ITS America National V2X Deployment Plan

An Infrastructure & Automaker Collaboration

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INTRODUCTION

Vehicle-to-Everything (V2X) technology, the ability of vehicles to communicate with each other and with the roadside infrastructure, presents the opportunity to prevent crashes, save lives, and add efficiency and sustainability to our transportation network. These benefits have been anticipated for over twenty years and are now within practical reach. Needed regulatory certainty appears to be imminent and the technologies have been tested, proven, and demonstrated in lab and field environments. It is time for the entire transportation industry – original equipment manufacturers (OEM), infrastructure owners and operators (IOO), federal agencies, and suppliers – to come together to scale interoperable deployments of this life-saving technology in both the infrastructure and production vehicles.

In August 2022, the USDOT convened a V2X Summit to discuss a path forward. Enthusiastic participants called for a national deployment of a V2X system to improve safety. The USDOT committed to developing a roadmap for this national deployment. 2023 is a pivotal year to realize the potential of this technology, to begin broad deployment, and to begin to reduce traffic fatalities from their high of nearly 43,000 lives. V2X is a tangible solution to a major national crisis.

This document presents a proposed National V2X Deployment Plan from the perspective of both IOOs and OEMs and includes a call to action for state and local transportation agencies and related federal agencies, and outlines expectations for OEM deployment. The most expeditious starting point for a national roll-out on the infrastructure is at signalized intersections. This document also presents guidelines on how to achieve interoperability, goals to achieve a rapid nationwide infrastructure rollout of the technology, an estimate of the cost associated with such a rollout, and a discussion on proposed sources of funding for infrastructure installation. The assumptions behind this plan and a discussion of some background issues are also included.

It is important to keep in mind that the roadmaps for IOOs and OEMs are distinct, yet equally vital, for the successful deployment of V2X. Through collaborative public-private efforts these two unique workstreams must align to realize the vision of a scalable connected environment that will make mobility safer, greener and more enjoyable. ITS America believes that this plan is achievable, realistic, and necessary and that now is the time to move forward aggressively.

BACKGROUND

V2X systems, often referred to as 'connected vehicle technology' include the ability of vehicles to exchange messages wirelessly and very quickly with other vehicles, roadside infrastructure, and other travelers – like bicyclists or pedestrians. These messages contain key information about the location and actions of vehicles and other travelers, traffic conditions – including the state of traffic signals and prevailing roadway conditions – such as weather, pavement conditions, work zones, and other disruptions. It is clear that low-latency V2X communications in the 5.9GHz spectrum will give drivers vastly improved awareness in increasingly hazardous traffic situations. While on-board sensors have improved the safety capabilities of vehicles, V2X addresses a key limitation in those capabilities – they are limited to line of sight. Sharing key information between the various parties in the transportation network allows responses that can improve safety, prevent crashes, optimize system performance, and reduce congestion.

V2X systems typically consist of two physical elements:

- On-Board Units (OBU): wireless radios installed on vehicles and other moving travelers, which send and receive V2X messages. These radios integrate with other elements of the vehicle to obtain and share useful information about the actions of the vehicle. They also receive information about external conditions and provide that to the driver or vehicle system itself.
- Roadside Units (RSU): wireless radios installed along the side of the roadway, which communicate with vehicles by sending and receiving V2X messages. These fixed radios are typically mounted on roadside infrastructure and can integrate with technologies operated by IOOs, such as traffic signal systems or sensors. The RSUs can be connected directly to a wireless or wired communication network – such as fiber optic networks – for backhaul of information to and from traffic operation systems or data analytics platforms.

After twenty years of research, testing, and evaluation, several significant developments have occurred in the past three years which set the stage for a national deployment. These developments have resulted in a variety of useful and important documents regarding policy, regulation, hardware standards, and deployment guidance, including the following:

- First Report and Order on the 5.9 GHz Band: Federal Communications Commission (FCC) 20-164, May 2021
- FCC C-V2X Experimental Licenses
- FCC C-V2X Waivers (pending)
- Connected Intersections Implementation Guide: Connected Transportation Interoperability (CTI) 4501 v01.01, June 2022
- Connected Intersections Validation Report – CTI 4502 v01.00, Feb 2022
- Roadside Unit (RSU) Standard – CTI 4001 v01.00, Sept 2021
- Connected Vehicle Infrastructure – Roadside Equipment: National Electrical Manufacturers Association (NEMA) TS10-2020 (new version in balloting)

- Object Definitions for Actuated Signal Controller Interface - National Transportation Communications for ITS Protocol (NTCIP) 1202 v03A, May 2019 (revision in balloting)
- Connected Intersection Performance Assessment: Crash Avoidance Metrics Partnership (CAMP), Dec 2022
- Connected Intersection Guidance Document: Connected Vehicle Pooled Fund Study (CV PFS), Dec 2022
- Connected Intersections Test Plan: CV PFS, v0.2, Mar 2022
- Guidance Document for MAP Preparation: CV PFS, Rev 1, May 2022 (new version in review)
- End-Entity Security Requirements, Design Guidance, and Validation Approach: Security Credential Management System (SCMS) Manager, v1.00, March 2021

THE BUSINESS CASE FOR A NATIONAL V2X DEPLOYMENT PLAN

A comprehensive National V2X Deployment Plan supports and elevates recent US Department of Transportation (USDOT) initiatives into real actionable strategies with identified milestones and timing. USDOT reports of note include the National Roadway Safety Strategy (https://www.transportation.gov/NRSS , January 2022), with its focus on safer people, safer roads, and safer vehicles, and the USDOT Research, Development, and Technology Strategic Plan (https://www.transportation.gov/rdtstrategicplan , January 2023), which includes a focus on several Grand Challenges, including Zero Fatalities and a Future Transportation System-of-Systems consisting of intelligent infrastructure. In addition to being a logical next step for these USDOT strategies, transportation agencies are motivated to deploy interoperable V2X systems nationwide based on the following considerations.

Industry is Ready

The August 2022 V2X Summit demonstrated that industry, IOOs and OEMs are eager to see V2X technologies deployed and active on our roadways. Without stakeholder interest in V2X technologies, a USDOT push for a V2X strategy would be unsuccessful; however, there is an active and willing market in this field that USDOT can help launch into a full-scale national deployment to meet national safety and mobility goals.

Improved Roadway Safety

The V2X promise has always been about safety. With deaths on US highways exceeding 43,000 per year, it is imperative that this technology be deployed to curb this crisis. V2X has been referred to as a digital seatbelt needed in every car. In their 2016 regulatory analysis associated with the proposed change to Federal Motor Vehicle Safety Standard (FMVSS) 150, the National Highway Traffic Safety Administration (NHTSA) noted that the implementation of just two V2X safety applications, Intersection Movement Assist (IMA) and Left Turn Assist (LTA) would

prevent 439,000 to 615,000 crashes, 13 to 18 percent of the total, and save 987 to 1366 lives. The resulting savings from these reduced crashes would be $55 to 74 billion. Implementation of dozens of safety applications would multiply these benefits significantly.

The National Transportation Safety Board (NTSB), following its investigations into multiple, high-profile traffic collisions, issued safety recommendations to NHTSA calling for V2X performance standards, and requirements for V2X in new vehicles. NTSB also listed V2X on its "Most Wanted List" of transportation safety improvements.

Increased Traffic Efficiency and Environmental Benefit

In addition to the safety benefits, V2X can reduce emissions and improve traffic movements. Studies of V2X-based signal priority and preemption systems in Utah indicate that transit reliability can be improved by six percent, and schedule deviation reduced. Further, snowplow travel times can be slashed to almost half.

A recent study in Europe noted that traffic management and signal control using V2X can reduce CO_2 emissions by up to 16 percent and platooning can reduce emissions by up to 33 percent. For an individual vehicle an eco-driving application can provide an emissions reduction of almost 10 percent. An initial deployment of C-V2X in some Fulton County, Georgia school buses proved that fuel savings of more than 10% can be expected due to signal priority.

Proven Technology

V2X, as noted in the previous section's list of standards, is proven to work. Not only is the technology beyond "testing", but it has also shown its capabilities in deployments across the Nation (see the national SPaT Challenge map and the USDOT Connected Vehicle Deployment map), largely using Dedicated Short Range Communication (DSRC) radios. Deployments of V2X technologies in several states have been operational for over five years. Various agencies have demonstrated it can work in a wide range of applications, including vulnerable roadway safety, platooning, road hazard warning messages, and transit and freight mobility solutions.

The current generation of V2X technology that is being designated for use by the FCC, Cellular V2X (C-V2X or LTE-V2X) has been successfully deployed by many agencies under experimental licenses. Preliminary laboratory and field testing of C-V2X devices, summarized by the USDOT at the V2X Summit, indicates that these devices meet minimum operational requirements, can broadcast effectively within expected distances, and have acceptable performance in environments with expected and realistic congestion levels.

Faster & Cheaper

Intelligent Transportation Systems (ITS) have always been a faster and cheaper deployment strategy compared to constructing major civil projects. An ITS device, like V2X technology, can and is often deployed within a year or two of funding, compared to years-long civil projects. Knowing the technology is scalable quickly can help achieve safety and mobility benefits for the public much faster than traditional roadway improvement projects. Of course, ITS technology is

also compatible with traditional projects and can help with asset management, safety, mobility, and many other aspects of managing and operating the roadway.

International Competitiveness

Long has the United States been a leader in innovation. While the US remains competitive in innovation overall, in the field of V2X and automated vehicles, the US has failed to make itself a leader. As a result, the international community is moving ahead of the US in technology capabilities that would set the standards and market trends in our nation. Without active engagement and establishing a space for the US, the resulting available products will be determined by others, which may not meet our community or economic needs.

ASSUMPTIONS

This proposed National V2X Deployment Plan was created based on a series of assumptions about the technology, the regulated environment, the condition of US infrastructure, interoperability, and the nature of OEM development cycles. These assumptions include the following:

Technology

This plan assumes the use of C-V2X low-latency, wireless communications systems that operate in the 5.9 GHz band, primarily for safety applications. The FCC has made the decision to provide 30MHz of spectrum in the 5.9GHz band and to designate C-V2X as the technology platform to be used in that spectrum. Since C-V2X uses one 20MHz channel, this plan assumes the long-term availability of that single channel. While other communication technologies exist for some applications, the broad deployment of low-latency C-V2X systems on production vehicles and the infrastructure is needed to make use of the spectrum that has been allocated and realize the crash-reduction benefits promised from “connected vehicles”. It is understood that a larger digital infrastructure effort is needed to accommodate all technologies and applications; this plan focuses on uses within the 5.9GHz band and the immediate benefit these will produce.

Regulatory Environment

Although the FCC has issued a First Report and Order as a first step in establishing regulatory certainty in the 5.9GHz band, other actions are still pending. A Second Report and Order is needed to establish broadcast power limits, establish certification requirements, define procedures to register RSUs within jurisdictional licenses, address interference, and other important elements. OEMs, in particular, need certainty before committing resources to deployment on millions of vehicles, including an assurance that the 5.9GHz spectrum will remain protected by the FCC. This plan assumes that the Second Report and Order will be issued at least two years before any significant deployment “deadlines” so that the FCC will have certified C-V2X technology as compliant for use in the 5.9 GHz band.

In the interim before the issuance of a Second Report and Order, the FCC has offered to provide Waivers for the deployment of C-V2X devices. Several Waiver Requests are currently pending with the FCC – some for more than a year. Without these Waivers, many agencies will not be able to deploy RSUs and automakers will continue to wait. To move deployment forward withing the timelines outlined herein, this plan assumes that the Waivers are issued by the end of 2023. In the interim, IOOs are also continuing to apply for experimental licenses to meet financial and project deadlines.

OEMs need NHTSA, their primary safety regulator, to be involved in substantive discussions, including elevating C-V2X as an element within their safety rating system, the New Car Assessment Program (NCAP). This plan assumes that NHTSA has joined FHWA in promoting and encouraging V2X deployment in automobiles. Additionally, this plan expects that NHTSA will use its marketing and outreach resources to build greater public awareness about V2X benefits and signal to state and local road operators that the full weight of the federal transportation regulatory structure supports deployments.

Infrastructure

This document's initial recommendation is to focus on the deployment of V2X at signalized intersections. Signalized intersections provide a ready foundation for V2X deployment, including poles, power, electronics cabinets, and, in many cases, backhaul communications. This foundational infrastructure will facilitate the most expedient deployment of V2X systems in a shortened timeline – saving lives sooner. While there are beneficial applications that can be applied on interstates and unsignalized urban and rural corridors, those locations, with the possible exception of tolling facilities, often lack the "ready infrastructure" found at signalized intersections. Further, some of those non-intersection applications might be better suited to virtual RSUs or communication technologies other than low-latency V2X. Because of a desire for fast, and immediately impactful, benefits to the public, this plan's recommendations focus on deployment at signalized intersections.

In addition, there has been significant attention in the automaker and IOO community in recent years on V2X applications at signalized intersections, such as Red-Light Violation Warning (RLVW), Pedestrian Safety Messages (PSM), and "Eco-Driving" solutions (e.g., time to red or green). Some of the recent V2X standards have been based on those applications. A renewed focus on vulnerable road user safety also directs attention to intersections. Supporting the decision to intersections the first deployment priority is a survey of automakers by ITS America in 2022, which indicated that there are numerous Vehicle to Infrastructure (V2I) applications of interest, including several that are intersection specific.

Signalized Intersections

It is estimated that there are 330,000 signalized intersections in the United States. The operational responsibility for these signal systems lies with various levels of government. Some state Departments of Transportation (DOT) operate many signals, others manage none. Among the thousands of transportation agencies, some large and some small, it is estimated that

operational responsibility for the majority of signals in the U.S. falls to agencies who individually control more than 500 intersections.

This plan suggests targets for equipping substantial proportions of those 330,000 intersections with C-V2X RSUs over a period of years. State and local agencies will determine which intersections to equip in both urban and rural settings based on guidelines suggested herein and will lead the deployment effort.

The proposed plan assigns responsibility for the oversight of V2X systems to the various state DOTs despite the fact that some of them operate and manage no signalized intersections. The statewide jurisdiction of state DOTs, their frequent interaction with local agencies in regulatory and funding matters, and their familiarity with federal standards, rules, and funding render state DOTs as the logical point-of-contact in each state for a national deployment plan.

A study in 2004 by the USDOT estimated that 75% of signalized intersections needed upgrades, improvements, and retiming. This plan assumes this estimate to still be true. Some upgrades may entail the complete replacement of roadside cabinets, the signal controller, and other components to prepare the signal systems to be compatible with V2X systems and enable it to provide essential data. Other upgrades may be less substantial.

National Interoperability

To achieve interoperability, it is essential to reduce the broad array of variables and potential message sets implicit in intelligent transportation systems to a defined set of priority messages. The following set of messages are necessary and sufficient to drive robust deployment of C-V2X technology:

- Basic Safety Message (BSM) – information about a vehicle's state
- Signal Phase and Timing (SPaT) – information about a traffic signal's signal state
- MAP – information about the roadway geometry and lane attributes
- Radio Technical Commission for Maritime Services (RTCM) – correction values for the Global Positioning System (GPS) coordinates to improve location determination
- Traveler Information Message (TIM) – information about roadside advisories, work zones, road signs, etc. provided in the form of International Traveler Information Systems (ITIS) codes
- Signal Request Message (SRM) – request for preferential treatment at a signalized intersection for certain vehicle types
- Signal Status Message (SSM) – confirmation of a preferential treatment request by an SRM
- Road Safety Message (RSM) – information about curve and work zones speeds, lane closures and other dynamic traveler information

System Verification

As part of the deployment of RSUs and supporting hardware and software at signalized intersections, a certification process needs to be executed to verify that the data being broadcast is accurate, consistent, reliable, and secure according to national standards. Unless data broadcast at the roadside meets these criteria, the vehicles receiving the data will not be able to rely on it to make life-safety decisions. The process for this verification is still being developed but it will be a necessary element of all deployments. The development of a system to manage security credential systems on a national level are also under development.

Deployment on Production Vehicles

To realize the goals of crash avoidance and fatality reduction, it is absolutely critical that a national V2X deployment include both the infrastructure element – RSUs along the roadside transmitting and receiving essential data – and the vehicle element – OBUs installed in production vehicles manufactured for public sale and use. Improved safety for the vehicle's occupants relies on the OBUs' ability to receive, process, and use valuable information from the infrastructure. This plan assumes that vehicle and infrastructure deployment happen simultaneously and collaboratively. The success of this plan's recommendations also depends on vehicle manufacturers installing OBUs on production vehicles that can broadcast the full BSM Part 1 message, and specified elements of BSM Part 2. IOOs need data on vehicle and traffic conditions (such as braking and air bag deployment status) to support life-saving applications and optimize the safety and mobility of transportation systems they operate.

NATIONAL V2X DEPLOYMENT - INFRASTRUCTURE

Infrastructure Deployment Goals

To achieve the safety benefits promised by V2X systems, a nationwide deployment must be expansive, concentrated, uniform and interoperable. A haphazard deployment of differing systems in diverse places will neither realize the desired safety and mobility results nor provide the ubiquity necessary to justify broad deployments on production vehicles. In support of that premise, this proposed National V2X Deployment Plan provides a comprehensive long-term plan for deployment. Recognizing that achieving the long-term goals will take many years, this Plan also provides an interim step, goals for a short-term milestone.

The long-term goal – the ultimate deployment goal of this Plan – is to achieve the following deployments within 10 years of the adoption of this Plan:

- Install RSUs and supporting infrastructure and systems on 250,000 intersections, comprising about 75% of all signalized intersections in the United States. The general distribution of these RSUs should be as follows:
    - Equip 85% of all signalized intersections in metro areas with populations greater than 400k people, sometimes referred to as "large communities". There are approximately 138 metro areas in 44 states that meet this population criteria.

- Equip 60% of all signalized intersections in “mid-size communities”, metro areas with populations between 50,000 and 400,000.
- Equip 20% of all signalized intersections in “rural communities”, communities with fewer than 50,000 population and outside of a designated urbanized area, with a focus on intersections with demonstrated safety challenges.

The short-term goal is to build a foundation toward the long-term goals, through achieving the following deployments within 5 years of the adoption of this Plan:

- Installations of RSUs and supporting infrastructure and systems on 100,000 intersections, or about 40% of the long-term targets, as follows:
  - Equip 35% of all signalized intersections in “large communities”,
  - Equip 25% of all signalized intersections in “mid-size communities”,
  - Equip 8% of all signalized intersections in “rural communities”.

Each of the signalized intersections equipped with RSUs shall include the following features:

- Be configured to broadcast SPaT, MAP, and RTCM messages meeting current standards and be capable of broadcasting TIM, SRM, SSM, and RSM.
- Each broadcast message shall be secured with a security certificate from a recognized security credential provider.
- The broadcast data shall be verified to meet the (pending) standardized criteria for accuracy, consistency, and reliability.

Primary Infrastructure Strategy: Create State-level V2X Deployment Plans

Each state DOT will be required to develop a V2X Deployment Plan within 18 months of the adoption of this National V2X Deployment Plan. These State Plans will provide the details needed to collectively achieve the goals of the National Plan. The submission of the state-specific Plan will be a requirement prior to agencies within that state receiving federal funds intended to be used for V2X deployment.

As noted in Assumptions, above, state DOTs are the logical nexus for the oversight of V2X systems with their state despite the fact that some of them operate and manage no signalized intersections. While much of the anticipated deployment work will be accomplished by local agencies, state DOTs have relationships with local jurisdictions across their state and have the unique ability to coordinate and support systems that need to be interoperable and uniform. State DOTs also have familiarity with federal standards, rules and funding that are foundational to these deployments.

State V2X Deployment Plans shall generally include the following elements:

- A description of the plan for collaboration and coordination between the various state, county, and local agencies in the state to achieve deployment.
- A discussion of the objectives for the deployments – the anticipated safety and mobility benefits - and how those justify the proposed deployment locations.

- Deployers are encouraged to consider initial use cases that are informative rather than actionable, such as warnings about the presence of vulnerable road users (VRU) or other "see me / see you" types of applications.
- Deployers are also encouraged to focus on applications that prevent intersection crashes.
- Deployers may consider emergency vehicle preemption, snowplow preemption and transit signal priority as use cases that can yield immediate local benefits to help justify the expense of installing these systems.

- A map or tabulation of deployment locations for both the short-term and long-term horizon, in support of the National V2X Deployment Plan, including the rationale for selecting these locations, an indication of whether these locations serve disadvantaged or underserved neighborhoods, a discussion of the areas of the state which will not be included in planned deployments, and a narrative that demonstrates how these deployments fit into the National Plan.
- An outline of the plan to design, install and verify the deployments, including a discussion of how the state and local agencies will obtain, deploy, and refresh security certificates and the approach for populating and broadcasting position correction messages (RTCM).
- A discussion of whether connected vehicle data will be gathered, stored, and analyzed and, if so, a description of the anticipated backhaul and storage systems and the measures which will be undertaken to secure the data and whether the data will be shared.
- An indication of whether vehicles will be equipped with aftermarket OBUs to support the deployment, testing and use of signalized intersection applications and, if so, a discussion on the number of types of vehicles.
- A description of the anticipated long-term monitoring, operation and maintenance of the deployed systems and the level of effort needed.
- A plan for funding the deployments.
- Discussion of funding for on-going maintenance and operational costs.

State V2X Deployment Plans may include non-intersection deployments (interstates, rural corridors, etc.) if they identify beneficial applications and use cases, but those will not replace the signalized intersection targets described in the National Plan.

Estimated Infrastructure Deployment Costs

A wide variety of factors influence the cost for deployment of a V2X system at a signalized intersection.

For an intersection that is "ready" for RSU deployment, meaning that the signal cabinet has the capacity for new equipment and the controller has the capability to provide data necessary to support a SPaT message development, the estimated deployment costs are $7,000 to $15,000 per intersection. This includes the development of a MAP message, FCC site registration, and

the installation of security credentials. It also includes the cost to verify the message accuracy. This cost may not include the planning, engineering, and procurement costs, which can vary widely based on whether those functions occur within the agency or are performed by a consultant and are subject to the scale of the deployment. Some states require the full planning, engineering, and procurement process to be followed with marked milestones separate from Federal requirements (such as the NEPA process, to varying extents, for an ITS device). These requirements can escalate the cost at a single intersection to as much as $50,000.

For an intersection that is not "ready" for RSU deployment, additional costs to make the intersection "ready" could include:

- New cabinet, signal controller, and other features: $20,000 to $25,000
- Non-intrusive detection systems at an intersection (i.e., radar): $20,000 to $40,000

These estimates do not include the cost of backhaul to transfer the data to a server or cloud platform for storage, analysis and sharing. Agencies use fiber optic systems, IP radios, and cell connections to accomplish this backhaul. Some agencies currently have no backhaul systems in place. While it is not essential that data be retrieved from the intersection, connectivity is necessary to provide position correction data for the RTCM message and updated security certificates to the RSU.

In addition to the capital cost for equipping the intersections, there will be on-going costs for maintenance, monitoring, replacement, and compliance testing. Agencies should consider their current costs for maintenance of traffic signal systems or ITS components to estimate the annual cost requirements for V2X systems, keeping in mind that V2X systems will have a higher standard of care than these other systems because vehicles will rely on V2X data for life-safety decisions.

While the initial and annual cost of updated security certificates is small, the agency may incur an annual fee for an agency-wide license or management portal for the security credential system. This fee could range from $10,000 to $100,000 per year for statewide or agency-wide coverage depending on the features desired.

Based on the range of per-intersection capital costs noted above, assuming that some existing signal cabinets will need substantial upgrades, and a many will require minor upgrades, some type of backhaul to the intersection exists, and including only a nominal cost for planning, engineering, and procurement, the initial, estimated cost of the long-term (10-year) national deployment goal described above is **$6.5 billion**. In the context of transportation projects at a national scale, this is a reasonable and attainable cost.

For broad planning purposes, the following examples suggest cost ranges for localized deployments:

- For an agency in a "large community", or a group of cooperating agencies, that plan to equip 1700 intersections the initial, estimated cost of deployment is between $25 and $45 million.
- For a small deployment, consisting of 100 intersections, the initial estimated cost of deployment is between $1.5 and 2.7 million.

Available Infrastructure Funding Options

There are a variety of currently available funding mechanisms for the deployment of V2X systems at signalized intersections.

As a result of the recent Infrastructure Investment and Jobs Act (IIJA) (Public Law 117-58), more funding programs allow V2X deployment at a 100% federal share. Some state DOTs could and have been able to deploy V2X systems within these federal funding programs. If V2X technology is included within the scope of a large capital project, such as a road widening, the incremental cost could be less than one percent of the total project cost. Installing fiber backhaul often adds less than two percent to a significant road reconstruction project.

Federal formula funding (funding that every state receives) that is currently available and used by state and local agencies to deploy V2X includes:

- Congestion Mitigation and Air Quality (CMAQ)
    - Note: some states have already fully committed their CMAQ funds for several years and may run into barriers adding more projects to this list.
- Highway Safety Improvement Program (HSIP)
    - A program focused on achieving significant reductions in traffic fatalities and injuries, with a data-driven strategic approach.
- State Planning & Research (SPR)
    - Can be used to help plan for the deployment of V2X technology.
- National Highway Performance Program (NHPP)
    - Frequently used by operations at state DOTs to deploy ITS.
- National Highway Freight Program (NHFP)
    - Freight focused but deployments can be leveraged to support both cars and freight.
- Carbon Reduction Program (CRP)
    - Funding for projects designed to reduce transportation emissions.

Several other USDOT formula funding programs allow for ITS and V2X deployments, as long as they meet the program funding goals and requirements. This plan encourages state and local agencies to champion V2X within their DOT leadership to allow the use of these funds for V2X.

Within the IIJA, new and revised federal discretionary grants (i.e., states and locals have to compete nationally to receive funds) are available, including SMART, ATTAIN, RAISE, and SS4A that encourage V2X projects. However, it should be noted the USDOT allows V2X deployments for a wide variety of discretionary grants (e.g., MAA and FTA grants) so long as they meet the requirements of that grant; for example, an airport or transit specific safety grant could consider a pedestrian safety message deployment at an intersection where traditional solutions may have considered civil improvements.

Dedicated funding for a nationwide V2X deployment would be an ideal solution, but regulatory limitations on USDOT prohibit the agency from taking such an action. Congressional approval would be required to establish dedicated funding, such as in the next transportation reauthorization bill – something that is at least 4 years away. It is unclear at this time if there is a viable pathway for dedicated funding to accelerate the deployment of V2X. Agencies are encouraged to leverage currently available funding sources.

NATIONAL V2X DEPLOYMENT – PRODUCTION VEHICLES

Expectations for OEM Deployment

Vehicle OEMs fall within three camps relative to V2X deployment:

- The "coalition of the willing" group– a small subset of OEMs most eager to deploy the technology voluntarily;
- The "wait and see" group – OEMs that could be motivated by including V2X systems in safety ratings from the Insurance Institute of Highway Safety (IIHS) or the NHTSA NCAP, or by movement toward a NHTSA "if equipped" standard;
- The "need a mandate" group – OEMs that will not likely deploy V2X equipment without a national mandate, such as the NHTSA FMVSS 150 proposed in 2016.

The key challenge in V2X deployments is the hockey stick value proposition where benefits of deployment materialize late in the cycle after a critical mass of deployed units is achieved. OEM deployments can be accelerated if IOOs and other stakeholders deploy applications with immediate benefits to vehicle manufacturers and drivers. For example, there are significant opportunities to catalyze deployment with V2X applications focused on improving the safety of vulnerable road users (VRU), such as pedestrians and bicyclists. V2X on-board units can be installed on bicycles, for instance, far more rapidly than OEM vehicle development cycles, and can feature both C-V2X (short range) and Uu (cellular long range) technologies to provide a unique opportunity to address VRU safety. The Uu long range connectivity can be used early in the deployment cycle to provide awareness to the driver of the presence of other travelers. This is particularly useful in scenarios with low visibility, non-line of sight conditions where bicycles are most vulnerable. Most if not all vehicles manufactured today have the technical capability to receive messages from such devices. Later, direct, short-range communications will be used as V2X implementation grows in the infrastructure and on vehicles.

There are indications that it is possible to install applicable devices at a price point that bicycle and scooter manufacturers would find acceptable. Given low costs and a strong need for improved VRU safety, one can expect a rapid proliferation of such devices in the market. Since these devices also transmit short-range (C-V2X) direct messages installations of this type would create conditions where vehicle manufactures in the "wait and see" camp would be drawn into installing modems with C-V2X capability. This would enable them to deliver higher fidelity alerts and warnings to the driver, eventually leading to integration with ADAS systems.

Deployment Timelines/Milestones

Vehicle OEM deployments are strongly gated by vehicle development times, usually 2 to 5 years. Some OEMs may have already started such efforts and launched or announced products (primarily due to other leading markets such as China), but many will fall into the longer end of the range. It is important to note that new applications will be added to address unique VRU and vehicle-to-vehicle (V2V) use cases once vehicles are equipped with V2X systems.

Likely OEM deployment timelines and scenarios are as follows:
Within 3 years:

- A "coalition of the willing" deploys, including OEMs initially operating under FCC waivers. Expected applications utilizing C-V2X or Uu, include:
    - V2I/I2V applications;
    - Basic V2V communications;
    - Some VRU focused applications (e.g. road work zone alerts, school bus or school zone alerts, emergency vehicle proximity alerts, and vehicle-to-cyclist alerts);
- Forward-leaning IOOs and their partners will utilize (or expand) V2X aftermarket solutions that will generate value and educate the public through public fleets, including transit buses, school buses, and emergency vehicles.

Within 5 years (anticipated to be 3 years post Second FCC Report & Order on 5.9 GHz spectrum):

- Potential for deployment in more production vehicles that utilize the installed infrastructure base and presence of V2X equipped VRUs;
- Potential for a NHTSA "If-Equipped" standard

Within 5-7 years:

- Acceleration of buy-in started during development of a NHTSA "if-equipped" standard;
    - Could reduce production timeline for OEMs;
- V2X included in NHTSA NCAP providing an incentive for "wait and see" OEMs to deploy.

No earlier than 8-13 years:

- All models are equipped with C-V2X, especially if an FMVSS is mandated.

OEM Deployment Costs and Funding Options

Due to anti-trust and confidential business information considerations, alongside initial volume planning uncertainties, it is difficult to confirm accurate deployment costs for OEMs. Some estimates outside of the automotive industry have been suggested in recent years, but these may be dated. Updating those projections to level-set public-private deployment expectations would be a valuable exercise for the USDOT to consider.

Here are two existing estimates of OBU equipment costs:

2018 P3 North America study on the costs of DSRC and C-V2X OBU Design Alternatives

- Distinct Products: an OBU (DSRC or C-V2X) equipped with a Global Navigation Satellite System (GNSS) is detached from an optional transmission control unit (TCU) equipped with a GNSS and a cellular modem - $129 (Range: $104-$165)
- Highly Integrated System: an OBU (DSRC or C-V2X) is highly integrated with a TCU and a cellular modem and share a GNSS - $61 (Range: $50-$74)
- Fully Integrated System: an OBU (C-V2X only) is integrated with an existing TCU – $160 to $171 per vehicle

2014 NHTSA estimate of costs for V2V aftermarket implementation

- Range from $81 to $291

THE USDOT ROLE IN SUPPORTING V2X DEPLOYMENT

To encourage and support the development of state-level V2X deployment plans and V2X installation in production vehicles, the USDOT should increase their emphasis on V2X technology as a proven technology for safety and mobility improvements. Examples of how this can be accomplished include:

- Giving V2X deployment programs the emphasis and visibility that has been applied to the National Electric Vehicle Infrastructure (NEVI) program (recognizing that NEVI had the benefit of specific Congressional approval) or the ITS4US program, including in statements by USDOT leadership.
- Increasing the importance of V2X deployment as a selection criterion in discretionary grant programs, such as SMART, ATTAIN, and SS4A, to encourage more V2X projects.
- Issue an update to the USDOT National Roadway Safety Strategy that introduces and highlights V2X technology as a key, near-term action to enable safer roads.
- Increasing the visibility and participation of NHTSA in discussions around V2X, including NHTSA efforts to educate, inform and encourage the use of V2X to curtail traffic crashes and fatalities.
- Inclusion of V2X technology in the NHTSA NCAP safety rating program.
- Forward movement of an effort to make V2X a NHTSA “if equipped” standard.
- Require each FHWA discretionary grant, regardless of type, to include a V2X component.
- Incentivize the aftermarket installation of V2X by state and local agencies in transit fleets, school buses, emergency vehicles and other government-owned fleets.
- Require that state DOTs update their ITS architectures to include V2X solutions. Until a state DOT funds their update, the State DOT would be required to justify each ITS deployment that is not a V2X technology.

- Implement V2X within the Every Day Counts program as an eligible safety and mobility solution.
- Implement V2X as a Technology Readiness Level 7 or higher (to open more funding opportunities).

FUTURE ACTIONS

The primary, undivided focus of all stakeholders should be to deploy C-V2X systems in the 5.9GHz spectrum at signalized intersection to make beneficial use of the spectrum and bring about immediate safety benefits. If the deployment goals outlined in this plan are diluted with more technologies and more locations, a unified, interoperable system will not be realized. However, there are many other viable and useful approaches and applications that should be implemented in the long term to bring about a larger connected vehicle ecosystem. Once IOOs and OEMs establish deployments that fully utilize the 5.9 GHz spectrum, all stakeholders in the public and private sectors need to collaborate to develop additional, sequential, deployment plans, in the following focus areas:

- Expand deployment of C-V2X RSUs to locations other than signalized intersections and implement low-latency use cases that support safety and mobility in these other locations
- Expand beyond the 5.9GHz spectrum to make beneficial use of cellular, wifi, and other technologies to produce a wide variety of public benefits
- Work with the USDOT, the National Telecommunications and Information Administration (NTIA) and FCC to identify at least 40 MHz of additional spectrum that could accommodate deployments of 5G NR-V2X technology and automated vehicle applications, including cooperative perception, that will provide self-driving vehicles greater awareness of surrounding traffic considerations.

CONCLUSION

Now is the time for government and industry to come together in an unprecedented way and implement V2X technology to curtail the national emergency of increasing highway deaths. This technology provides a unique low-latency capability that cannot be achieved with other technologies and is ready for implantation now. Since the 5.9GHz 'safety spectrum' has recently been reduced due to perceived lack of use, it is imperative that this spectrum be used immediately for the public benefit – for safety and mobility. Factors which have caused many stakeholders to pause their V2X efforts are being overtaken by improved regulatory certainty and technological maturity.

This proposed National V2X Deployment Plan is a call to action for state and local transportation agencies, automotive OEMs, the federal government, and other stakeholders to move beyond years of inaction and install V2X systems for public safety – beginning with signalized intersections, other road users, and selected production vehicles. This Plan outlines strategies and actions that can accomplish this goal. Stakeholders should focus intently on the objectives of this plan before broadening to other initiatives. **Time is of the essence.**

About ITS America

The Intelligent Transportation Society of America advances the research and deployment of intelligent transportation technologies to save lives, improve mobility, promote sustainability, and increase efficiency and productivity. Our vision is a better future transformed by transportation technology and innovation: Safer, Greener, Smarter. For All.
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