7] Ajit Pai, *Column: Florida is on the leading edge of 5G*, Tampa Bay Times, May 14, 2018, https://www.tbo.com/-opinion/columns/Column-Florida-is-on-the-leading-edge-of-5G_168227409.

Unfortunately, widespread implementation of C-V2X technology in the United States is not feasible today. The Commission's current rules for the 5.9 GHz band – adopted well before the development of C-V2X – restrict ITS operations to those that use the DSRC standard.

The negative repercussions of this restriction are considerable. Opening the 5.9 GHz to a newer technology, C-V2X, will bring great societal benefits. Congress, the U.S. Department of Transportation ("DOT"), and the Commission have acknowledged for decades the potential life-saving and societal benefits enabled by ITS. With respect to safety in particular, NHTSA – the nation's expert agency in traffic safety – has stated that ITS technologies in the 5.9 GHz band have the potential to "revolutionize motor vehicle safety."[8] This is due, among other reasons, to the fact that ITS technologies can address crashes that cannot be prevented by current vehicle-resident technologies.[9] For example, ITS technologies offer non-line-of-sight capabilities (i.e., the ability to "see" around corners and "see" through other vehicles) that vehicle-resident sensors cannot match.[10] In addition, NHTSA expects the fusion of ITS with vehicle-resident technologies to enhance the reliability and accuracy of sensor-based information in the short term and, in the longer term, advance the further development of vehicle automation systems.[11] Consistent with the importance of ITS services in the 5.9 GHz band, the DOT recently issued guidance "encourage[ing] the automotive industry, wireless technology companies,

[8] *See, e.g.*, Federal Motor Vehicle Safety Standards; V2V Communications, 82 Fed. Reg. 3854, 3855 (Jan. 12, 2017) ("Federal Motor Vehicle Safety Standards").

[9] *See id*. Vehicle-resident technologies include in-vehicle camera and sensor-based technologies.

[10] In addition to increased non-line-of-sight capabilities, ITS offers a number of additional benefits. For example, ITS basic safety messages contain additional information, such as path predictions and driver actions, not available from traditional sensors. Moreover, ITS offers an operational range that far exceeds that of vehicle-resident systems, and ITS technology is not subject to the same system limitations as vehicle-resident sensors, which may be affected by weather, sunlight, shadows, or cleanliness.

[11] *See* Federal Motor Vehicle Safety Standards, 82 Fed. Reg. at 3855.

[infrastructure owners and operators], and other stakeholders to continue developing technologies that leverage the 5.9 GHz spectrum for transportation safety benefits."[12]

To accelerate the realization of the expected benefits from C-V2X services, and consistent with the DOT's guidance regarding the development of technologies that leverage the 5.9 GHz band, the Commission should grant this Waiver Request to allow for the near-term deployment of C-V2X technology. While this Waiver Request seeks permission to deploy C-V2X in the upper 20 MHz of 5.9 GHz band, this request should not be misconstrued as an indication that C-V2X requires only 20 MHz of spectrum. While 20 MHz is the ideal channel size for 4G LTE-based C-V2X, i.e., the initial version of C-V2X, the bandwidth requirements to support more intensive 5G-enabled road safety applications will be much higher. This should come as no surprise. It is a simple matter of physics that 5G technology requires access to large swaths of spectrum to meet the speed and latency requirements of 5G applications. 5G-based C-V2X is no different. 5GAA thus plans to file a complementary petition for rulemaking in the near future requesting that the Commission initiate a proceeding to modify its 5.9 GHz band ITS rules to provide stakeholders the flexibility to take the evolutionary leap forward in connected vehicle technologies enabled by 5G.

III. C-V2X is a Modern, Standards-Based Technology Designed to Meet Today's Transportation Challenges as Well as the Evolving Demands of Tomorrow's 5G Connected Transportation Ecosystem

Building upon decades of continuous evolution in cellular technologies, the standards development for C-V2X began in 2015 when 3GPP specified C-V2X features based on the 4G

[12] *See* U.S. Department of Transportation, *Automated Vehicles 3.0, Preparing For the Future of Transportation*, at 16 (Oct. 4, 2018), https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/320711/preparing-future-transportation-automated-vehicle-30.pdf.

LTE-Pro system in 3GPP Release 14.[13] The Release 14 version of LTE, which was finalized in 2017, was the first cellular standard to incorporate C-V2X technology, but it would not be the last.[14] 3GPP Release 15 also incorporated C-V2X,[15] and work already is underway to develop 5G C-V2X in 3GPP Release 16, which is expected to be completed next year.[16]

C-V2X is comprised of two complementary communications modes for vehicular operations: peer-to-peer (called PC5 in 3GPP specifications) and network (called Uu in the specifications) communications. Peer-to-peer mode communications, which can operate independently of cellular networks and without a network subscription,[17] include: (1) V2V communications, which are expected to be used to communicate safety information between nearby vehicles to prevent collisions; (2) V2I communications (e.g., traffic signals, variable message signs, etc.), which are expected to communicate safety and traffic information to prevent accidents associated with roadway conditions and improve traffic efficiency, and (3) V2P communications, which are expected to be used to communicate safety information between vehicles and other road users such as pedestrians, bicyclists, motorcyclists, etc. to

[13] Dino Flore, *Initial Cellular V2X standard completed*, 3GPP (Sept. 26, 2016), http://www.3gpp.org/news-events/3gpp-news/1798-v2x_r14ietf%20ipwave; NGMN Alliance, *V2X White Paper v. 1.0*, at 19 (June 17, 2018), https://www.ngmn.org/fileadmin/ngmn/content/downloads/Technical/2018/V2X_white_paper_v1_0.pdf.

[14] 3GPP, *Release 14*, http://www.3gpp.org/release-14 (last visited Nov. 19, 2018).

[15] 3GPP, *Release 15*, http://www.3gpp.org/release-15 (last visited Nov. 19, 2018).

[16] *See* 3GPP, *3GPP Features and Study Items*, http://www.3gpp.org/DynaReport/FeatureListFrameSet.htm (last visited Nov. 19, 2018) (identifying a study on NR Vehicle-to-Everything as part of the feature and study item list for Release 16).

[17] As excitement grows about the potential for C-V2X to improve traffic safety, productivity, mobility, and energy efficiency, there inevitably also has developed a few inaccuracies regarding the nature of this service. One such inaccuracy is that the V2V, V2I, and V2P services that C-V2X enables will require a subscription. The peer-to-peer mode communications enabled by C-V2X do not require cellular network connectivity and thus do not require a subscription. *See* Tom Rebbeck et al., *Socio-Economic Benefits of Cellular V2X*, at 28, Analysys Mason (Dec. 2017), http://5gaa.org/wp-content/uploads/2017/12/Final-report-for-5GAA-on-cellular-V2X-socio-economic-benefits-051217_FINAL.pdf.

prevent accidents.[18] To augment these peer-to-peer mode communications, C-V2X's network (V2N) mode capabilities allow vehicles to communicate with the rest of the world over the Uu interface and through cellular networks. These V2N mode communications enable key supporting functions for the peer-to-peer mode communications uses and expand the universe of applications enabled by C-V2X services.

Individually and in concert, these two communications modes of C-V2X make this technology uniquely suited to further the objectives of ITS in the 5.9 GHz band.

A. C-V2X Offers Capabilities Today that are Superior to Those of Other Technologies – Enabling Safety and Other Benefits

The superior capabilities of C-V2X primarily are enabled by the radio performance of C-V2X peer-to-peer mode communications, which far exceeds the performance of DSRC radios in key areas. This performance advantage is augmented in turn by C-V2X's V2N mode communications in a number of ways. In their totality, the resulting capabilities of C-V2X hold the potential to deliver a range of societal benefits.

1. 5GAA Testing Confirms the Significant Performance Advantages of C-V2X Peer-to-Peer Mode when Measured Against DSRC

A number of 5GAA members recently conducted extensive comparative benchmark testing to measure the radio performance of C-V2X peer-to-peer mode communications against DSRC. Using technology-agnostic test procedures documented and harmonized in 5GAA for global consistency and meticulous management of parameters affecting radio propagation to ensure fair comparison, the testing demonstrates that the radio performance of C-V2X peer-to-

[18] *See* 5G Americas White Paper, *Cellular V2X Communications Towards 5G*, at 4 (Mar. 2018), http://www.5gamericas.org/files/9615/2096/4441/2018_5G_Americas_White_Paper_Cellular_V2X_Communications_Towards_5G__Final_for_Distribution.pdf. Because C-V2X is part of the 3GPP standard, any vulnerable road user carrying a mobile device could potentially benefit from the protections offered by C-V2X. *Id*. at 29.

peer mode consistently outperforms DSRC in key areas.[19] Most notably, when compared to DSRC, C-V2X peer-to-peer mode delivers superior reliability over a much greater communications range, better non-line-of-sight performance, and greater resiliency to interference. Moreover, C-V2X implements congestion control mechanisms that meet the standards set by the Society of Automotive Engineers ("SAE").[20] While the complete 5GAA Test Report is attached in Appendix B, an overview of the highlights of this testing provides valuable insight into the performance advantages of C-V2X.

C-V2X's Superior Reliability Over a Much Greater Communications Range

5GAA's line-of-sight field testing assessed the baseline range capability for V2V message exchanges using C-V2X peer-to-peer mode and DSRC. In one scenario, a stationary vehicle received communications from a vehicle in its line of sight.

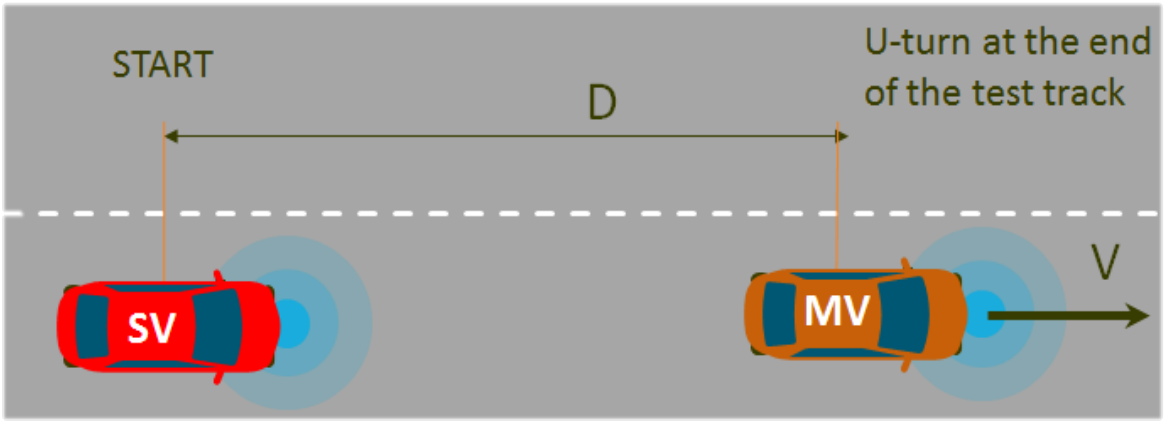

***Figure 1**: Depiction of 5GAA's Line-of-Sight field test.*

As demonstrated in Figure 2, and discussed in detail at pages 72-78 of the 5GAA Test Report, under 5GAA's testing parameters, C-V2X reliably received messages at distances up to 1,175 meters, which amounts to an approximate line-of-sight range advantage of 500 meters

[19] *See* 5GAA Test Report at Appendix B.

[20] Moreover, this radio is designed with a consistently achieved, highly reliable latency regardless of channel congestion. *See* 5G Americas White Paper, *supra* note 18, at 22.

when compared to those vehicles equipped with DSRC. In other words, C-V2X's ability to reliably deliver messages in a line-of-sight scenario was almost 75% greater than that of DSRC.

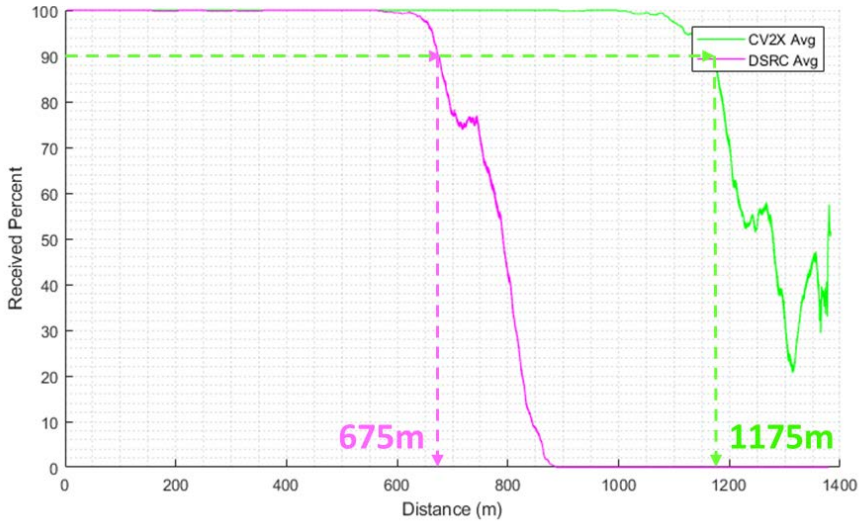

Figure 2*: Line-of-sight field test results in a scenario in which a stationary vehicle received communications from an approaching vehicle that was transmitting communications.*

C-V2X's Better Non-Line of-Sight Performance

An examination of two specific tests helps to illustrate the better non-line-of-sight performance of C-V2X peer-to-peer mode compared to DSRC. These tests are (1) the intersection test with an obstructed view and (2) the shadowing test.

Intersection Test with an Obstructed View. 5GAA's intersection test with an obstructed view assessed V2V communication capabilities in situations in which an obstruction is blocking the line of sight between a vehicle at an intersection and vehicles in lateral traffic crossing the intersection. An illustration of this test scenario is provided in Figure 3.

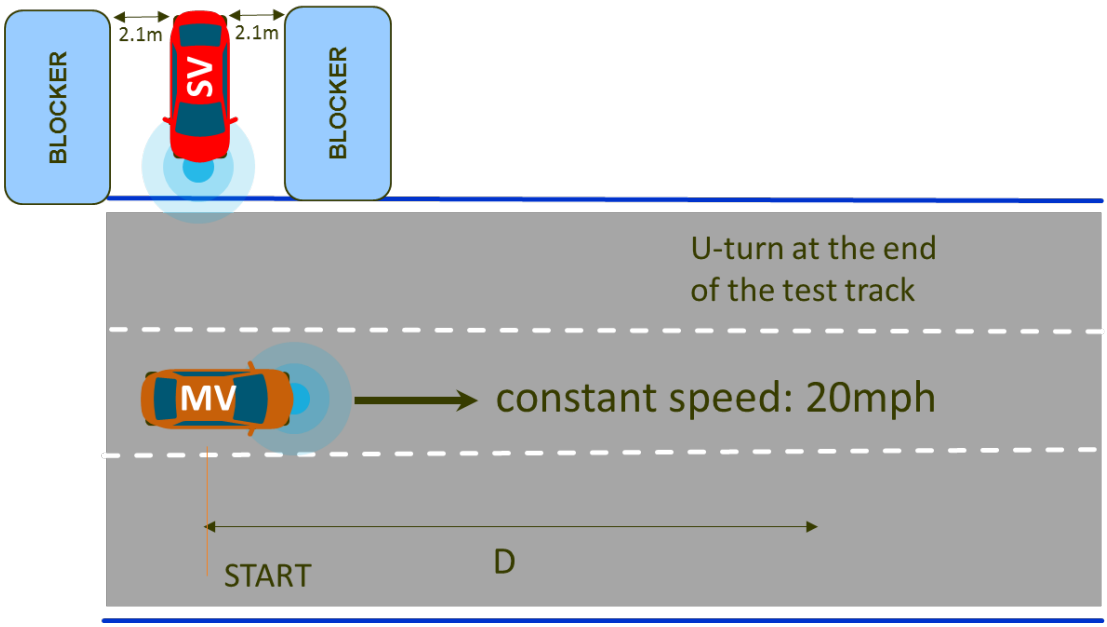

***Figure 3**: Depiction of 5GAA's Intersection Test with Obstructed View.*
In this scenario, the stationary vehicle (SV) is receiving communications and the vehicle moving lateral across the intersection (MV) is transmitting communications.

In this scenario, C-V2X peer-to-peer mode communications again outperformed DSRC by a wide margin. As illustrated in Figure 4 and discussed in detail at pages 84-87 of the 5GAA Test Report, C-V2X demonstrated a reliable range of approximately 875 meters in this scenario, outperforming DSRC's reliable range of approximately 375 meters. In other words, the testing results indicate that C-V2X's reliable range is more than twice that of DSRC in this scenario.

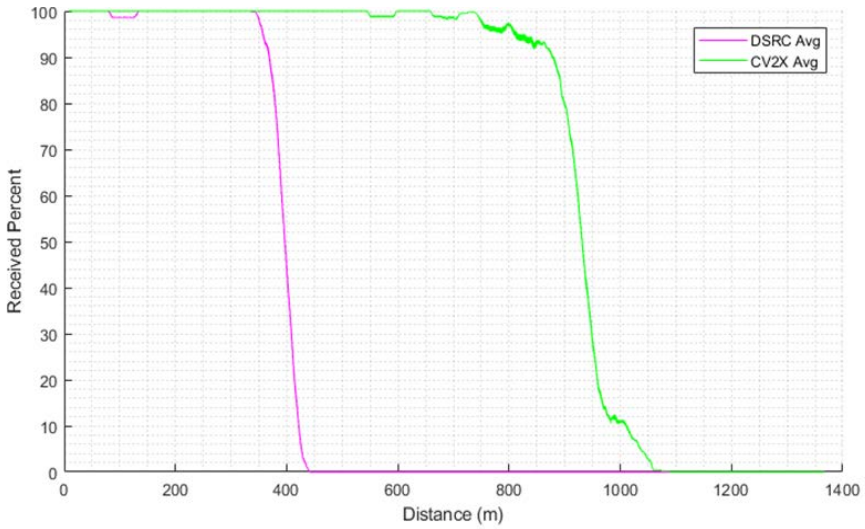

***Figure 4**: Intersection Test with Obstructed View in a scenario in which a stationary vehicle is receiving communications and the vehicle moving lateral across the intersection is transmitting communications.*

Shadowing Field Test. 5GAA's shadowing test assessed the capability for V2V message exchange in non-line of sight scenarios in which there is a significant obstruction between the vehicles trying to communicate with one another. In this scenario, which is illustrated in Figure 5 below, the stationary vehicle and blocker remain motionless while the moving vehicle travels away from the blocker.

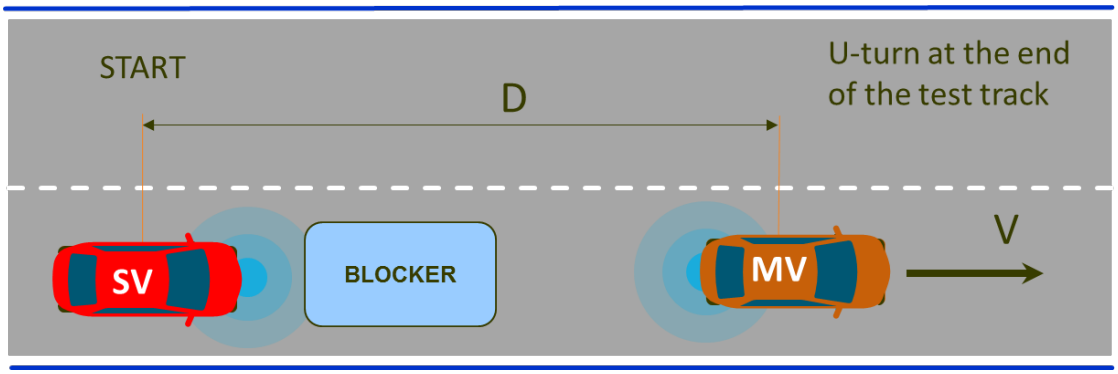

***Figure 5**: Shadowing Test in a scenario in which a stationary blocker is positioned in front of a stationary vehicle (SV) that is transmitting to a vehicle moving (MV) away from the SV and blocker. In this scenario, the blocker creates a significant line of sight obstruction between the vehicles.*

In the shadowing test scenario, C-V2X peer-to-peer mode communications once again outperformed DSRC by a wide margin. As illustrated in Figure 6 and discussed in detail at pages 79-83 of the 5GAA Test Report, C-V2X achieved a reliable range of approximately 425 meters, compared to DSRC's reliable range of only 125 meters. In other words, the testing

results indicate that C-V2X delivers superior transmission reliability at almost three times the range of DSRC in this scenario. As discussed in greater detail below, the results of the shadowing field testing, which are depicted in Figure 6, and the intersection test with an obstructed view are significant because they demonstrate the potential of C-V2X to provide vehicles with information about the surrounding environment that cannot be seen by the driver and that may not be detected by current in-vehicle camera and sensor-based technologies.

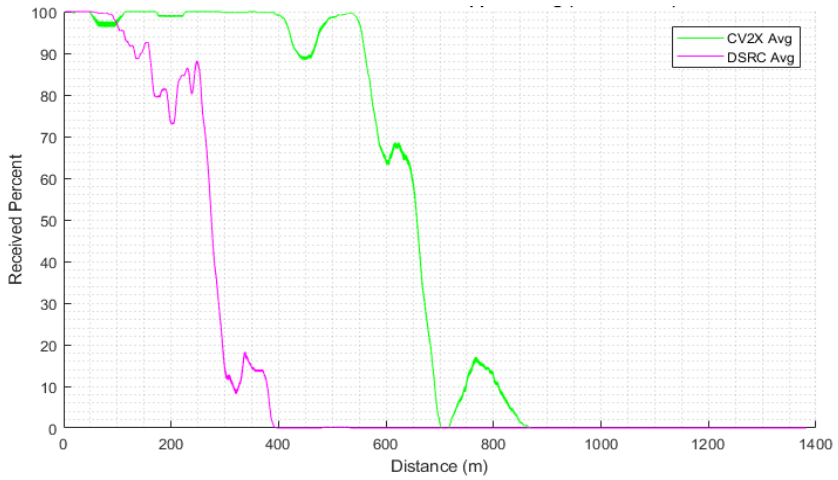

***Figure 6**: Shadowing Test results in a scenario in which a blocker is positioned in front of a stationary vehicle to create a significant line of sight obstruction.*

C-V2X's Superior Resiliency to Interference

5GAA's testing also demonstrates a significant advantage for C-V2X in its resilience to out of band interference. In one scenario, line-of-sight range for C-V2X and DSRC was measured while a wireless hot spot operated in an adjacent channel. As demonstrated in Figure 7 and discussed in detail at pages 79-83 of the 5GAA Test Report, C-V2X once again demonstrated a significant advantage with a reliable range of more than seven times that of DSRC.

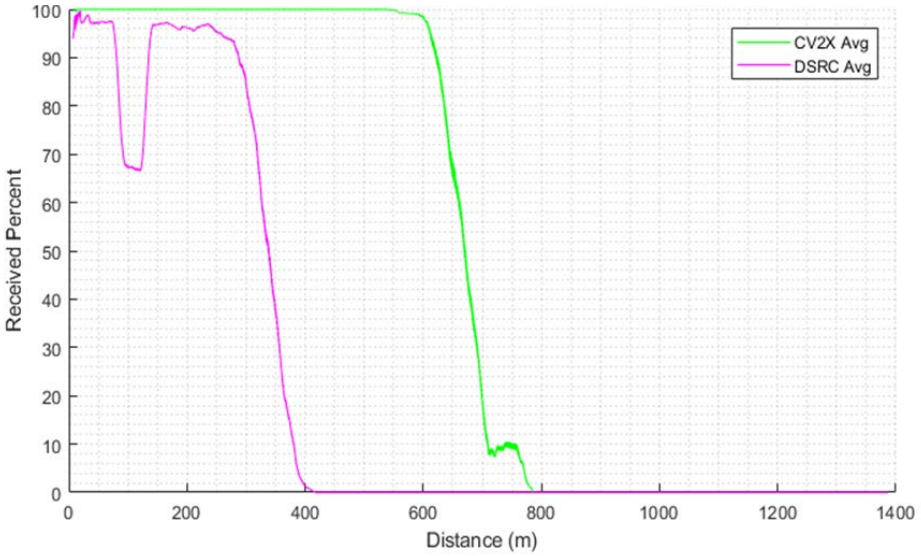

***Figure 7**: Line-of-sight range with out of band interference was measured in a scenario in which a moving, transmitting vehicle approached a stationary vehicle while a Wi-Fi hotspot using an 80 MHz channel operated with a 40 MHz separation to the C-V2X or DSRC operations.*[21]

C-V2X's Congestion Control

5GAA's testing also confirms C-V2X's ability to implement congestion control. As demonstrated more fully in the 5GAA Test Report, testing indicates that C-V2X can implement communications congestion control in accordance with the industry standard specified by the SAE, which was designed specifically for DSRC. By employing additional congestion management techniques, C-V2X is likely to demonstrate performance that exceeds the SAE standards.[22]

2. The Performance Advantages of C-V2X Peer-to-Peer Mode, Which are Further Augmented by V2N Mode Capabilities, Can Help Unlock Safety and Other Benefits on America's Roads

The performance advantages of C-V2X peer-to-peer mode can help unlock improvements in a variety of ITS applications and in a variety of different scenarios (e.g., varying road/traffic

[21] The initial dip observed in DSRC performance is a consequence of out-of-band emissions, which effectively raise the floor of receiver sensitivity and amplify the effect of reflected-ray destructive interference. This is not observed in C-V2X results because of C-V2X's higher link-budget. The importance of such resiliency in a world where Wi-Fi presence will be pervasive cannot be understated.

[22] For example, C-V2X can manage radio resources at a more granular level as channel widths increase, which holds the promise to enable further improvements in C-V2X's implementation of congestion control.

conditions and vehicle speeds). With C-V2X, drivers and vehicles will have access to a more complete and accurate picture of the surrounding road environment. For example:

- ***C-V2X's improved non-line-of-sight performance*** allows vehicles and drivers to "see" more clearly through obstructions and further around corners, providing an earlier, more expanded view of the surroundings;[23]

- ***C-V2X's enhanced reliability*** provides more certainty that critical safety messages reach their intended destination at a much greater communications range;[24]

- ***C-V2X's superior resiliency*** to out of band emissions provides a more dependable performance for vehicles and drivers;

- ***C-V2X's higher capacity*** to transmit data, a feature expected in future versions of C-V2X, will allow more and higher quality information to reach the driver and vehicle; and

- ***C-V2X's communications congestion control*** in traffic jams and other scenarios in which there is a high volume of vehicles in the same vicinity helps to ensure more consistent performance.[25]

These unique characteristics will translate into a variety of societal benefits. For example, the performance advantages of C-V2X peer-to-peer mode was a key factor contributing to a recent analysis published by 5GAA estimating that thousands more lives could be saved and tens of thousands – if not hundreds of thousands – of serious injuries avoided over a 22 year period if C-V2X were to be deployed in Europe.[26]

C-V2X's performance advantages over DSRC are particularly important in non-line-of-sight scenarios (e.g., around corners, around large trucks, etc.). Current and near-term in-vehicle camera and sensor-based technologies experience limitations in these scenarios. C-V2X's non-

[23] *See* 5G Americas White Paper, *supra* note 18, at 21-22.

[24] *See id.*

[25] *See id.* at 22.

[26] *See* 5GAA, *An assessment of LTE-V2X (PC5) and 802.11p direct communications technologies for improved road safety in the EU*, at 22 (Dec. 5, 2017), http://5gaa.org/wp-content/uploads/2017/12/5GAA-Road-safety-FINAL2017-12-05.pdf ("The modelling indicates that LTE-V2X (PC5) has a superior radio performance, particularly in dense urban settings with large numbers of competing vehicles, and in high speed roads. The superior reliability of LTE-V2X (PC5) results in a higher number of avoided fatalities and serious injuries compared to 802.11p….").

line-of-sight performance advantage over DSRC thus may allow vehicles to perceive and provide earlier warnings of threats hidden from detection by current and near-term vehicle-resident technologies. Such warnings are particularly useful near intersections and in highway passing and braking scenarios. Indeed, as referenced in Section II, NHTSA repeatedly has endorsed the potential of V2V ITS technologies to help address crashes in scenarios such as these.[27]

The performance advantages of C-V2X peer-to-peer mode are further augmented by C-V2X's V2N mode communications. V2N mode communications play an important complementary role to peer-to-peer mode communications by, among other things, providing the ability to offload less time-sensitive V2V, V2I, and V2P communications to the cellular network during times of peak congestion.[28] This offloading feature increases the reliability of C-V2X's peer-to-peer mode communications, enhancing the effectiveness of critical time-sensitive services enabled by C-V2X. In addition, vehicles will be able to unlock a host of new applications by utilizing C-V2X's V2N mode to communicate with almost anyone at any time. This V2N mode functionality would allow, for example, integration with smart-city and other connected transportation initiatives that also use cellular technology.[29]

These capabilities allow C-V2X to support all of the V2V and V2I applications identified by NHTSA in its 2016 notice of proposed rulemaking on V2V communications.[30] All told, the safety, efficiency, mobility, and environmental benefits resulting from these capabilities are

[27] *See supra* pp. 4-5. *See also, e.g.*, Federal Motor Vehicle Safety Standards, 82 Fed. Reg. at 3855 ("This ability to communicate certain information that cannot be acquired by vehicle-resident onboard sensors makes V2V particularly good at preventing impending intersection crashes, such as when a vehicle is attempting to make a left turn from one road to another.").

[28] Rebbeck, *supra* note 17, at 2.

[29] *Id.*

[30] *See* Federal Motor Vehicle Safety Standards, 82 Fed. Reg. 3854.

considerable.[31] While these public interest benefits alone are sufficient to merit an expedited grant of the requested waiver, and ultimately changes to modernize the Commission's rules, the benefits of C-V2X will only increase in a 5G world.

B. C-V2X's Evolutionary Path to 5G and Subsequent Wireless Generations Will Help to Amplify and Expand Upon the Safety and Other Benefits Enabled by C-V2X Services

Fifth-generation wireless technologies will enable transformative societal benefits in a wide range of areas. With data speeds of 100Mbit/s or more, ultra-low latency of a few milliseconds or less, extremely high reliability, and massive capacity, 5G will spur the development of myriad innovative applications that will revolutionize a broad range of industries, transforming the way we work, learn, and get around. The transportation industry – and specifically the automotive industry – is widely viewed as one of the key sectors that will benefit from 5G capabilities and services. For this reason, C-V2X is designed with a clear path to 5G, subsequent 5G advances, and subsequent wireless generations.

While the initial 3GPP standards specify a 4G LTE-based version of C-V2X peer-to-peer mode, work is already underway to develop 5G C-V2X peer-to-peer mode. The specifications for the first version of 5G-based C-V2X are expected to be finalized as soon as next year. Because C-V2X peer-to-peer mode was developed with an evolution path to 5G,[32] all future versions of C-V2X are expected to be functionally backward compatible with earlier versions,

[31] In addition, C-V2X peer-to-peer communications will benefit from established and developing security and transport layers and application protocols defined by the automotive standards communities, including the SAE, International Organization for Standardization, European Telecommunications Standards Institute, and Institute of Electrical and Electronics Engineers. C-V2X network communications will be able to reuse various security components that are already implemented in cellular networks. Working in concert, these security components will help to ensure robust security for C-V2X communications.

[32] 3GPP, *Release 14*, *supra* note 14; *see also* Rebbeck, *supra* note 17, at 1.

including 4G LTE C-V2X.[33] As such, when future versions of C-V2X peer-to-peer mode are introduced, new vehicles will be able to communicate with older versions of C-V2X-enabled vehicles, infrastructure, and networks, effectively future-proofing the technology by ensuring seamless communications between all enabled devices.[34] Thus, as the commercial wireless industry evolves to 5G, C-V2X peer-to-peer mode can and will evolve as well – adding 5G capabilities to C-V2X communications.[35]

This evolutionary path will allow C-V2X to unlock the power of 5G technologies, driving further improvements in performance, introducing new capabilities to connected vehicles and infrastructure, and extending the number of use cases for C-V2X. 5G C-V2X peer-to-peer mode communications, for example, will use advanced radio technologies such as massive MIMO and beamforming to achieve ultra-low latency and ultra-high capacity capabilities.[36] With respect to 5G-enabled V2N and V2I, the combination of high-bandwidth operations and edge computing capabilities will allow for the movement of larger amounts of data, over shorter distances, in smaller amounts of time, maximizing the safety benefits of C-V2X.[37]

While the applications for 5G C-V2X likely will expand in ways that are difficult to predict, 5GAA is aggressively exploring 5G C-V2X's role in advanced driving applications. For example, C-V2X will complement and augment advanced driving applications that enhance semi-automated or fully-automated driving features (likely with the assistance of vehicle-

[33] Rebbeck, *supra* note 17, at 21 (noting that 3GPP Release 16, which is expected in 2019, will consider the specifications for 5G C-V2X).

[34] *See id.* at 30.

[35] *See id.* at 13.

[36] 5G Americas White Paper, *supra* note 18, at 14.

[37] 5GAA White Paper, *Toward fully connected vehicles: Edge computing for advanced automotive communications*, at 6 (Dec. 2017), http://5gaa.org/wp-content/uploads/2017/12/5GAA_T-170219-whitepaper-EdgeComputing_-5GAA.pdf.

mounted radar and other sensors) by coordinating the behaviors of vehicles. These applications allow a vehicle to share the trajectory data obtained from its local sensors with vehicles in its proximity. In addition, vehicles will be able to share their future intentions (i.e., lane changes, etc.) and engage in persistent information exchanges with vehicles in their proximity. Such exchanges will involve extended sensor data. Extended sensor applications allow vehicles to obtain information about objects around them located beyond the view of their own onboard sensors. These applications accomplish this by sharing sensor data (for example, data obtained from cameras, radar, and LIDAR) with nearby vehicles, providing a more complete picture of road and traffic conditions. Successful implementation of these extended sensors applications will require the type of ultra-low latency and ultra-high data rate communications supported by 5G capabilities.[38]

To enable these types of advanced driving applications, initial research suggests that the communications requirements will include high bandwidth to support burst transmission of large quantities of data, 99.99 percent message reliability for highest degree of automation, and 10 ms latency for the highest degree of automation.[39] These types of communications may only be possible with 5G C-V2X capabilities.

C. C-V2X's Unique Cost Efficiency Supports an Accelerated Timeline for Deployment

Of course, to maximize the safety and other societal benefits resulting from C-V2X services, the technology must be deployed commercially. C-V2X offers a unique cost efficiency that supports deployment on an accelerated timeline. This cost efficiency is based on a number of factors.

[38] 5G Americas White Paper, *supra* note 18, at 24-25.

[39] *Id*. at 24.

First, C-V2X technology can be economically integrated into vehicles. In response to the overwhelming consumer demand for cellular-connected vehicles, virtually all new vehicles are or soon will be equipped with cellular modem chipsets.[40] C-V2X can be added as an additional feature in these chipset products, lowering bill of materials costs, simplifying the supply chain and logistics, and reducing vehicle maintenance costs.[41] These savings can be significant.

Second, C-V2X can leverage today's cellular networks and tomorrow's 5G networks to reduce infrastructure deployment costs. By re-using existing commercial mobile infrastructure in certain situations, C-V2X can offer enhanced functionality and increased reliability at reduced costs. The opportunities for cost-saving synergies will further increase with the deployment of 5G networks, which is expected to see an additional $275 billion of investment in the coming years.[42]

Third, C-V2X's evolutionary path to 5G will help accelerate the development of a market for C-V2X, creating economies of scale and driving down costs. This path to 5G will ensure that future versions of C-V2X modules remain functionally backwards compatible with the current

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[40] *See e.g.*, Press Release, Ford, *Ford Readies North America's Freshest Lineup By 2020 With Onslaught Of Connected New Trucks, SUVs And Hybrids* (Mar. 15, 2018), https://media.ford.com/content/fordmedia/fna/us/en-/news/2018/03/15/ford-readies-north-americas-freshest-lineup-by-2020.html (Ford announcing that all new Ford vehicles will have 4G LTE connectivity by the end of 2019); AT&T, *Connected Car News*, http://about.att.com-/sites/internet-of-things/connected_car (last visited Nov. 19, 2018) (noting that AT&T has 21 million connected cars and 3.2 connected fleet vehicles on its network); Daimler, *Daimler's Perspective on Car-to-X Technologies (5GAA member)*, at 2 (June 2018), http://5gaa.org/wp-content/uploads/2018/06/5.-Daimler-view-on-V2X-5GAA-Policy-Debate.pdf (noting 90% of new Mercedes-Benz cars are already connected worldwide); Kristen Hall-Geisler, *More cars than phones were connected to cell service in Q1*, TechCrunch (June 20, 2016), https://techcrunch.com/2016/-06/20/more-cars-than-phones-were-connected-to-cell-service-in-q1 (in the first quarter of 2016, connected cars accounted for a third of all new cellular devices); Press Release, Gartner, *Gartner Says Connected Car Production to Grow Rapidly Over Next Five Years* (Sept. 29, 2016), https://www.gartner.com/newsroom/id/3460018 (calculating how there will be approximately 120 million connected vehicles on the road globally by 2020).

[41] NGMN Alliance, *supra* note 13, at 42-43.

[42] Accenture Strategy, *How 5G Can Help Municipalities Become Vibrant Smart Cities*, at 1 (Jan. 2017), https://newsroom.accenture.com/content/1101/files/Accenture_5G-Municipalities-Become-Smart-Cities.pdf.

versions of this technology,[43] providing consumers, automakers, roadway operators, infrastructure providers, and network operators with the assurance that C-V2X products purchased today will retain functionality in the future. In turn, C-V2X may even accelerate the deployment of 5G wireless networks. With the opportunity to connect with 5G C-V2X-equipped vehicles, mobile network operators and roadway operators may see incentives to speed the deployment of 5G networks, creating a self-reinforcing spiral of investment in both 5G networks and 5G C-V2X.

Fourth, the growing momentum towards the adoption of C-V2X internationally will further increase economies of scale, driving down the cost curve for this technology. As reflected in 5GAA's rapidly growing membership, many of the world's major automotive, technology and telecommunications companies are seriously exploring – if not committed to – the deployment of C-V2X.[44] In addition, the Chinese Ministry of Industry and Information Technology already has allocated spectrum for C-V2X, and regulators in other parts of the world are contemplating similar action.[45] This international momentum will grow as automobile manufacturers, technology companies, mobile network operators, and governments continue to demonstrate the superior performance capabilities of C-V2X in tests and trials around the globe.[46]

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[43] Rebbeck, *supra* note 17, at 2 (citing the certainty of C-V2X's future evolution to 5G as facilitating earlier deployment and after-market deployment).

[44] Similarly, the Next Generation Mobile Alliance, a forum founded by world-leading mobile network operators, recently created a C-V2X task force to, among other things, accelerate the global deployment of C-V2X technology. NGMN Alliance, *supra* note 13, at 8.

[45] *See* Ministry of Industry and Information Technology of the People's Republic of China, MIIT (2018) No. 203 regulation (Nov. 2018). *See also* TU Automotive, *C-V2X's Momentum in China May Drive Connected-Car Development* (Nov. 7, 2018), https://www.tu-auto.com/c-v2xs-momentum-in-china-may-drive-connected-car-development/.

[46] *See* Appendix C.

IV. The Commission Should Grant a Waiver of Its Rules to Expedite the Deployment of C-V2X

In light of the transformational effect C-V2X is expected to have on motor vehicle travel, 5GAA requests that the Commission grant a blanket waiver, with conditions, of footnote NG160 to Section 2.106 of the Commission's rules[47] to allow for the near term deployment of C-V2X in 5905-5925 MHz.[48] The proposed waiver conditions set forth in Appendix D are narrowly constructed to allow for the introduction of C-V2X services in the near term during the pendency of the Commission's broader rulemaking. To be clear, 5GAA is not seeking access to the full 5.9 GHz band under this waiver request. Rather, 5GAA is merely seeking access to the 5.905-5.925 GHz frequency range to begin C-V2X operations as soon as possible.[49] Significantly, as noted below, 5GAA has crafted this Waiver Request to ensure that C-V2X deployment under the requested relief should have no significant impact on any existing DSRC operations in the band.

The requested waiver will allow for basic C-V2X services, which will support V2V and V2I messages that enable many important safety applications, such as red light warnings, basic

[47] 47 C.F.R. § 2.106, NG160 ("In the 5850–5925 MHz band, the use of the non-Federal government mobile service is limited to Dedicated Short Range Communications operating in the Intelligent Transportation System radio service.").

[48] 5GAA has structured this request as a waiver of footnote NG160 in part because, as noted previously, the Commission's Dedicated Short Range Communications Service has been conflated with the IEEE 802.11p standard, which in turn is based on the ASTM E2213-03 standard. As a result, a waiver permitting C-V2X operations under the Dedicated Short Range Communications Service may cause confusion to the public. To the extent that the Commission finds that waiver of specific rules within Part 90 and 95 are more appropriate in this context, 5GAA requests waiver of Sections 90.375, 90.377, 90.379, 95.3159, 95.3163, 95.3167, 95.3189, and any others the Commission views as barriers for the deployment of C-V2X. 47 C.F.R. §§ 90.375, 90.377, 90.379, 95.3159, 95.3163, 95.3167, 95.3189.

[49] Granting C-V2X permission to operate on a 20 MHz channel will enhance C-V2X's ability to implement congestion control, should help improve its resiliency to out of band interference, and will enable capacity to adjust dynamically between V2V and V2I applications in any given location, depending on usage. A 20 MHz channel allows for soft multiplexing of the various peer-to-peer mode communications supported by C-V2X. The communications system therefore will dynamically adjust to the capacity demands, ensuring a high reliability for message delivery. While the 5GAA Test Report reflects testing performed on a 10 MHz channel, 5GAA members have validated C-V2X operation in a 20 MHz channel in laboratory tests and are planning to conduct additional field tests using a 20 MHz channel in the very near future. Congestion control test results are expected to improve when utilizing a 20 MHz channel because a wider channel naturally accommodates more simultaneous users. In addition, resiliency test results using 20 MHz may similarly improve due to C-V2X's channel sensing, which will choose less polluted parts of the channel for message transmission.

safety messages, emergency alerts, and others, to enhance traffic systems and operations. [50] 5GAA's forthcoming petition for rulemaking will request that the Commission initiate a rulemaking to modernize the 5.9 GHz band to enable advanced C-V2X services, which will support the delivery of 5G C-V2X applications. To unleash these advanced features, 5G C-V2X will need to access much more spectrum in the 5.9 GHz band than the 20 MHz that are the subject of this Waiver Request.

A. The Good Cause Standard

The Commission is authorized to waive its rules where the petitioner demonstrates good cause for such action.[51] Good cause may be found where "particular facts would make strict compliance inconsistent with the public interest."[52] In making this determination, the Commission may "take into account considerations of hardship, equity, or more effective implementation of overall policy."[53] To satisfy the public interest requirement, "the waiver cannot undermine the purposes of the rule, and there must be a stronger public interest benefit in granting the waiver than in applying the rule."[54] The Commission has also found that a waiver request satisfies its public interest requirement where it would serve some larger public interest

[50] The requested waiver will enable basic C-V2X services, which will support V2V and V2I messages such as the Basic Safety Message, Signal Phase and Timing, Emergency Vehicle Alert, Probe Data Management, Probe Vehicle Data, Signal Request Message, Signal Status Message, Geometric Intersection Description, Traveler Information Message, & others encompassed by the Road Safety Message.

[51] *Northeast Cellular Telephone Co. v. FCC*, 897 F.2d 1164 (D.C. Cir. 1990); *WAIT Radio v. FCC*, 418 F.2d 1153 (D.C. Cir. 1969).

[52] *Northeast Cellular*, 897 F.2d at 1166; *see also ICO Global Communications v. FCC*, 428 F.3d 264, 269 (quoting *Northeast Cellular*); *WAIT Radio*, 418 F.2d at 1157-59; *Deere & Company Request for Limited Waiver of Part 15 Rules for Fixed White Space Device*, Order, 31 FCC Rcd 2131, 2134 ¶ 8 (OET 2016) ("*Deere Order*") (quoting *Northeast Cellular*).

[53] *WAIT Radio*, 418 F.2d at 1159.

[54] *Deere Order*, 31 FCC Rcd at 2134 ¶ 8; *see also WAIT Radio*, 418 F.2d at 1157 (stating that even though the overall objectives of a general rule have been adjudged to be in the public interest, it is possible that application of the rule to a specific case may not serve the public interest if an applicant's proposal does not undermine the public interest policy served by the rule); *Kyma Medical Technologies Ltd.*, Order, 31 FCC Rcd 9705, 9707 ¶ 5 (OET 2016) ("*Kyma Order*").

objective (e.g., advancement of new technologies or services) that could not be achieved via strict application of the rule in question.[55]

B. Good Cause Exists for the Grant of the Requested Waiver

1. *A Grant of the Requested Waiver is in the Public Interest Because it Will Expedite the Availability of ITS Services*

For decades, Congress, the DOT, and the Commission have acknowledged the life-saving and societal benefits of connected vehicle technologies. ITS traces its modern day origins to the mid-1980s, when the DOT, in partnership with state departments of transportation, academia, and industry, began evaluating how to incorporate communication technology into transportation infrastructure to improve safety, mobility, and emissions.[56] Shortly thereafter, in the Intermodal Surface Transportation Efficiency Act of 1991 ("ISTEA"), Congress established a national program within the DOT for the development of ITS, which Congress identified as a means to improve traveler safety, decrease traffic congestion, facilitate the reduction of air pollution, and conserve vital fossil fuels by incorporating technology and advanced electronics into the nation's transportation infrastructure.[57] The passage of ISTEA represented the first in a sequence of

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[55] *Kyma Order*, 31 FCC Rcd at 9707 ¶ 5. *See also Amendment of Part 15 of the Commission's Rules To Establish Regulations for Tank Level Probing Radars in the Frequency Band 77-81 GHz*, Notice of Proposed Rulemaking, 25 FCC Rcd 601, 612 ¶ 31 (2010) ("*77-81 GHz NPRM*"); *Deere Order*, 31 FCC Rcd at 2138 ¶¶ 15-16.

[56] *See* Federal Motor Vehicle Safety Standards, 82 Fed. Reg. at 3867 (discussion of the history of V2V research).

[57] Intelligent Vehicle-Highway Systems Act, Pub. L. No. 102-240 § 6052 (b), 105 Stat. 1914, 2189-90 (1991), https://www.gpo.gov/fdsys/pkg/STATUTE-105/pdf/STATUTE-105-Pg1914.pdf. The DOT embraced Congress' approach:

> Surface transportation systems – the networks of highways, local streets, bus routes, and rail lines – are the ties that bind communities and facilitate commerce, connecting businesses and residents to work, homes, schools, services, and each other. During the past 20 years, however, transportation systems have struggled to keep pace with Americans' growing and changing travel needs …. Rather than continuing to rely simply upon quantitative additions to the existing transportation infrastructure, Congress has chosen to also emphasize the use of technology to improve the performance of that infrastructure.

Comments of the U.S. Department of Transportation, ET Docket No. 98-95, at 2 (filed July 28, 1997), https://ecfsapi.fcc.gov/file/1879770001.pdf.

collective actions by Congress,[58] the DOT,[59] and the FCC that ultimately led to the Commission's allocation of the 5.9 GHz band for ITS.[60] In the *Allocation Report and Order*, the Commission found that the ITS allocation would "further the goals of the United States Congress and the Department of Transportation to improve the efficiency of the Nation's transportation infrastructure and will facilitate the growth and development of the ITS industry."[61]

Today, the need for ITS has only increased. Hundreds of Americans are losing their lives every day on our nation's roadways,[62] with millions more being injured annually in motor vehicle accidents.[63] More and more road use has contributed significantly to increased traffic congestion, higher energy consumption and worsening pollution.[64] Furthermore, millions of

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[58] *See, e.g.*, Transportation Equity Act for the 21st Century, Pub. L. No. 105-178, 112 Stat. 107 (1998), https://www.congress.gov/105/plaws/publ178/PLAW-105publ178.pdf.

[59] For example, in 1994, the DOT officially sanctioned the term "ITS" as a replacement for "IVHS," or "Intelligent Vehicle Highway System," and established the ITS Joint Program Office to oversee and manage a national ITS program. *See* Ashley Auer, Shelley Feese, and Stephen Lockwood, *History of Intelligent Transportation Systems*, at 15, U.S. Department of Transportation, ITS Joint Program Office (May 2016), https://rosap.ntl.bts.gov/view/dot-/30826. In 1998, the DOT's Intelligent Vehicle Initiative Program was established to help develop driver assistance products and reduce the number and severity of vehicular collisions. *Id*. at 26. The following year, the DOT established a Commercial Vehicle Information Systems and Networks Grant Program to support states in the deployment of advanced technologies in safety information exchange, electronic credentialing, and electronic screening. *Id*. at 16.

[60] *See Amendment of Parts 2 and 90 of the Commission's Rules to Allocate the 5.850-5.925 GHz Band to the Mobile Service for Dedicated Short Range Communications of Intelligent Transportation Services*, Report and Order, 14 FCC Rcd 18221 (1999) ("*Allocation Report and Order*").

[61] *Id*. at 18221 ¶ 1.l.

[62] Press Release, NHTSA, *USDOT Releases 2016 Fatal Traffic Crash Data* (Oct. 6, 2017), https://www.nhtsa.gov/-press-releases/usdot-releases-2016-fatal-traffic-crash-data.

[63] NHTSA, *Summary of Motor Vehicle Crashes* (Sept. 2018), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812580.

[64] Martin Knopp, *America's Drivers Continue to Spend More Time Stuck in Traffic, 2016 Data Shows*, Connections – U.S. Department of Transportation Blog (June 12, 2017), https://www.transportation.gov/connections/america-%E2%80%99s-drivers-continue-spend-more-time-stuck-traffic-2016-data-shows ("[D]rivers are spending more time stuck in rush-hour traffic than ever.… Congestion got worse [from 2016 to 2017] during peak hours in 2016, as represented by the Travel Time Index which compares peak hour or commuter travel times to free flow travel times. The index increased slightly to 1.35 in 2016 from 1.34 in 2015, meaning that a trip taking 10 minutes in free-flow traffic would now take 13.5 minutes during peak hours."); U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks (1990-2016)*, at 2-11 (April 12, 2018), https://www.epa.gov/sites/production-/files/2018-01/documents/2018_complete_report.pdf ("Emissions from petroleum consumption for transportation have increased by 21.7 percent since 1990, which can be primarily attributed to a 48.0 percent increase in vehicle

elderly and disabled Americans continue to struggle to find reliable and affordable mobility options.[65] In the face of these challenges, the DOT and NHTSA continue to stress the importance of deploying ITS technologies that leverage the 5.9 GHz band.[66]

Grant of the requested waiver would help to further the vision of ITS in the 5.9 GHz band and respond to the societal needs that Congress, the Commission, the DOT, and NHTSA repeatedly have identified over the better part of the past three decades. Most importantly, the waiver grant is expected to enable important safety benefits. As demonstrated in the 5GAA Test Report, C-V2X peer to-peer mode promises advantages that will help realize the benefits of ITS technology, advantages which are augmented by C-V2X's V2N mode. Particularly important in non-line-of-sight scenarios (e.g., around corners and around large trucks, etc.), these advantages enable a host of applications that will help to provide drivers and vehicles access to a more complete and accurate picture of the surrounding road environment. These characteristics contributed to an estimate by 5GAA that thousands more lives could be saved and tens of thousands – if not hundreds of thousands – of serious injuries avoided over a 22 year period if C-V2X were to be deployed in Europe. Grant of the requested waiver will enable the deployment of C-V2X in the United States, allowing for the realization of similar projected safety benefits for American drivers, passengers, pedestrians, and cyclists.

The waiver will help to enable other important public interest benefits as well. Because C-V2X was designed to meet all of the V2X applications designed by the ITS community, C-

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miles traveled (VMT) over the time series.… Total transportation sector CO2 emissions have increased by 5.2 percent since 2010.").

[65] National Aging and Disability Transportation Center, *Travel Patterns of American Adults with Disabilities*, (Nov. 8, 2018) https://www.nadtc.org/news/blog/travel-patterns-of-american-adults-with-disabilities/ (showing that there are over 25 million Americans who have self-reported travel-limiting disabilities).

[66] *See, e.g.*, U.S. Department of Transportation, *Preparing for the Future of Transportation: Automated Vehicles 3.0 (AV 3.0)*, at 16 (Oct. 4, 2018), https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/-automated-vehicles/320711/preparing-future-transportation-automated-vehicle-30.pdf.

V2X can enable ITS applications that will improve traffic efficiency and productivity, facilitate the reduction of air pollution, and help to conserve vital fossil fuels. In addition, as other countries, including China, dedicate spectrum for the deployment of C-V2X, the waiver grant will both ensure that Americans have access to the same modern ITS technologies as are available in other parts of the world and help to facilitate the growth of the ITS industry in America. And, because C-V2X can be economically deployed, a waiver grant likely will enable consumers to benefit from ITS technology at lower societal costs and on an expedited timeframe.

Finally, a waiver grant prior to the adoption of final rules modernizing the 5.9 GHz band is supported by both Commission precedent and the instant facts.[67] An expedited waiver will allow for the immediate deployment of new and improved safety and efficiency services enabled by C-V2X. Moreover, while there will be many near-term benefits during the early stage deployment of C-V2X-equipped vehicles, the benefits of V2V ITS technologies will grow as the percentage of vehicles equipped with C-V2X increases. With C-V2X chipsets available commercially beginning in early 2019, a grant of the requested waiver can expedite C-V2X achieving critical mass in the vehicle fleet deployed on America's roads.

2. The Requested Waiver Would Advance, Rather than Undermine, the Underlying Policy Which the Rule in Question is Intended to Serve

The requested waiver is expected to help further the underlying policy objectives of the ITS rules in the 5.9 GHz band. When the Commission adopted the ITS allocation and then service rules limiting operations in the 5.9 GHz band to the use of DSRC technology – the only short-range vehicular ITS technology available at the time – it did so for the primary purpose of

[67] The Commission has granted waivers to expedite the deployment of new technologies prior to the adoption of final rules in numerous other instances. *See, e.g., 77-81 GHz NPRM*, 25 FCC Rcd at 610 ¶ 25 (granting a waiver to allow for the utilization of new radar technology during the pendency of a rulemaking in which the Commission proposed rules that would allow the use of such technology); *iRobot Corporation Request for Waiver of Section 15.250 of the Commission's Rules*, Order, 30 FCC Rcd 8377 (OET 2015) (granting a waiver to enable the deployment of new technology with the potential of offering safety and environmental benefits).

improving vehicular safety and travel while preventing interference to other authorized users of the band.[68] Grant of the requested waiver will advance, rather than frustrate, these policy objectives.

By granting the requested waiver, the Commission will further the objective of improving vehicular safety and travel by enabling the deployment and availability of ITS services. As previously explained, C-V2X technology offers capabilities that can enable new and improved ITS services,[69] featuring a cost efficiency that supports an accelerated timeline for deployment,[70] and presents a path to 5G that will greatly expand and enhance C-V2X services in the future.[71] In short, C-V2X is poised for deployment, which will enable the safety, efficiency, and other societal benefits envisioned by the Commission when it adopted the ITS allocation and service rules for the band.

Moreover, a grant of the waiver request will enable robust ITS communications. Industry members from across the ITS ecosystem stand ready to deploy C-V2X technology. [72] The very creation of 5GAA, the exponential growth in membership over a relatively short time, and the investments made by members to date underscore this point. Grant of the instant request will provide the regulatory footing to unleash industry's pent-up eagerness to deploy this

[68] *See Allocation Report and Order*, *supra* 60, at 18221 ¶ 1.l (discussing the expectation that ITS services will "improve traveler safety" and "decrease traffic congestion"); *Amendment of the Commission's Rules Regarding Dedicated Short-Range Communication Services in the 5.850-5.925 GHz Band (5.9 GHz) Band et al.*, Report and Order, 19 FCC Rcd 2458, 2461 ¶ 3 (2004) (discussing the important safety functions of short-range ITS services), *id*. at 2461-62 ¶ 4 (discussing the potential of short-range ITS services to improve the efficiency of America's surface transportation system) (2004); *id* at 2470 ¶ 18 (noting "that the record presents no alternative standard").

[69] *See supra* Section III.A.

[70] *See supra* Section III.C.

[71] *See supra* Section III. B.

[72] *See* Appendix C.

technology.[73] Further, under the proposed waiver conditions, C-V2X operations would occur only in the 5.905-5.925 GHz portion of the 5.9 GHz band.[74] Because C-V2X and DSRC operations will occur on different channels, each technology will be protected from interference from the other.

In addition, because C-V2X operations will be subject to nearly identical operating parameters as those required of DSRC under the current rules, other non-ITS authorized users of the 5.9 GHz band will not be affected by a grant of the waiver. Specifically, in Appendix D, 5GAA proposes conditions that would impose substantially similar technical and service requirements on C-V2X operations under the waiver grant as those that are currently codified in the Commission's rules for DSRC operations. As a result, any deployment of C-V2X under the requested waiver will not increase the potential for interference to these other users in the band. A brief analysis of these conditions follows.

Power limits. The proposed transmit power limits for all C-V2X devices permitted under the waiver (i.e., Vehicular, Portable, and Roadside units) will be 20 dBm antenna input power as specified in § 8.10.1 of ASTM E2213 - 03. The EIRP for an OBU (vehicular and portable) will be limited to 23 dBm. The EIRP for an RSU will be limited to 33 dBm.

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[73] *See, e.g.*, Qualcomm, *2019 will see commercial C-V2X rollouts throughout the world*, OnQ Blog (Nov. 1, 2018), https://www.qualcomm.com/news/onq/2018/11/01/2019-will-see-commercial-c-v2x-rollouts-throughout-world (noting the availability and integration of the 9150 C-V2X chipset solution into infrastructure and vehicles; how Qualcomm partnered with Ford, Panasonic, and the Colorado Department of Transportation, to demonstrate the first production-grade C-V2X system in the U.S.; and how leading connected vehicle and V2X technologies companies in the U.S., such as Savari, Kaspch, and Ficose, plan to include C-V2X technology in their RSUs); 5GAA, *Timeline for deployment of LTE-V2X*, at 3 (Dec. 18, 2017), http://5gaa.org/wp-content/uploads/2018/02/5GAA_Timeline-for-deployment-of-LTE-V2X_FINAL.pdf (noting that nearly major chipset vendors, such as Intel, Qualcomm, and Samsung are committed to provide C-V2X chipsets).

[74] 5GAA is aware of pilots involving DSRC Roadside Units which use all or a portion of the 5.905-5.925 frequencies for support. 5GAA will engage in discussions with the parties involved with these pilots to ensure that any operations using any portion of 5905-5925 MHz can either transition to lower DSRC channels or use C-V2X technology.

Emission limits. All C-V2X devices must attenuate out-of-band emissions consistent with the limits shown below, which may be measured at the antenna input. These are consistent with the existing FCC rules, but allow for the variable transmit power nature of C-V2X, and the planned 20 MHz bandwidth.

Offset from Band Edge	Out-of-Band Emission Limit
± 0 MHz	-29 dBm/100 kHz
± 1.0 MHz	-35 dBm/100 kHz
±10 MHz	-43 dBm/100 kHz
±20 MHz	-53 dBm/100 kHz

These limits are consistent with the current OOBE limits from Class C DSRC devices.

All C-V2X OBUs and RSUs also will limit emissions to -25 dBm/100 kHz EIRP or less outside the channel edges of 5905 MHz and 5925 MHz and below the band edge of 5855 MHz. The -25 dBm/100 kHz EIRP limit comes from § 8.10.2.2 of ASTM E2213 – 03.

RF Exposure. 5GAA proposes that C-V2X devices will be evaluated for RF Exposure consistent with the current rules. Devices that would operate in mobile or portable configurations will be evaluated consistent with the procedures in § 2.1091 and § 2.1093, respectively, of the Commission's rules. RSUs will be required to indicate compliance with the Maximum Permissible Exposure limits in § 1.1310 of the Commission's rules.

Equipment Certification. 5GAA proposes that all equipment subject to the waiver must be certified in accordance with Subpart J of Part 2 of the Commission's rules.

Antenna Height for RSUs. 5GAA proposes that an RSU may employ an antenna with a height not to exceed 8 meters, with the exception that the antenna height may be between 8 and 15 meters provided the EIRP is reduced by a factor of 20 log(Ht/8) in dB where Ht is the height of the radiation center of the antenna in meters above the roadway bed surface. The EIRP is

measured as the maximum EIRP toward the horizon or horizontal, whichever is greater, of the gain associated with the main or center of the transmission beam. The RSU antenna height shall not exceed 15 meters above the roadway bed surface. This proposal is consistent with § 90.377(b) of the rules for DSRC RSUs.

Permitted Uses. 5GAA proposes that communications permitted under this waiver will include messages such as the Basic Safety Message, Signal Phase and Timing, Emergency Vehicle Alert, Probe Data Management, Probe Vehicle Data, Signal Request Message, Signal Status Message, Geometric Intersection Description, Traveler Information Message, and others encompassed by the Road Safety Message.

Licensing. The proposal that On-Board and Portable Units should be licensed by rule is consistent with the approach used for DSRC On-Board Units. Individuals operating On-Board and Portable Units would not require a station license issued by the FCC.

5GAA proposes that parties desiring to operate RSUs should apply for non-exclusive nationwide licenses with individual site registration through the FCC's Universal Licensing System ("ULS"). C-V2X RSU operators will comply with the process used by operators of DSRC RSUs detailed in § 9.375(b).

Eligibility to Operate RSUs. 5GAA proposes that any territory, possession, state, city, county, town or similar governmental entity will be eligible to hold an authorization to operate RSUs. Any entity meeting the eligibility requirements of § 90.33 or § 90.35 would also be eligible to hold an authorization to operate RSUs.

Coordination of RSUs. 5GAA proposes that all RSUs shall not receive protection from Government Radiolocation services in operation prior to the establishment of the RSU station. Operation of C-V2X RSU stations within 75 kilometers of the locations listed in the table in

§ 90.371 must be coordinated through the National Telecommunications and Information Administration.

RSUs near the U.S./Canada or U.S./Mexico Border. 5GAA proposes that RSUs will be subject to the international coordination conditions identified in § 90.383 of the FCC Rules.

V. Conclusion

Permitting C-V2X operations in the upper 20 MHz portion of the 5.9 GHz band, subject to the conditions detailed herein, would have substantial, long term benefits without causing a material impact on any current DSRC operations or increasing any risk of interference to other authorized users of the band. Rather than undermine the underlying purpose of the rules, the requested waiver will help facilitate the deployment of robust ITS services to Americans and realize the benefits that Congress, the DOT and the FCC have envisioned for decades: improving traveler safety and mobility, decreasing traffic congestion, facilitating the reduction of air pollution, and conserving vital fossil fuels by incorporating technology and advanced electronics into the nation's transportation infrastructure.

Based upon the foregoing, 5GAA respectfully requests a blanket waiver of footnote NG160 to Section 2.106 of the Commission's rules,[75] subject to the conditions described in Appendix D, to allow for the deployment of C-V2X technology in the 5.905-5.925 GHz range of the 5.9 GHz band, and to facilitate the wide-spread deployment of C-V2X technology across America.

Respectfully submitted,

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November 21, 2018

[75] 47 C.F.R. § 2.106, NG160.

Appendix A - 5GAA Membership

Membership list as of October 5, 2018:

- Airgain, Inc.
- Alpine Electronics Inc.
- American Tower Corp
- Analog Devices Inc.
- Anritzu A/S
- AT&T Foundry
- Audi AG
- BAIC Group (Beijing Automotive Group Co., Ltd.)
- Baidu
- Beijing University of Technology
- Bell
- BlackBerry UK Limited
- BMW Group (Bayerische Motoren Werke AG)
- Bosch (Robert Bosch GmbH)
- CATT (China Academy of Telecommunication Technology)
- CETECOM GmbH
- China Mobile
- China Transinfo
- China Unicom (China United Network Communications Group Co.,Ltd)
- China Mobile Research Institute
- Cohda Wireless
- Commsignia Inc.
- Continental Teves AG & Co. oHG
- Daimler AG
- Danlaw Inc.
- Dekra
- DENSO AUTOMOTIVE Deutschland GmbH
- Deutsche Telekom AG
- Dt&C
- Ericsson AB
- Faradai Future
- FarEasTone
- FEV Group GmbH
- Ford
- Fraunhofer Institute
- Geely Auto
- Gemalto SA
- General Motors
- Hirschmann Car Communication GmbH
- Hitachi

- Honda
- Huawei
- Hyundai America Technical Center
- Infineon Technologies AG
- Intel
- InterDigital Communications, Inc.
- Jaguar Land Rover Ltd.
- Juniper Networks
- KDDI
- Keysight Technologies UK Limited
- KT R&D Center
- Laird Bochum GmbH
- Latvijas Mobilais Telefons
- Lear
- LG Electronics Inc.
- Mitsubishi
- Murata Manufacturing
- NavInfo
- Neusoft
- NIO China
- Nissan
- Nokia
- Noris Network AG
- NTT-DoCoMo
- OKI
- Orange SA
- P3 Group
- Panasonic
- Proximus B.V.
- PSA Groupe
- Qualcomm Incorporated
- Rohde & Schwarz GmbH & Co. KG
- Rohm Semiconductor
- SAIC Motor Corporation Limited
- Samsung Electronics Co., Ltd
- Savari Inc.
- SGS
- Shanghai Gotell Communication Technology Holdings Co., Ltd.
- SIAC (Shanghai Int. Automobile City)
- SK Telecom
- Skyworks
- Smart Mobile Labs
- Softbank Corp.
- Sumitomo Electric

- TELEFONICA DIGITAL ESPAÑA SL
- Telekom Austria Aktiengesellschaft
- Telstra
- TELUS
- Terranet, SE
- TÜV Rheinland AG
- Valeo (peiker acustic GmbH & Co.KG)
- Veniam Inc.
- Verizon
- Viavi
- Vodafone Group Services Ltd
- Volkswagen AG
- Volvocars
- VT Direct
- Wistron NeWeb Corp.
- ZF
- ZTE Corporation

Appendix B - 5GAA C-V2X Test Results

Appendix C - C-V2X Test and Trials

A growing number of road tests across the globe are demonstrating C-V2X for V2V safety applications. Below is a description of those tests in which 5GAA members are participating.

Fowlerville, Michigan	Qualcomm, Ford
Denver, Colorado	Panasonic, Ford, Qualcomm, CO DoT
Paris, France	5GAA, BMW Group, Ford and Groupe PSA, Qualcomm, Savari
Ingolstadt, Germany	Audi, Ducati, Qualcomm
Shanghai, China	Ford and Datang
Japan	Continental, Ericsson, Nissan, NTT DOCOMO, OKI and Qualcomm
Shanghai, China	Continental and Huawei
San Diego, California	AT&T, McCain, Ford, Nokia, Qualcomm
Columbia, Maryland	Rohde & Schwarz, Qualcomm
Towards 5G, France	Ericsson, Orange, Qualcomm, PSA Group
Mobilifunk (A9), Germany	Vodafone, Bosch and Huawei
RACC track, MWC 2017	Audi, Vodafone, Huawei @ MWC
ConVeX (A9), Germany	Audi, Ericsson, Qualcomm, Swarco, Kaiserslautern Univ.
Car2X in Wuzhen, China	CMCC, Continental, Nokia, Fraunhofer
DT (A9), Germany	Audi, Deutsche Telekom, Huawei, Toyota
UK	Jaguar Land Rover, Vodafone, et al
MEC pilot project, Germany	Bosch, DT/T-Systems, Nokia
Car2X at A9, Germany	Continental, DT/T-Systems, Nokia, Fraunhofer

Ford, Qualcomm (Fowlerville, Michigan): Qualcomm and Ford have partnered up to test C-V2X radio capabilities such as the Line-of-Sight range / reliability.[76]

Panasonic, Ford, Qualcomm, and the Colorado Department of Transportation (August 2018, Denver, Colorado): Panasonic, Ford, Qualcomm, and the Colorado Department of Transportation demonstrated the "first real-world application of C-V2X technology connecting the vehicle, the roadways and a regional traffic management center" and showcased the technology's ability to detect oncoming traffic, data from Road Side Units, and aggregate traffic data to allow real-time monitoring of roadways connected with C-V2X.[77] Testing on C-V2X

[76] Jovan Zagajac, *The C-V2X Proposition*, 5GAA (Apr. 26, 2018), http://5gaa.org/wp-content/uploads/2018/05/3.-The-C-V2X-Proposition-Ford.pdf.

[77] Press Release, Panasonic, *Panasonic, Qualcomm and Ford Demo the First Real-World Application of C-V2X in Colorado* (Aug. 15, 2018), https://www.prnewswire.com/news-releases/panasonic-qualcomm-and-ford-demo-the-first-real-world-application-of-c-v2x-in-colorado-300697513.html.

capabilities will continue on select roadways throughout Panasonic's CityNOW headquarters in Denver and will be followed by deployment in select areas along the I-70 Mountain Corridor in the back half of 2018.[78]

5GAA, BMW Group, Ford and Groupe PSA, Qualcomm, Savari (July 2018, Paris, France): Conducted first live demonstration of C-V2X direct communication technology operating across vehicles from multiple auto manufacturers. The demonstration also featured a live showcase of C-V2X direct communication technology operating between passenger cars, motorcycles, and roadside infrastructure.[79] Six demonstrations were shown including: Emergency Electronic Brake Light, Intersection Collision Warning, Across Traffic Turn Collision Risk Warning, Slow Vehicle Warning and Stationary Vehicle Warning, Signal Phase and Timing / Signal Violation Warning and Vulnerable Road User (pedestrian) Warning. The vehicles involved included two-wheel e-scooters provided by BMW Group, and automotive passenger vehicles provided by Ford, Groupe PSA, and BMW Group, all of which were equipped with C-V2X direct communication technology using the Qualcomm® 9150 C-V2X chipset solution. V2X software stack and application software, along with roadside infrastructure, were provided by industry leader, Savari.[80]

Audi, Ducati, Qualcomm (July, 2018, Ingolstadt, Germany): ConVex (Connected Vehicle to Everything of Tomorrow) trial in Ingolstadt, Germany, featured Audi Q7 and A4 cars and a Ducati Multistrada 1200 Enduro motorbike fitted with the Qualcomm 9150 C-V2X chipset solution, and showed how C-V2X can aid road safety in common scenarios involving motorcycles and cars.[81]

Ford and Datang (March, 2018, Shanghai, China): Ford and Datang have partnered to trial C-V2X "at the National Intelligent Vehicle Pilot Zone in Shanghai, the first intelligent connected car demonstration area in China. The tests built on Datang's extensive work in creating LTE-V2X technology, which is the first phase of C-V2X technology and Ford's key role in the area of intelligent connected vehicles (ICV) in China. The evaluations were carried out according to industry harmonized test procedures from 5G Automobile Association."[82]

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[78] Press Release, Qualcomm, *Panasonic, Qualcomm and Ford Join Forces on First U.S. Deployment for C-V2X Vehicle Communications in Colorado* (June 1, 2018), https://www.qualcomm.com/news/releases/2018/06/01/-panasonic-qualcomm-and-ford-join-forces-first-us-deployment-c-v2x-vehicle.

[79] Press Release, Ford, *5GAA, BMW Group, Ford And Groupe PSA Exhibit First European C-V2x Direct Communication Interoperability Between Multiple Automakers* (July 11, 2018), https://media.ford.com/-content/fordmedia/feu/en/news/2018/07/11/-5gaa--bmw-group--ford-and-groupe-psa--exhibit-first-european-c-.html.

[80] *Id.*

[81] Farah Alkhalisi, *C-V2X demos incorporate motorcycles, vehicles and infrastructure, communications between carmakers*, automotiveIT International (July 11, 2018), http://www.automotiveit.com/news/c-v2x-demos-incorporate-motorcycles-vehicles-and-infrastructure-communications-between-carmakers.

[82] Press Release, Ford, *Ford And Datang Trial C-V2X Connected Car Technology In Shanghai To Support Global Connectivity Initiative* (Mar. 29, 2018), https://media.ford.com/content/fordmedia/fap/cn/en/news/2018/03/29-/Ford_and_Datang_Trial_C-V2X_Connected_Car_Technology_in_Shanghai_to_Support_Global_Connectivity_-Initiative.html.

Continental, Ericsson, Nissan, NTT DOCOMO, OKI and Qualcomm (January, 2018, Japan): Continental, Ericsson, Nissan, NTT DOCOMO, OKI and Qualcomm have partnered to trial C-V2X capabilities where "Continental will utilize the Qualcomm C-V2X Reference Design, which features the Qualcomm 9150 C-V2X chipset with integrated Global Navigation Satellite System (GNSS) capability to build connected car systems and integrate the systems into Nissan vehicles. Nissan will perform V2X use case selection and develop test scenarios with key performance indicators (KPIs) for C-V2X technology validation. OKI, one of the leading companies in ITS, will bring their expertise in roadside unit (RSU) infrastructure and applications to demonstrate V2I as a viable technology for advanced traffic applications by integrating the Qualcomm® 9150 C-V2X chipset into their RSU. Ericsson, as one of the leading companies in the technology and service for telecommunications, will join to the V2N use case discussion, considering a combination of direct communication and LTE-A network technologies. NTT DOCOMO will provide an LTE-A network and V2N applications to demonstrate the benefits of complementary use of network-based communications for a variety of advanced automotive informational safety use cases."[83]

Continental and Huawei (December 2017, Shanghai, China): Continental and Huawei have conducted field trials on C-V2X performance, including reliability and latency. "To test in realistic conditions, Continental conducted its driving tests in China's National Intelligent Connected Vehicle Pilot Zone in Shanghai named 'A Nice City'. The joint tests leveraged Huawei's prototype C-V2X module and infrastructure for use cases such as Emergency Brake Light and Stationary Vehicle Warning. While the average latency was 11 ms, single event message latencies as low as 8 ms were achieved, and throughout the tests the packet reception rate was nearly 100 percent."[84]

AT&T, McCain, Ford, Nokia, and Qualcomm (October, 2017, San Diego, California): AT&T, McCain, Ford, Nokia, and Qualcomm, are cooperating with local government bodies to conduct C-V2X trials at the San Diego Regional Proving Ground. Ford vehicles will be using C-V2X technology and the Qualcomm 9150 C-V2X solution to facilitate direct communications, and will be complemented by AT&T's 4G LTE network communications and ITS platform that takes advantage of wireless base stations and multi-access edge computing technology from Nokia. McCain will help facilitate the effective integration with existing and emerging traffic signal control infrastructure. Testing will support direct C-V2X communications operating in the 5.9 GHz ITS spectrum to explore the safety enhancements of V2V use cases, including do not pass warning, intersection movement assist, and left turn assist, among others. The trials will also support advanced vehicle communication capabilities for improved traffic efficiencies, such as real-time mapping updates and event notifications relayed using AT&T's cellular network and Nokia Cloud Infrastructure.[85]

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[83] Press Release, Qualcomm, *Leading Automotive, Telecom and ITS Companies Unveil First Announced Cellular V2X Trials in Japan* (Jan. 11, 2018), https://www.qualcomm.com/news/releases/2018/01/11/leading-automotive-telecom-and-its-companies-unveil-first-announced.

[84] Press Release, Continental, *Cellular V2X: Continental Successfully Conducts Field Trials in China* (Dec. 18, 2017), https://www.continental-corporation.com/en/press/press-releases/2017-12-18-cellular-v2x-116994.

[85] Press Release, Qualcomm, *AT&T, Ford, Nokia and Qualcomm Launch Cellular-V2X Connected Car Technology Trials Planned for the San Diego Regional Proving Ground with Support From McCain* (Oct. 31, 2017), https://-

Rohde & Schwarz and Qualcomm (October 2017, Columbia, Maryland): The R&S CMW500 Wideband Radio Communication Tester Was Used to Successfully Test a Pre-Commercial Qualcomm® 9150 C-V2X Chipset.[86]

Ericsson, Orange, Qualcomm, PSA Group (February, 2017, Towards 5G, France): The initial phase of testing demonstrated Cellular V2X capabilities on the evolution towards 5G in a real environment over two use cases dedicated to connected vehicles: "see through" between two connected vehicles on a road, and "emergency vehicle approaching," aimed at notifying drivers when an emergency vehicle is nearby in real-time. These two use cases have taken advantage of improved latency, and high throughput performance, using the network-based capabilities of Cellular V2X to deliver a high-resolution video stream between two vehicles, and demonstrating reactivity to show real time event notification.

Vodafone, Bosch and Huawei (February, 2017, Mobilifunk (A9), Germany): Trial underway in the stretch of the A9 between Nuremberg and Munich in Germany. During the trial, the consortium demonstrated the viability of direct V2V communications and the ability to exhibit very low latency. In addition, the tests were intended to investigate how Cellular V2X differs from the IEEE 802.11p technology.

Audi, Vodafone and Huawei (February 2017, Barcelona): On the Circuit de Barcelona-Catalunya race track at the Mobile World Congress 2017, Audi, Huawei and Vodafone demonstrated the use of 4G cellular to enhance safety by enabling rapid exchange of information between vehicles (V2V), other road users and infrastructure (V2I). They demonstrated "see through" (connected cars can see a video feed from a vehicle in front of them in situations where it will help them to have visibility of other traffic, upcoming entry roads or other issues to negotiate); a traffic light warning (traffic light is about to change alerting the driver to slow down), pedestrian in the roadway warning; and emergency braking warning (other connected vehicles suddenly braking or changing lanes).

Audi, Ericsson, Qualcomm, Swarco, Kaiserslautern Univ (January, 2017, ConVeX (A9), Germany): The goal of the trial was to demonstrate the benefits of a Cellular V2X connectivity platform, as defined by 3GPP Release 14, to showcase range, reliability and latency advantage for real-time V2V communications. Additionally, the trial aimed to highlight new use cases that help support traffic flow optimization and improve safety. The goals of ConVeX were to use the results of the trial to inform regulators, provide important inputs to ongoing global standardization work and shape a path for further development and future evolution of Cellular V2X technology.

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www.qualcomm.com/news/releases/2017/10/31/att-ford-nokia-and-qualcomm-launch-cellular-v2x-connected-car-technology.

[86] Press Release, Rohde & Schwarz, *Rohde & Schwarz Supports 3GPP Cellular V2X Device Testing for Vehicle-to-Vehicle Connectivity*, ACCESSWIRE (Oct. 19, 2017), https://www.accesswire.com/478295/Rohde--Schwarz-Supports-3GPP-Cellular-V2X-Device-Testing-for-Vehicle-to-Vehicle-Connectivity.

CMCC, Continental, Nokia, Fraunhofer (November 2016, Car2X in Wuzhen, China): At the 2016 World Internet Conference in Wuzhen, China, the partners demonstrated Cellular V2V applications such as Emergency Brake Light that lets you know when traffic in front of you slows down and Cooperative Passing Assistant, that determines whether it is safe to change lanes, advising oncoming traffic to slow down and warning vehicles in front not to change lanes.

Audi, Deutsche Telekom, Huawei, Toyota (July, 2016, DT (A9), Germany): The companies conducted trials of Cellular V2V technology on a section of the "digital A9 motorway test bed" near Ingolstadt, Germany. Audi AG and Toyota Motor Europe research cars, and Deutsche Telekom infrastructure were specially equipped with V2V hardware from Huawei to support the trial scenarios.

Jaguar Land Rover, Vodafone et al (June, 2016, UK): Connected Intelligent Transport Environment (UKCITE) is a project to create the most advanced environment for testing connected and autonomous vehicles. It involved equipping over 40 miles of urban roads, dual-carriageways and motorways with various V2V technologies including Cellular V2X. The project established how this technology can improve journeys; reduce traffic congestion; and provide entertainment and safety services through better connectivity.

Bosch, DT/T-Systems, Nokia (June 2016, MEC pilot project, Germany): The development partnership demonstrated the application of Cellular V2X utilizing local clouds for fast vehicle-to-vehicle communication for hazard warnings and for cooperative and coordinated driving maneuvers. The work included implementing driver assistance functions such as intersection assistance and electronic brake lights.

Continental, DT/T-Systems, Nokia, Fraunhofer (November 2015, Car2X at A9, Germany): The trial demonstrated how vehicles on the motorway can share hazard information using the LTE network of Deutsche Telekom. As extremely short transmission times are vital for this purpose, a section of the Deutsche Telekom network was equipped with innovative Mobile Edge Computing technology from Nokia Networks, and upgraded with position-locating technology developed by Fraunhofer ESK. This combination permitted signal transport times between two vehicles of less than 20 milliseconds.

Appendix D - Proposed Conditions Applicable to C-V2X Operations Pursuant to the Waiver Request

The following conditions are proposed for all operations under the requested waiver. These conditions are largely consistent with the technical rules for DSRC, to ensure that C-V2X will not have any larger potential for interference than DSRC operations currently permitted under the FCC Rules.

Conditions Applicable to All C-V2X Equipment:

- C-V2X operations will be limited to the 5905-5925 MHz band. DSRC operations will be prohibited from operating in these frequencies.
- The transmit power limits for all C-V2X devices permitted under the waiver (i.e., Vehicular, Portable, and Roadside units) will be 20 dBm antenna input power as specified in § 8.10.1 of ASTM E2213 - 03. The EIRP for an OBU (vehicular and portable) will be limited to 23 dBm. The EIRP for an RSU will be limited to 33 dBm.
- All C-V2X devices must attenuate out-of-band emissions consistent with the limits shown below, which may be measured at the antenna input. These are consistent with the existing FCC rules, but allow for the variable transmit power nature of C-V2X, and the planned 20 MHz bandwidth.

Offset from Band Edge	Out-of-Band Emission Limit
± 0 MHz	-29 dBm/100 kHz
± 1.0 MHz	-35 dBm/100 kHz
±10 MHz	-43 dBm/100 kHz
±20 MHz	-53 dBm/100 kHz

- All C-V2X OBUs and RSUs also will limit emissions to -25 dBm/100 kHz EIRP or less outside the channel edges of 5905 MHz and 5925 MHz and below the band edge of 5855 MHz. The -25 dBm/100 kHz EIRP limit comes from § 8.10.2.2 of ASTM E2213 – 03.
- C-V2X devices will be evaluated for RF Exposure consistent with the current FCC rules. Devices that would operate in mobile or portable configurations will be evaluated consistent with the procedures in § 2.1091 and § 2.1093 of the FCC Rules respectively. RSUs will be required to indicate compliance with the Maximum Permissible Exposure (MPE) limits in § 1.1310 of the FCC Rules.
- All equipment subject to the waiver must be certified in accordance with Subpart J of Part 2 of the Commission's rules.

Conditions Applicable to Roadside Units:

- A Roadside Unit may employ an antenna with a height not to exceed 8 meters, with the exception that the antenna height may be between 8 and 15 meters provided the EIRP is reduced by a factor of 20 log(Ht/8) in dB where Ht is the height of the radiation center of the antenna in meters above the roadway bed surface. The EIRP is measured as the maximum EIRP toward the horizon or horizontal, whichever is greater, of the gain associated with the main or center of the transmission beam. The RSU antenna height shall not exceed 15 meters above the roadway bed surface.

Conditions on C-V2X Operations:

- Communications permitted under this waiver will include Vehicle to Vehicle and Vehicle to Infrastructure messages such as the Basic Safety Message, Signal Phase and Timing, Emergency Vehicle Alert, Probe Data Management, Probe Vehicle Data, Signal Request Message, Signal Status Message, Geometric Intersection Description, Traveler Information Message, & others encompassed by the Road Safety Message.
- Operation under this waiver will be limited to the use of cellular technology to enable vehicles to communicate with everything—including other vehicles, infrastructure, etc.—as standardized by the 3rd Generational Partnership.
- On-Board and Portable Units should be licensed by rule, consistent with the approach used for DSRC OBUs. Individuals operating On-Board and Portable Units would not require a station license issued by the FCC.
- Parties desiring to operate Roadside Units must apply for non-exclusive nationwide licenses with individual site registration through the FCC's Universal Licensing System (ULS). C-V2X Roadside Unit operators will comply with the registration process used by operators of DSRC RSUs detailed in § 9.375(b).
- All Roadside Units shall not receive protection from Government Radiolocation services in operation prior to the establishment of the Roadside Unit station. Operation of C-V2X Roadside Unit stations within 75 kilometers of the locations listed in the table in § 90.371 must be coordinated through the National Telecommunications and Information Administration.
- Roadside Units will be subject to the international coordination conditions identified in § 90.383 of the FCC Rules.