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Vehicle-to-Vehicle Safety Application Research Plan

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16. Abstract

The connected-vehicle research program is a major initiative under USDOT's Connect Vehicle Research Program and includes both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure research activities. The goal of the Vehicle-to-Vehicle Safety Application Research Plan is to describe the research needed to support this decision. The objectives of the research plan are to determine if vehicle-to-vehicle communication safety applications meet a safety need, are practicable technologically and economically, have objectively measurable compliance, have driver acceptance, and are effective. This research plan only reflects the V2V communication research portion of the connected-vehicles program. The research plan provides background, vision, goals and objects, and an overview, as well as a detailed roadmap and summary descriptions of the major research tracks that make up the V2V safety application research activities.

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Vehicle-to-Vehicle Safety Application Research Plan

1. BACKGROUND

A new generation of technologies has emerged that have demonstrated the ability to help drivers avoid crashes. These systems use onboard sensors such as radar to identify crash threats and then warn drivers or take corrective action. These vehicle-based safety systems will play a critical role helping to improve motor vehicle safety. However, the opportunity exists to improve the performance of these systems and to accelerate their widespread deployment by shifting the sensing capability from onboard sensors to inter-vehicle communications. The U.S. Department of Transportation has conducted research with the automotive industry that demonstrated that inter-vehicle communications will improve the overall effectiveness of these systems and that the cost to consumers can be reduced. In addition, an analysis of communication alternatives has shown that Dedicated Short Range Communications (DSRC) at 5.9 GHz is the only communication option at this time capable of effectively and reliably providing this safety-of-life capability. Vehicle-to-vehicle (V2V) communication for safety is a major component of the USDOT connected vehicle research program,[1] which also sponsors research and other activities to support future vehicle-to-infrastructure (V2I) connectivity and vehicles-to-consumer devices (V2D) to deliver safety and mobility benefits. There are several issues that cut across the entire connected vehicle program, such as outreach and international coordination. These issues are not included in the V2V Safety Application Research Plan but are addressed elsewhere in the connected vehicle program.

2. CONCEPT

V2V communication for safety refers to the exchange of data over a wireless network that provides critical information that allows each vehicle to perform calculations and issue driver advisories, driver warnings, or take pre-emptive actions to avoid and mitigate crashes. Data that may be exchanged includes each vehicle's latitude, longitude, time, heading angle, speed, lateral acceleration, longitudinal acceleration, yaw rate, throttle position, brake status, steering angle, headlight status, turn signal status, vehicle length, vehicle width, vehicle mass, bumper height, and the number of occupants in the vehicle. The data listed in the previous sentence may be impractical to measure from infrastructure locations using sensors such as radars, lidars, or cameras, but the data resides within each vehicle, and sharing that data with other vehicles in the vicinity offers the possibility to significantly improve crash avoidance and crash mitigation systems.

3. RESEARCH PLAN VISION

The vision for V2V is that all vehicles will be able to communicate with each other to support a new generation of effective safety systems for motor vehicles. Active safety systems enabled by V2V technology will foster development of a wider array of countermeasures and enhance the operation of current countermeasures that will potentially result in more lives saved and reduction in injuries.

4. RESEARCH PLAN GOAL AND OBJECTIVES

In November 2009, NHTSA published the *Final Vehicle Safety Rulemaking and Research Priority Plan 2009–2011*. In this document, NHTSA announced its intention to make an agency decision for vehicle communication safety systems by 2013. The goal of the Vehicle-to-Vehicle Safety Research Plan is to describe the research needed to support this decision. The objectives of the research plan are to determine if V2V communications safety applications meet the following criteria:

[1] www.its.dot.gov/connected_vehicle/connected_vehicle.htm

- Meet a safety need;
- Are practicable (technologically and economically);
- Have objectively measurable compliance;
- Meet driver acceptance standards; and
- Are effective.

5. RESEARCH PLAN PARTICIPANTS

Connected-vehicle research is a major program under the Department's Intelligent Transportations Systems (ITS) Program. In addition, the cooperative nature of the connected-vehicles paradigm will bring together infrastructure as well as vehicles of all types. The program includes both V2V and V2I research activities. Although this plan only reflects the V2V portion of the research that is being led by NHTSA, the widespread cooperative nature of this effort will necessitate the involvement of a variety of stakeholders. Within USDOT, NHTSA will collaborate with the following modal administrations on this program: the Federal Highway Administration (FHWA), the Federal Motor Carrier Safety Administration (FMCSA), the Research and Innovative Technology Administration (RITA), and the Federal Transit Administration (FTA).[2] External stakeholders are expected to include vehicle manufacturers, suppliers, and fleet operators. An extensive coordination and outreach effort will be conducted by the ITS Joint Program Office to facilitate participation.

6. RESEARCH PLAN ASSUMPTIONS

Given current aspects of vehicle communications (DSRC and other spectra), safety systems (crash avoidance latency needs), and other research activities (mobility and environment), the following assumptions were made to establish a basis from which to start identifying V2V-based safety application research needs and issues, and structure research activities:

1. The primary application of V2V is to enable safety applications. As a primary countermeasure, V2V applications can potentially address approximately 75 percent of all crashes involving all vehicle types.
2. The need for publicly provided infrastructure to support security requirements of V2V cannot be determined until several technical and policy issues, such as privacy requirements, are evaluated. The benefits derived from infrastructure-based communications that are used to support vehicle-to-infrastructure applications will be evaluated in other parts of the connected-vehicles program.
3. The connected-vehicles system architecture[3] will be compatible with the evolution in infrastructure technology and deployment. This will allow for future upgrades that could provide additional safety benefits such as from cooperative intersection collision avoidance systems.
4. DSRC at 5.9 GHz is the only communication option at this time capable of effectively and reliability supporting active safety applications. Any future communication technologies will have to be backward-compatible with DSRC in order to support the vehicles already deployed with this technology.

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[2] The FTA is currently developing the transit portion of the V2V research plan that will be incorporated after the research needs are identified and vetted with stakeholders.

[3] The connected-vehicles program system architecture is being updated as one of the activities of the overall connected-vehicles program and will establish a system basis by which to coordinate the development of the various elements, e.g. V2V, V2I of the connected-vehicles system.

7. RESEARCH PLAN

This section provides an overview as well as a detailed roadmap and summary descriptions of the major research tracks that make up the V2V program.

7.1 Overview

Since 2002, the USDOT has been conducting research with automotive manufacturers in order to assess the feasibility of developing effective crash avoidance systems that use V2V communications. Engineering prototypes have been developed at a level to support research development and evaluation and demonstrated with applications that address the most critical crash scenarios identified at the time of the research. These are:

- Emergency Stop Lamp Warning – This application enables a vehicle to broadcast an emergency braking event to surrounding vehicles so the host vehicle can warn other drivers/vehicles of a possible hazard.
- Forward Collision Warning - This application warns the host vehicle driver of an impending rear-end collision with a vehicle ahead in traffic, in the same lane, and traveling in the same direction.
- Intersection Movement Assist - This application warns the host-vehicle driver when—due to the likelihood of colliding with a remote vehicle coming from the side— it is not safe to enter an intersection.
- Blind Spot and Lane Change Warning – This application informs the driver when a vehicle is in a blind sport or if the driver activates the turn signal and the corresponding blind spot has a vehicle present, the application warns the driver not to change lanes.
- Do Not Pass Warning – This application warns the driver that a slower vehicle cannot be passed safely when a vehicle coming from the opposite direction occupies the passing zone.
- Control Loss Warning – This application enables a DSRC-equipped vehicle to broadcast a control loss event to surrounding vehicles. Upon receiving the information, each surrounding vehicle determines the relevance of the event and, if appropriate, warns the driver.

The development of these applications was critical to understanding the functional and performance requirements for the underlying technologies such as positioning and communications. However, additional work needs to be done to identify current priorities, advance the engineering prototypes, and address more complex crash scenarios for head-on collision avoidance, intersection collision avoidance, pedestrian crash warning and extending the capabilities to prevent motorcycle crashes. It is important to note that these capabilities could be achieved by providing V2V communication capabilities that complement other vehicle-based safety technologies.

This research plan consists of seven tracks that have been identified to represent the major activities that are required to attain accelerated deployment of V2V-based safety systems. Table 1 depicts the seven tracks of this plan, their outcomes, their links to one another, and the organizations responsible.

Table 1. Vehicle-to-Vehicle Safety Application Research Plan – Major Tracks

Track	Outcome	Workflow	Organizations
Track 1 – Crash Scenario Framework	Update 37 precrash scenarios and develop specific detailed pre-crash scenario descriptions to facilitate application developments	Support identification of applications for development and testing	**NHTSA**, RITA, FMCSA
Track 2 - Interoperability	Ensure safety applications work across all makes and models	Provide standards, protocols and security framework for testing and policy decisions	**NHTSA**, RITA, FHWA, FMCSA
Track 3 – Benefits Assessment	Estimate safety benefits and develop objective test procedures	Support agency decision with benefit estimates and practicability data	**NHTSA**, RITA
Track 4 – Application Development	Develop applications that meet requirements identified in Track 1	Provide applications for benefits assessment	**NHTSA**, RITA
Track 5 – Driver Issues	Measure driver performance and acceptance	Support benefits assessment with data on driver acceptance and behavior	**NHTSA**, RITA, FHWA
Track 6 – Policy Issues	Develop technical recommendation for aftermarket, governance, enforcement, and privacy policies; and coordinate with policy options	Support development of V2V and overall connected-vehicles deployment scenario	**NHTSA**, RITA, FHWA, FMCSA
Track 7 – Commercial Vehicles (CV)	Develop and test CV-specific safety applications	Address CV-specific issues	**NHTSA**, FMCSA, RITA

7.2 Roadmap

Figure 2 below shows the projected roadmap for the V2V research plan with key activities identified.

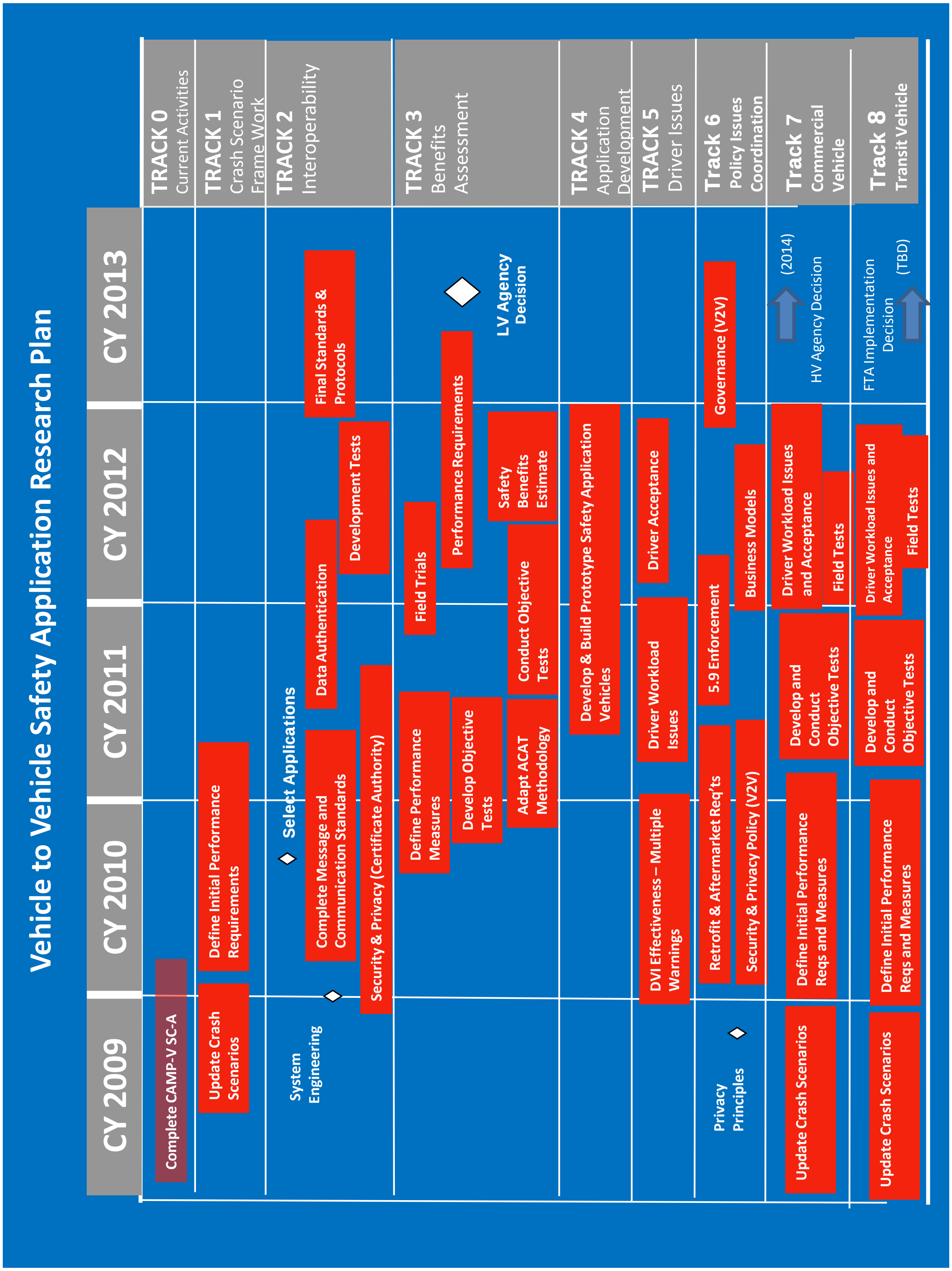

Figure 2. Safety Application Research Plan Roadmap

7.3 Track 1 – Crash Scenario Framework

The key objective of this track is to establish a framework by which the crash problem can be further defined and new crash avoidance capabilities identified and described. In 2007, the "Pre-Crash Scenario Typology for Crash Avoidance Research" (Najm, Smith, & Yanagisawa, DOT HS 810 767) was published by NHTSA. This track develops a framework that is based on the 37 pre-crash scenarios defined in that document.

The framework's function is to connect pre-crash scenarios to crash avoidance safety applications and provide information that will enable the identification of safety application function, performance, and initial effectiveness benchmarks. This framework will feed the research and development of new crash avoidance technology and applications that will address the most pressing aspects of the crash problem. The framework will also contribute to classifying and grouping crash avoidance technology so deployed crash avoidance systems can be ranked for their ability to reduce the likelihood and severity of crashes. This framework will be used to determine requirements for safety applications and set priorities for investment.

The following key tasks will be performed within this track:

- Update pre-crash scenario statistics;
- Develop pre-crash scenario depictions and rankings by frequency and severity;
- Determine performance requirements and specifications (including fail-safes) for priority scenario safety applications; and
- Select priority safety applications for development (Track 4).

7.4 Track 2 – Interoperability

The interoperability track's objective is to ensure that safety applications work across all equipped vehicles, regardless of make or model and original equipment or retrofit. Interoperability is critical to the effectiveness of V2V safety systems. V2V safety applications will need to meet certain specific requirements for a number of interoperability issues. This will require research for essential building block technologies and ensure common definition for critical standards and protocols for proper functioning of V2V systems.

The following key tasks will be performed within this track:

- Develop and test relevant communication standards and protocols (SAE J2735 message set, IEEE1609);
- Develop and test security protocols that are practical, scalable, and deployable. This must include definition of a certificate authority implementation that does not rely on the widespread deployment of public infrastructure;
- Develop procedures and test for ensuring message integrity and prevent misuse of communication capability. This will allow the host vehicle to determine the data received from another vehicle is valid and accurate.
- Establish data rights and other policies needed to define driver's privacy rights; and
- Test scalability of communications and use tests to establish tools to simulate real-world implementation scenarios.

7.5 Track 3 – Benefits Assessment

The widespread deployment of V2V safety applications depends on understanding the effectiveness of safety applications. This track's objective is to estimate the safety benefits that may be realized by deployment of various V2V safety applications. To provide these estimates of safety benefits, a methodology for estimating safety benefits for these and future safety applications will be implemented. Performance measures, objective test procedures, and an adapted version of the Advanced Crash Avoidance Technologies (ACAT) Safety Impact Methodology will be used to determine the safety benefits.

The following key tasks will be performed within this track:

- Develop safety application measures of performance;
- Develop safety application objective test procedures;
- Modify ACAT Safety Impact Methodology to support V2V safety applications evaluations;
- Evaluate market penetration levels needed to achieve safety benefits for individual and grouped applications. (This will include assessing the role of aftermarket and retrofit devices.);
- Identify aftermarket performance specifications and interface requirements;
- Conduct safety application system prototype objective tests;
- Estimate safety application benefits;
- Review and verify estimated safety benefits; and
- Make Agency decision.

7.6 Track 4 – Application Development

The objective of Track 4 is to develop the selected safety applications identified as the result of track 1 efforts into safety application prototypes. The development of the prototype will be facilitated by the requirements and specifications from Track 1; information about security, and communications from Track 2; and performance measures, and objective tests from Track 3. This information from the various tracks will provide an initial basis for the design and development of the selected safety application prototypes. Once the prototypes are developed, the prototypes will be transferred to Track 3 for testing and safety benefit estimation.

The following key tasks will be performed within this track:

- Transfer safety application prototype development information (Track 1);
- Design and develop fully functioning vehicle integrated safety application prototypes (includes positioning); and
- Transfer prototype to Track 3 for evaluation.

7.7 Track 5 – Driver Issues

The deployment of V2V communications will enable numerous safety applications that may compete for the driver's attention. It will be necessary to develop a framework for implementing driver-vehicle interfaces (DVIs) in an environment where applications may be periodically updated. This framework must take into account warning priorities, driver workload, and other related driver behavior issues. The objective of this track is to develop a framework that can assess the impact of driver issues on the effectiveness of DVIs used in conjunction with V2V-based safety applications.

The proliferation of collision warning systems, whether vehicle-based like V2V or cooperative such as V2I, is expected to produce significant safety improvements. However, care must be taken not to introduce unforeseen problems, particularly if drivers are unfamiliar with warnings from these technologies. A consideration to collision warning system effectiveness is the quality of its interface, which can affect the driver's performance as well as acceptance of the technology. Given the driver-centered design of these systems, it is necessary to assess if:

- Drivers understand these systems,
- The systems lead to appropriate driver reaction, and
- Drivers accept the system.

Unintended consequences of these systems may affect safety. Therefore, understanding if drivers have accurate mental models is essential to achieving the desired safety impact.

The following key tasks will be performed within this track:

- Develop a DVI guidance document to ensure proper integration of interfaces when several warning systems are installed;
- Develop test procedures to determine the effectiveness of various DVIs to obtain the desired driver response;
- Determine if drivers accept various DVI treatments; and
- Determine if the lack of standardization of the DVI among different vehicle makes and models may increase the likelihood of driver confusion in responding to the warning information intended to assist the driver.

This track compliments the work that will be conducted in relation to the human factors for connected-vehicles research area that will investigate and assess how to deal with the distractions to drivers in the connected-vehicles environment. The human factors for connected-vehicles research goal is to eliminate distraction related to connected-vehicles devices as a contributing factor to crashes.

7.8 Track 6 – Connected-Vehicles Policy Issues

Numerous policy issues must be resolved in order to enable the successful deployment of V2V safety applications. Many of these issues must be considered within the broader context of the connected-vehicles program that also encompasses V2I and V2D capabilities. For this reason, the V2V program plan identifies the policy issues that are critical but not always unique to V2V systems. The activities described here will be addressed from a technical perspective and coordinated with all the other research activities, e.g., V2I within the connected-vehicles research program. The same issues will also be present in the connected-vehicles Policy Program Plan so each is also addressed from a policy perspective and may be implemented in other parts of the connected-vehicles program. The main purpose of presenting them in this document is to ensure that all issues critical to the deployment of V2V are addressed. These are:

- How do we provide value to early adopters?
- What initial market penetration is needed to generate a significant level of safety benefits and what is the role of aftermarket and retrofit devices?
- What is an effective structure for governance of the system to ensure successful operations and security after deployment?
- What provisions are needed to enforce safe and appropriate use of the system?
- What are the policy issues such as privacy that will drive the technical design of the system?
- What is an effective investment model that will ensure the successful deployment of the V2V elements of connected vehicles?
- Is there a role for non-safety stakeholders such as toll operators?

7.9 Track 7 – Commercial Vehicles

The objective of this track is to identify and coordinate the commercial vehicle (includes vehicles such as tractor-trailers, single-unit trucks, and buses) component of V2V safety applications among the other research tracks. Heavy trucks and buses have different characteristics and needs in relation to the development of V2V-based safety applications. The research outline through the tracks identified will also be carried out to account for the different needs and aspects of heavy vehicles. Complementary research that corresponds to the research being conducted for light vehicles will be conducted to identify the priority crashes that involve trucks and buses; the heavy-truck interoperability issues; the development of heavy-vehicle-based V2V safety applications, and the assessment of these applications to assist heavy vehicles avoid crashes. This research will be coordinated with the light-vehicle research to facilitate compatible V2V safety applications for all vehicles. The following key tasks will be performed within this track:

- Update pre-crash scenarios to include heavy vehicles;
- Select of priority safety applications for development (Track 4);
- Determine interoperability needs that are specific to commercial vehicles;
- Develop capabilities to assess heavy vehicle safety application benefits;
- Identify and coordinate commercial vehicle policy issues; and
- Make Agency decision.

With respect to commercial vehicle connected-vehicle technology, an agency decision on how to proceed will be made toward the end of 2014.

8. Interdependencies

Given that the V2V research plan is a component of the overall connected-vehicles program, there are activities and areas that need to be coordinated and information exchanged. In relation to the V2V research plan there needs to be close coordination in relation to the connected-vehicles policy issues; however, the V2V activities related to policy issues will identify and document the issues from a V2V perspective. This V2V perspective will be intermingled at the connected-vehicles program level with other program components to develop comprehensive connected-vehicles policies that will support comprehensive deployment.

In relation to the research activities, the V2V tracks will need to be aware of and incorporate the program's system engineering developments, especially the concept of operations. In addition, at a higher level the V2V research will also account for the connected-vehicles principles.

On a complementary level, the research undertaken in relation to designing and implementing effective DVIs needs to be coordinated with the Human Factors for connected-vehicles research that will address driver distraction. These two efforts will cover the interface and environment issues needed to effectively and efficiently communicate with the driver such that the driver's attention and awareness can be raised to the level needed to operate safely and reduce the number of crashes in the connected-vehicles environment.

Other activities that include outreach, education, and international coordination will be directed at the connected-vehicles program level; however, each connected-vehicles program component will be integrated into these activities.

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