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Making Conservation
a California Way of Life

February 22, 2019

Mr. Finch Fulton
Deputy Assistant Secretary for Transportation Policy, Office of the Secretary
United States Department of Transportation (USDOT)
1200 New Jersey Avenue, S. E.
Washington, DC 20590

Dear Deputy Assistant Secretary for Transportation Policy Fulton:

The California Department of Transportation (Caltrans) hereby submits comments in response to the USDOT's "V2X Communications" Notice of Request for Comments (Docket Number DOT-OST-2018-0210), issued in Washington, DC on December 26, 2018. As the owner and operator of California's State Highway System, Caltrans is in a strong position to offer credible comments based our first-hand experience and lessons learned from experimenting with vehicle-to-everything (V2X) communications technology.

For more than 100 years, Caltrans and its predecessors have been responsible for planning, designing, building, operating, and maintaining California's State Highway System. Over time, that role has evolved to now include rail and mass transit. However, as California's transportation needs have broadened over the last century, so has Caltrans' focus.

Caltrans has been actively engaged in connected and automated vehicle research and development since the early 1990's. Over that period, Caltrans has invested more than $50 million investigating new ways to improve the safety and mobility of vehicles, and sincerely believes that vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, with Dedicated Short-Range Communications (DSRC) technology, will serve as the foundation for these improvements.

Caltrans has been actively engaged in research on connected and automated vehicles from the late 1980's through today, and along with the University of California's PATH Program, served as core participants in the National Automated Highway System Consortium (NAHSC) from 1994 to 1998. The NAHSC was a $200 million federal research program led by General Motors that was charged with developing the specifications for an automated highway system that would transform surface transportation and significantly improve our nation's roadway safety and mobility. When the NAHSC Program was ended prematurely due to concerns about the readiness of the technology, Caltrans also participated in its successor, the FHWA-sponsored Intelligent Vehicle Initiative (IVI), from 1999 through 2003. Under the IVI Program, Caltrans and PATH performed research related to snow plow and snow blower automation as well as intersection safety for left-turning vehicles.

Caltrans has also participated in the national Connected Vehicle Program since its inception in 2004, serving as one of the key infrastructure owner-operators that has advised FHWA on the challenges of deploying, operating, and maintaining the roadside equipment necessary to enable vehicle-to-infrastructure (V2I) communications.

Caltrans is proud to be one of the charter members of the Connected Vehicle Pooled Fund Study Program led by Virginia DOT, which now includes a total of 22 state DOT's, FHWA, Maricopa County DOT, and Transport Canada (the equivalent of USDOT in Canada). This program was formed in 2009, and has funded $8 million in research intended to advance the state-of-the-art in Connected Vehicles, focusing primarily on the perspective of an infrastructure owner-operator fulfilling its V2I responsibilities.

Through several decades of research, Caltrans has never lost sight of the need for vehicles to transition from being manually driven by human drivers to being automated (machine drivers), and for them to be connected to each other through vehicle-to-vehicle (V2V) communications, and to the infrastructure through V2I communications. These two critical components are essential in order for transformational improvements to safety and mobility to occur, allowing our nation to significantly reduce the number of fatal and injury crashes and reduce the stifling traffic congestion that afflicts our large urban regions, adversely affecting our nation's economy and livability.

Caltrans is a pioneer in the use of V2V and V2I communications technology. We were granted Radio Station Authorization WQBH796 by the Federal Communications Commission (FCC) on October 9, 2004 for operation in the Intelligent Transportation Service, which is currently reserved for use by DSRC. Caltrans was among the first state transportation agencies to implement stations in this service, and we currently have over 176 locations licensed in California in the Intelligent Transportation Service, with additional locations planned in the near future. We have built considerable experience since then developing and testing safety and mobility applications using DSRC technology operating in that radio spectrum. We currently operate a connected vehicle test bed in the City of Palo Alto consisting of 15 signalized intersections broadcasting via DSRC their Signal Phase and Timing (SPaT) information and geometric map (MAP) information to equipped vehicles approaching the intersections. We are partnering with auto companies and the local transit agency that operates Bus Rapid Transit lines along our test bed corridor to develop and test connected vehicle safety and mobility applications.

We strongly believe that Caltrans' broad and deep experience with connected and automated vehicles provides us with the insight to submit credible answers to the questions posed below:

1. **Please provide information on what existing or future technologies could be used for V2X communications, including, but not limited to, DSRC, LTE C-V2X and 5G New Radio. What are the advantages and disadvantages of each technology? What is the timeframe for deployment of technologies not yet in production? Please provide data supporting your position.**

   The primary advantage of using DSRC for V2X communications over the others mentioned is that it is a licensed and dedicated radio spectrum allocated by the Federal Communications Commission (FCC) specifically for V2V and V2I applications. For public safety applications such as V2V and V2I, it is imperative that the radio spectrum be dedicated and licensed. Dedicated spectrum ensures that public safety messages have a guaranteed transmittal and delivery medium, without competition from other applications. Holding an FCC license ensures ownership of the spectrum and a defined mitigation process should harmful interference occur. Furthermore, DSRC does not require any additional infrastructure (transmitters, repeaters, towers, antennas), as the radio and its associated equipment are installed in the vehicle. DSRC has been in existence since the mid 2000's, and is readily available today, with no additional system recurring fees.

   LTE C-V2X is not dedicated to V2X applications and does not require FCC licensing. Consequently, V2X applications will be competing with commercial applications, and therefore DSRC message transmittal and delivery are not guaranteed, or may experience latency. Additionally, LTE service may not be available in some areas; availability is dependent on the carrier, robustness of its system infrastructure, and coverage area. LTE has monthly recurring fees associated with the service, has been in existence since 2010, and is in operation today.

   5G service is in its infancy; system reliability and availability has yet to be proven. Since 5G uses cellular technology, its characteristics and features are very similar, if not identical to those of the aforementioned LTE technology.

2. **Of the V2X communications technologies previously discussed, at present only DSRC is permitted to be used in the 5.9 GHz spectrum band for transportation applications. If that allocation were to be changed to allow any communication technology for transportation applications, could DSRC and other technologies (*e.g.*, C-V2X, 5G or any future technology) operate in the same spectrum band or even the same channel without interference? Why or why not? If there are any technical challenges to achieving this goal, what are they and how can they be overcome?**

   It may be possible for DSRC to operate in the same spectrum band with other technologies, but this practice should be highly discouraged. The FCC allocated the 5850-5925 MHz spectrum for transportation applications and this spectrum should be operated as intended. Cellular systems in general operate at a much higher signal levels than DSRC systems, and consequently DSRC will suffer harmful interference at the minimum, or not be able to operate at all in the worst case. A similar concept was realized in 2004, as the FCC issued a “Report and Order” to reconfigure the 800 MHz band, as public safety users operating in the same band experienced harmful interference from the Sprint/Nextel cellular network. Similar to DSRC, the public safety 2-way Land Mobile Radio systems operate at much lower signal levels than those of cellular systems.

If the DSRC spectrum was to be shared with cellular systems, an additional concern is what the mitigation process might be, should each experience harmful interference from the other.

Identifying the source of interference, and then rectifying that interference, is a long and costly process; public safety applications, such as DSRC cannot, and should not be placed in an environment with a potential for interference. Every precaution must be taken to ensure that DSRC systems operate in an environment free from the potential of experiencing harmful interference.

3. **To what extent is it technically feasible for multiple V2X communications technologies and protocols to be interoperable with one another? Why or why not? Can this be done in a way that meets the performance requirements for safety of life applications, as they were discussed in the V2V NPRM? What additional equipment would be needed to achieve interoperability or changes in standards and specifications? What is the projected cost of any necessary changes? How soon can these changes and equipment prototypes be available for testing?**

Caltrans defers to others in the technical community to address the question of whether or not different V2X communications technologies can be interoperable. In the absence of a mandate for DSRC, as was intended with the V2V Notice of Proposed Rulemaking, the uncertainty faced by an infrastructure owner-operator (IOO), such as Caltrans, as to which communication technology to begin deploying becomes large and daunting. IOO’s typically require years of advanced planning in order to program limited public funding to invest in infrastructure improvements, and then additional years in order to proceed through the design, build, and operate/maintain that infrastructure.

Because of these timelines, our infrastructure needs to have a long life, typically lasting decades before it needs to be replaced. When there is uncertainty and risk involved with deploying infrastructure that may be made obsolete in a short timeframe, IOO’s will be paralyzed with indecision about how to invest their limited funding. Roadside Cell Phone Call Boxes are the best example of this dilemma; they were widely installed at considerable public expense, and yet became obsolete almost overnight with the advent and widespread use of personal mobile phones. IOO’s are concerned that choosing the wrong V2X communications technology could have the same result.

For critical, safety-of-life connected vehicle applications, high-availability and low latency are essential requirements, both of which are the trademarks of DSRC. High-availability is enabled by the fact that there is dedicated spectrum for DSRC and only authorized users may obtain FCC licenses. Low latency is achieved by the fact that the design for DSRC has been streamlined to minimize the amount of time necessary for exchanging messages

V2V and V2I, allowing messages to be exchanged 10 times per second to enable safety applications.

4. **To what extent is it technically feasible for different generations of the same V2X communications technologies and protocols to be interoperable with one another? Why or why not? Can this be done in a way that meets the performance requirements for safety of life applications? What additional equipment or changes in standards and specifications would be needed to achieve interoperability? What is the projected cost of any necessary changes?**

   Caltrans again defers to the technical experts in our industry to address these complicated questions. It is important to note, however, that efforts to update the standards related to DSRC are already underway, and the resulting technology will be backward-compatible with the existing equipment. This effort is called "Next Generation V2X" (NGV), and is led by the Institute of Electrical and Electronics Engineers (IEEE), the Standards Development Organization responsible for the existing physical and link layers of the DSRC standard.

   Again, it is being guided by representatives from the transportation industry, including IOO's and OEM's, and recognizes that improvements have been made to the underlying IEEE 802.11 standards and overall technologies that form the foundation for DSRC in the time since the original standards were ratified. The outcome of these efforts will be improved V2X DSRC equipment that performs better than that which is available today. However, this evolutionary step will ensure that today's installed equipment still remains operational while new and replacement installations will realize better radio performance.

5. **Even if they are interoperable across different technologies and generations of the same technology, would there be advantages if a single communications protocol were to be used for V2V safety communications? What about other V2X safety applications, such as those involving V2I and V2P communications?**
   Caltrans believes that there are maintenance and operational advantages for using a single communications protocol for V2X applications: system interoperability, user training, maintainability, equipment inventory, scalability, and system administration. These factors result in significantly reduced life-cycle costs for the IOO, and presumably for the OEM's as well.

6. **How would the development of alternative communication technologies affect other V2I and V2P communications, such as those supporting mobility or environmental applications? Do these applications have the same or different interoperability issues as V2V safety communications? Do different V2X applications (e.g., platooning) have different communication needs, particularly latency?**
   Caltrans recognizes that not all connected vehicle applications require the high-availability and low latency features present in DSRC radios. However, for applications where safety-of-life is required, DSRC is the best and currently only method for achieving this requirement. For intersection safety, the best example is the Red Light Violation Warning

(RLVW) application, which combines information in SPaT and MAP messages broadcast over DSRC to approaching vehicles with information on the dynamic state of the vehicle (distance to stop bar; speed; and deceleration) to determine if a warning should be delivered to the driver. Intersection Movement Assist is another example of an intersection safety application that requires DSRC in order to perform correctly.

It is possible to provide SPaT and MAP using C-V2X technology, and much of the time the RLVW application will probably work; however, due to inherent latencies associated with cellular technologies, there is also be times when the messages will arrive too late to be effective in issuing a warning.

Caltrans contends that the platooning application listed as an example of a mobility application is actually a safety one too. The only way to safely reduce the time gap between vehicles travelling in a platoon is to ensure that reliable V2V communication of related safety messages, primarily the Basic Safety Message, occurs between vehicles in the platoon. Caltrans funded research and field testing of platooning for passenger cars as well as commercial trucks, and we state with confidence that the safety of this application is based entirely on the reliability of the V2V link between the vehicles. During field testing, when that link was lost, all the vehicles travelling in the platoon were required to back-off from the vehicle in front of them to maintain a larger time gap consistent with safe following distances.

7. **Do different communication technologies present different issues concerning physical security (i.e., how to integrate alternative communication technologies into vehicle systems), message security (i.e., SCMS design or other approaches), or other issues such as cybersecurity or privacy? Would these concerns be affected if multiple but still interoperable communication technologies are used rather than one?**

Caltrans defers to security experts to address this question. Our connected vehicle test bed leaves a placeholder in its message header broadcasts for security certificates, but as of now we have not enabled security for our testing. These certificates are a critical component of the overall Public Key Infrastructure implementation to ensure that messages are being received from a trusted source, and that they have not been modified during broadcast, both of which are critical requirements for the connected vehicle system.

However, we have met with companies offering access to Security Credential Management Systems (SCMS), including ISS/Greenhills and Blackberry, but have not yet selected an SCMS provider. Both of these companies offered to allow us to evaluate the performance of their SCMS implementation by providing test certificates that would behave as real ones do, and we intend to begin testing with certificates soon.

To realize mobility benefits from applications such as Transit Signal Priority, Caltrans will be changing the signal timing at our intersections based on messages received from equipped vehicles, so we must be certain that these messages are being generated by a trusted source. The certificate system developed for the SCMS will provide this peace of mind.

8. **How could communications technologies (DSRC, C-V2X, 5G or some other technology) be leveraged to support current and emerging automated vehicle applications? Will different communication technologies be used in different ways? How?**

   It is important to note that the DSRC standards were developed by the transportation partners associated with connected vehicles: the infrastructure owner-operators (IOO's) and the vehicle manufacturing industry (OEM's), guided by the FHWA. This development was based on the open-source principle, meaning that there were no intellectual property constraints imposed that would require licenses for companies producing DSRC equipment. DSRC was developed for the transportation industry, by the transportation industry, and satisfies all of our requirements. Because it is open-source, any manufacturer can build equipment that meets the standards, and the open competition in the market will drive down the costs and increase the pool of companies pursuing business opportunities with DSRC.

   In contrast to DSRC, C-V2X technology was developed by companies associated with the cellular industry, and they are pushing their technology to the transportation industry for its use. The C-V2X standards are not open source, meaning that companies wanting to manufacture equipment will need to purchase licenses from the companies that own the associated intellectual property, resulting in higher costs for the manufacturer that they will then pass along to the end users, the IOO's and the OEM's. This market situation will reduce the number of companies pursuing the business opportunity and drive up the cost of the products that do become available.

9. **How could deployments, both existing and planned, assess communications needs and determine which technologies are most appropriate and whether and how interoperability could be achieved?**

   In addition to the three connected vehicle Pilot Projects underway in New York City, Tampa, and the State of Wyoming, as well as the Smart City initiative in Columbus, Caltrans is aware of other sites that have operational connected vehicle applications. In particular, the State of Utah is operating a Transit Signal Priority application using DSRC along two corridors, one in Salt Lake City and one in Provo. These sites have already overcome any start-up challenges that they faced, and may have lessons learned that can be disseminated to others.

   In addition, the State of Michigan has deployed DSRC technology at many sites along their right-of-way, and probably have similar experiences to share. Michigan has publicly stated that they will install DSRC-based roadside units at every intersection under their control. The State of Georgia has also made a bold announcement that they will deploy DSRC-based equipment at 1,700 locations over the next three years.

Caltrans thanks the USDOT for its continued efforts to protect the radio spectrum currently reserved for V2X, as promised in the AV 3.0 policy statement, and to use that spectrum more efficiently. Caltrans stands ready to work with the USDOT and all other interested partners and stakeholders to explore and test ideas for the use and potential sharing of the V2X radio spectrum.

Should you have any questions or require additional information, please call me at (916) 227-8008 or by e-mail at greg.larson@dot.ca.gov

Sincerely,

[original signed by Greg A. Larson]

GREG A. LARSON, Chief
Office of Traffic Operations Research