

I262 Vehicle-to-Vehicle ITS Standards for Project Managers

Ken Leonard: ITS standards can make your life easier. Your procurements will go more smoothly and you'll encourage competition, but only if you know how to write them into your specifications and test them. This module is one in a series that covers practical applications for acquiring and testing standards-based ITS systems. I am Ken Leonard, the Director of the U.S. Department of Transportation's Intelligent Transportation Systems Joint Program Office. Welcome to our ITS Standards Training Program. We're pleased to be working with our partner, the Institute of Transportation Engineers, to deliver this approach to training that combines web-based modules with instructor interaction to bring the latest in ITS learning to busy professionals like yourself. This combined approach allows interested professionals to schedule training at your convenience without the need to travel. After you complete this training, we hope you'll tell your colleagues and customers about the latest ITS standards and encourage them to take advantage of these training modules as well as archived webinars. ITS standards training is one of the first offerings of our updated Professional Capacity Training Program. Through the PCB program, we prepare professionals to adopt proven and emerging ITS technologies that will make surface transportation safer, smarter, and greener. You can find information on additional modules and training programs on our website at www.pcb.its.dot.gov. Please help us make even more improvements to our training modules through the evaluation process. We look forward to hearing your comments, and thank you again for participating, and we hope you find this module helpful.

Narrator: Throughout the presentation, this activity slide will appear, indicating there is a multiple choice pop quiz following this slide. You will receive a pop-up message, and you can select your answer by selecting the Submit button. There is only one correct answer. You can select the Clear button to remove your answer if you wish to select another answer. You will receive instant feedback on your answer choice. This module is I262, Vehicle-to-Vehicle ITS Standards for Project Managers. Patrick Chan has 23 years of ITS experience, including four years as an ITS project manager with a public agency. Specifically, he has applied the systems engineering process to numerous NTCIP data dictionary standards, the ITE AASHTO Traffic Management Data Dictionary, a center-to-center standard; and to SAE J3067, which is a comment to SAE J2735, dedicated short-range communications message set dictionary, the data dictionary for connected vehicles with system engineering content.

Patrick Chan: Thank you everyone for joining me today. I would like to begin by acknowledging the contributions of Jim Misener, who is the current chair of the SAE DSRC technical committee, and Tom Kurihara, who is the chair of the IEEE 1609 working group. Although I'm presenting this module, both Jim and Tom helped develop and are coauthors of this module. Although the course is available to all stakeholders and interested parties, the materials in this module appeal to public sector managers of

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service transportation systems and agencies, procurement officials, decision makers, and private and public sector users, including the automobile industry. In summary, this module will help the target audience help to understand how a vehicle-to-vehicle environment might address some of the transportation problems they are facing, how it may impact the transportation system and how they do business, and help them understand the standards can help design an implementation that will address those transportation problems. It is highly recommended that participants who are not familiar with the ITS standards take Module I-101 before this module. Module I-101 is an introductory module that provides an overview of ITS standards, and this course builds on the concepts that were taught in Module I-101. I'd also like to note that this module being presented today is not intended to be an introduction to connected vehicles, although a brief overview is provided. USDOT has a CV-101 module, which can be found on the Professional Capacity Building website that provides a more complete introduction to connected vehicles. The focus of this module is on standards that support the connected vehicle environment, specifically the vehicle-to-vehicle environment. However, at the end of this module and the student supplement we provide a list of some resources if the participant is interested in a more thorough introduction to connected vehicles. This slide is just a graphical representation and it is suggested that the participant view Module I-101 on ITS standards before completing this course.

Now, let's review the learning objectives for this module. Upon completing this course, participants should be able to, one, describe the connected vehicle environment; two, discuss the vehicle-to-vehicle environment; three, describe the roles of standards in a connected vehicle environment; four, identify and address high-level technical or institutional challenges to deploying a vehicle-to-vehicle environment; and five, describe the current status of the connected vehicle environment. It is important to note that the materials in this module, such as the technical content and the current status, are as of March 2015. As we will see, the development of standards for the connected vehicle environment is still progressing and the status of the connected vehicle environment may be different in a few months. However, this module will provide transportation managers and implementers with a foundation of understanding the role of standards in the vehicle-to-vehicle environment.

Learning objective number 1 is to provide a quick overview of what a connected vehicle environment is. Over the next several slides, we'll review the definition of DSRC and review some of the benefits of a vehicle-to-vehicle environment. USDOT has identified three major transportation challenges that service transportation agencies face today. They are safety-there were over 33 thousand deaths and 5.5 million crashes in 2012; mobility-USDOT estimates travelers experience over 5.5 billion hours of travel delay at economic cost of 121 billion dollars due to urban congestion alone; and environment-with

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over 2.9 billion dollars of wasted fuel and 56 billion pounds of carbon dioxide due to delay in one year.

But looking at an individual vehicle, a vehicle today is more than just a vehicle. It is a complex network with many sensors and processors. These sensors can help your vehicle adapt to the environment for a more safe and comfortable, stress-free ride. For example, rain sensors to automatically change the rate your wiper swipes, slipper sensors for traction control, main departure warnings, et cetera. The vehicle also can be a navigation device, providing directions to your destination based on your current location. The vehicle is also a multimedia center, providing driver assistance and location services, media such as radio entertainment, and connections for your smartphone. In addition, millions of people around the world carry smartphones today that know where you are and can be used to access data, including travel information. With these capabilities today, let's imagine a world where vehicles can share their sensor data with other vehicles on the roadway; vehicles can share their current position with other vehicles on the roadway; vehicles themselves can receive data from the roadway that can reduce the likelihood of incidents, and also can receive data from the roadway to improve mobility, that is, for example, reduce delays.

What would such a scenario look like, where this data is shared through some type of wireless communications? Such a scenario could improve roadway safety as vehicles are aware of each other's position and where they are going, such that a connected vehicle can provide warnings so that incidents can be avoided. This scenario can improve mobility if there are less collisions, resulting in less blocked roadways and less delays. This scenario can also improve the environment, as delays and congestion are reduced, and thus reducing emissions and improving fuel efficiency. In such a scenario, infrastructure might also wirelessly send messages to vehicles about the signal timing at traffic signals, broadcast driver advisory information, and broadcast travel information. This also leads to improved safety and mobility and an improved environment. This scenario is what USDOT has terms the Connected Vehicle Environment. The Connected Vehicle Environment is a research program led by USDOT to investigate how transportation connectivity—the wireless exchange of information—can potentially enable applications to improve the U.S.'s transportation in the areas of safety, mobility, and the environment. Transportation connectivity can take place between vehicles to enable crash prevention, between vehicles and infrastructure to enable additional safety and mobility and environmental benefits, and among vehicles, infrastructure, and wireless devices, such as a smartphone, to provide continuous real-time connectivity, although we are not very far along with the mobile phone implementation, but it is being explored. A visualization of all the components—centers, devices and flows for the vehicle-to-vehicle environment—have been identified by USDOT and can be found in the Connected

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Vehicle Reference Implementation Architecture, which we will discuss more in detail towards the end of this module.

Pushing the Connected Vehicle Environment in August 2014, the National Highway Traffic Safety Administration, NHTSA, released an Advanced Notice of Proposed Rulemaking and a supporting research report indicating their intent to create a new federal motor vehicle standard to require vehicle-to-vehicle communications capability for light vehicles, passenger cars. The proposed rulemaking included the research report that concluded a fully mature vehicle-to-vehicle safety system alone can potentially address 79 percent of all vehicle crashes, and a vehicle-to-vehicle and a vehicle-to-infrastructure together can potentially address 81 percent of all crash types. The rulemaking on if vehicle-to-vehicle capability is to be required on light vehicles is expected to be released in 2016.

In addition to the safety challenges, the Connected Vehicle Environment has the potential to address mobility challenges, such as addressing nonrecurring vehicle congestion through V2V and V2I communications, and environmental challenges by increasing fuel efficiency and reducing recurrent congestion. So why is it that managers need to learn more about the Connected Vehicle Environment? The Connected Vehicle Environment will be part of our transportation system, which all the managers will have to face and understand. With transportation connectivity, a new class of vehicles will arrive on the highways and streets that the transportation managers own, faster-moving and possibly autonomous. Transportation managers will need to adapt to changes that may result because of the vehicle technology and transportation connectivity. This may impact our engineering analysis on roadway geometry and how we manage traffic. If the vehicle-to-vehicle connectivity is mandated, infrastructure owner-operators realize that this environment will open the gates for other V2X, such as vehicle-to-infrastructure or vehicle-to-pedestrian via smart devices. Thus vehicle-to-vehicle may be only the first, but a very important first step.

So this module focuses on the standards that will support and enable the vehicle-to-vehicle communications capability. There's a system module, I-261, that focuses on the vehicle-to-infrastructure aspects of the Connected Vehicle Environment. By knowing what standards exist and/or are being developed, project managers can begin deploying projects that will support and take advantage of the vehicle-to-vehicle environment to realize its full benefits. Just to reemphasize, the Connected Vehicle Environment is an ongoing research program. The materials, future dates, and activities are as of March 2015.

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But first we'll go on to define what DSRC, or dedicated short-range communications, is. Connected vehicles is incorrectly synonymous with DSRC. DSRC is a communications technology, and just one communications technology that may be used in the Connected Vehicle Environment. There are different technical definitions of DSRC. This slide shows the definition of DSRC is defined by the FCC, the Federal Communications Commission. The full reference to the FCC report and order can be found in the Student Supplement. Note that this definition is applicable only in North America. In Europe, for example, they have their own technical definition of DSRC, but they are similar in that they have frequencies that are used solely for ITS applications only. Note that the term DSRC originally came from the American Society of Testing Materials Standard, ASTM, which we'll discuss later. But in general, DSRCs have broadcast short- to medium-range wireless communication capability that permits very high data transmission, which is critical for V2V safety applications. The term is used to describe the radio system and it is used for traffic services at specific frequencies. It was originally defined in Europe for use with tolling applications. The actual frequencies allocated for ITS vary in the U.S., Japan, and in Europe. In the U.S., the FCC allocated 75 megahertz, a spectrum in the 5.9 gigahertz span, for use for ITS vehicle safety and mobility applications. Only the DSRC communications technology is being considered for vehicle-to-vehicle safety applications at this time because, as we'll see in the next slide, it is the only communications technology that has the needed bandwidth and the low latency, which are critical for safety. FCC originally allocated the spectrum for DSRC in 1999 and has revised and clarified those rules in 2004 and 2006. Currently the 75 megahertz spectrum range for DSRC is divided into seven 10 megahertz channels, with one channel to be used for control, and one channel allocated for safety data, and one higher-powered channel for public safety.

This slide identifies some of the advantages of using DSRC radios for connected vehicles. As we mentioned, the first is low latency. Low latency allows a high rate of transmission. A high rate of transmission of short messages is critical for the vehicle-to-vehicle safety applications. Based on safety policy, it was determined that the transmission of short messages from equipped vehicles are needed at ten times per second for the safety applications to operate effectively. Another advantage is the effective range. DSRC radios have 300 meters of range on a consistent basis, although it has to be measured up to one kilometer. The advantage is that DSRC radios will hear only those messages that are nearby. For example, it will hear only messages from vehicles around it that may immediately impact the safety of its occupants. It will not hear messages from vehicles that have no immediate impact, let's say a kilometer away. However, it could also be a disadvantage for some other messages—a message indicating that the vehicle is disabled, for example. So if it's disabled and it's more than 300 meters away from a roadway, it may not hear that message that it is disabled and needs help. Note that emergency response vehicles are permitted to broadcast at a higher power, increasing its range.

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A third advantage is that DSRC is free for the public good. No ODS subscription is needed, unlike cellular telephone service. This makes it much more easier for the general public to receive the safety benefits. Other advantages are that the DSRC has proven to be reliable with few false alarms.

Now, hopefully we clearly defined what DSRC is. It's only one communications technology, but the technology will be used for the V2V safety environment in the near future. Let's review the potential benefits of the vehicle-to-vehicle environment. The primary benefit of vehicle-to-vehicle is in the area of safety. Connected vehicles have the potential to increase the awareness of situations that may not be readily visible to the driver, such as upcoming roadway hazards, vehicle movements occurring from behind another vehicle, a vehicle moving around a blind spot, such as around the corner. In a vehicle-to-vehicle environment, I can receive information from any vehicles anywhere around me, providing 360-degree visibility around the vehicle I'm driving, not just what I can see in front of me. With the increased situational awareness, software systems in the vehicle has the potential to reduce the severity of crashes or incident, or possibly eliminate crashes but enabling vehicles to inform drivers of potentially hazardous conditions through driver advisories, driver warnings, or vehicle control, such as Vehicle Operator Assist and Deterrence. It is not limited to crashes either. It can also reduce other incidents such as events that may take the vehicle off the road, or rollovers.

The vehicle-to-vehicle environment can also yield mobility and environmental benefits. Mobility benefits can be in the form of reduced collisions or incidents, which should lead to less non-recurring congestion. Another potential mobility benefit is optimized travel speeds as vehicles broadcast their current locations and speeds, so vehicles traveling in the same direction may form platoons and move at the same suggested speed, optimized for some benefit. For environmental benefits, tailpipe emissions from vehicles are the single largest human-made source of carbon dioxide, nitrogen oxides, and methane. Vehicles that are stationary, idling, or traveling in a stop-and-go pattern due to congestion emit more greenhouse gases than those traveling in free-flow conditions. In a vehicle-to-vehicle environment, vehicle software systems can generate and capture environmentally relevant real-time transportation data and use this data to create actionable information to support and facilitate green transportation choices.

So we've reached our first activity. It's a poll question. Which of the following is not a primary benefit in the Connected Vehicle Environment according to USDOT? Your choices are a) safety; b) mobility; c) environment; and d) entertainment experience. Again, which of the following is not a primary benefit in the Connected Vehicle Environment according to USDOT? So the correct answer is D, entertainment experience. The entertainment experience is not a primary benefit according to USDOT. While the Connected Vehicle Environment may result in benefits in numerous different

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areas, including the safety, mobility, and environment, it might provide benefits in entertainment experience, but it is not the primary benefit that's driving the research program. So in summary, the Connected Vehicle Environment is the use of wireless communications to broadcast information among transportation devices, whether it's a vehicle, road infrastructure, or a mobile device. The vehicle-to-vehicle environment specifically involves vehicle broadcasting information to other vehicles. DSRC describes the short- to medium-range wireless radio system that permits very high data transmissions dedicated to vehicle safety and mobility, and the vehicle-to-vehicle environment can result in safety, mobility, environmental benefits. The benefit with the most potential in the vehicle-to-vehicle environment is safety, such as crash prevention.

Learning objective number 2 describes the vehicle-to-vehicle environment in more detail by first introducing the components that make up the vehicle-to-vehicle environment, and then introducing the vehicle-to-vehicle applications that are currently being considered and tested. This section will end by reviewing what type of information may need to be exchanged between vehicles to support these applications. We'll start off by first reviewing the components that make up the vehicle-to-vehicle environment. The primary component is the onboard equipment, or OBE. The OBEs on the vehicle can broadcast and/or receive a set of data, such as vehicle location, speed, and direction of travel. The picture is a visualization of how a vehicle-to-vehicle environment might work. It consists of equipped or connected vehicles on the roadway broadcasting and receiving this data. The OBE itself consists of four components, which can be seen within the teal box. These components are the DSRC radio, a device for communicating with other DSRC-equipped devices; the GPS receiver, which receives location data from the GNSS, Global Navigation Satellite System; safety application electronic control unit, a processing unit that runs the software applications on the vehicle; and memory, which stores security certificates and application data. In addition, the vehicle needs to contain a driver-to-vehicle interface, which displays information to the driver, and the vehicle's internal communications network, sometimes called a CAN bus, which collects data from the vehicle's sensors.

First, a clarification. The words OBU and OBE have been used interchangeably. According to USDOT, the OBU is the DSRC radio on a vehicle, while the OBE includes the DSRC radio and other components that we have just listed.

Moving on, there may be different types of OBEs, each containing a DSRC radio, but each having different capabilities and performing different functions. This slide identifies different types of OBEs that might be encountered. Note that what's identified on this slide are the research project names. Each of these devices are standard-spaced devices that can perform a number of different safety-related functions, but those functions and capabilities are what differentiates them. In the interest of time, I'm not

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going to read the remaining bullet points, but will note that the first two are potential devices that may be wired to the vehicle, while the latter two are services that can be delivered by personal navigation devices. An RSD can also be an ASD, so the list is not mutually exclusive. Note that there might be a liability issue that is still to be resolved for non-factory-installed units.

Next we'll go on to discuss vehicle-to-vehicle applications. Earlier in the module, we discussed vehicle-to-vehicle benefits, but how are those benefits realized? The answer is through a V2V applications. Applications are software systems that takes the inputs—in this context, from other vehicles—in addition to its own sensor readings, and uses those readings to provide relevant information to the vehicle operator, or other processing software on the vehicle. These applications are stored on the vehicles, so it is primarily through these applications how we gain those benefits. The next several slides summarize some of the vehicle-to-vehicle applications that have been identified by USDOT today and are being researched and prototyped. There will probably be more applications identified in the future. Each OBE on a vehicle may have one or all of these applications. Note that a vehicle may be a motorcycle, a school bus that's stopped and loading or unloading, or an emergency vehicle. This is a view of some of the vehicle-to-vehicle safety applications that are being considered for immediate implementation. The first app is the Do Not Pass Warning. The Do Not Pass Warning application warns the driver of a vehicle—say on a two-lane, two-way road—if a slower-moving vehicle ahead of it in the same lane cannot be safely passed because of a vehicle traveling in the opposite direction. This is a situation where the 300 meters operating range of the DSRC can be important. The Blind Spot and Lane Change Warning application is intended to warn a driver—say the vehicle in the right lane at the bottom—if a vehicle in the left lane, in this example, is occupying or will soon be occupying the space into which the vehicle intends to switch to. Forward Collision Warning warns the driver if there's a possibility of a rear-end collision with another vehicle ahead of it, and in the same lane and direction of travel. And the Emergency Electronic Brake Light application enables a vehicle—say the first vehicle at the bottom—to broadcast a brake event to surrounding vehicles. Upon receiving the vehicle information, the receiving vehicle, even if there are other vehicles between them, can determine if the event has any relevance and provides a warning to the driver, if appropriate.

The next application is the Intersection Movement Assist. It warns the driver when it is not safe to enter an intersection due to a high collision probability with other vehicles that might be going through the intersection, whether it's a signalized or a stop sign controlling an intersection. And Left Turn Assist will warn the driver if it is not safe to make a left turn because of an oncoming vehicle from the other direction.

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There are also other safety applications that involve specific types of vehicles. The first two applications involve emergency vehicles, and the last two applications involve transit vehicles. In the interest of time, I won't go into details for any of these applications, but you can read about these applications on the PowerPoint presentation or on the Connected Vehicle Reference Implementation Architecture website, which we provided the link for at the beginning of this module.

So those were some vehicle-to-vehicle safety applications. This slide describes three V2V mobility applications that have been identified. Again, for the interest of time, we're just going to continue to the next slide. And this slide contains two vehicle-to-vehicle environmental applications that have been identified. Again, if you would like to read more about the applications, I refer you back to the Connected Vehicle Reference Implementation Architecture.

This slide is an example of how vehicle-to-vehicle safety applications, specifically Intersection Movement Assist, may work. "Lauren is driving home with her son after a day at school. She is stopped at a red light. When the light turns green, she is about to move through the intersection when she is warned of a vehicle crossing the path in front of her. She quickly brakes to avoid a T-bone crash." So this is the type of information that we may need from the other vehicle for the Intersection Movement Assist application to work. We need a location from the other vehicle, the speed that the other vehicle is traveling, the direction of travel, acceleration rate—is it accelerating through the intersection or decelerating?—the brake status—is the driver trying to brake right now?—the length and width of the vehicle—is it a small, tiny vehicle, or is it a large truck?—and the steering wheel angle from the other vehicle—is it trying to make a left, or is it trying to go straight through the intersection? So similar information is needed for all the vehicle-to-vehicle applications.

So, we've reached another activity. Which of the following is not a component of the vehicle-to-vehicle environment? Your choices are: a) the vehicle powertrain; b) the safety application electronic control unit; c) the GNSS or GPS receiver; or d) memory for security certificates or application data. Which of the following is not a component of the vehicle-to-vehicle environment? So, the correct answer is a, vehicle powertrain. While the vehicle powertrain is a component of the vehicle, is it not a component of the vehicle-to-vehicle environment. The electronic control unit includes the processor that runs the safety applications, so that's part of the vehicle-to-vehicle environment. The GNSS receiver provides the vehicle position and time for the vehicle, so that's, again, part of the vehicle-to-vehicle environment. And the memory is needed for the security certificates and the application data. So that's also part of the vehicle-to-vehicle environment.

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So to summarize, the vehicle-to-vehicle environment consists of vehicles with onboard equipment consisting of DSRC radios, antenna, the GPS receiver, the memory, and the electronic control unit. Each OBE provides a number of different safety-related services. Some of these may be as simple as only broadcasting vehicle information. All these standards-based devices might be installed by the manufacturer or on maybe an after-market device. Applications of software on the vehicle that uses data is received from other vehicles in addition to its own sensor readings. Most vehicle-to-vehicle applications are expected to be safety applications, but several mobility and environmental applications have been identified also. These applications rely on a basic set of data, such as vehicle location, speed, and direction of travel needed from other vehicles to support these applications.

Now that we've introduced the Connected Vehicle Environment and how it can help improve our transportation system, this section introduces the standards that will help project managers implement and deploy the Connected Vehicle Environment. This section begins with introducing the benefits of standards, followed by the communication standards that have been developed or are in development for communications between connected vehicles, and the second ends with a review of the hardware specifications that have been developed by USDOT for its research pilots.

So, why is it that standards are essential? Well, it is with standards that we can support interoperability, which is the ability of two or more systems or components regardless of the manufacturer to exchange information and use information that has been exchanged. Imagine a scenario where standards don't exist. Model Z is broadcasting on Frequency A and using a proprietary data dictionary while Model Y is listening on Frequency B and only knows Model Y's proprietary dictionary. That would not be very useful. That is why interoperability is important. An example of interoperability is the use of AM/FM radio broadcasts. Because of the radio frequency separation standards, it doesn't matter who made a radio receiver or transmitter. The radio receiver is able to listen to broadcasts on different radio channels. That is why standards is important, regardless of who developed them. To maximize the potential benefits of the vehicle-to-vehicle environment, it is important that all vehicles speak the same language, speak the same way, use the same grammar, and the same vocabulary. So for example, right now, I'm using the English language, communicating by speaking and following the rules of the English language and English dictionary. Other benefits of the standard is that it makes testing for conformance and interoperability easier and helps in the design and procurement of the system.

Looking at vehicle-to-vehicle environment, what's our current situation? The current situation now is that there are many vehicles and types of vehicles on the roadway from different manufacturers. For the required transportation connectivity to happen, there are

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several questions that we need to answer: How do we communicate? We know it has to be wireless, but what type of technology are we using? Is it cellular communications or radios? If it's a radio, what frequency? What language are we using? What are the rules, the grammar and the words in the dictionary that we will be using? How many people can talk so that we can listen to each other? Should we talk louder if there's lots of cars talking? Move to a different room or a different channel? How do I know what you're telling me is the truth and not a lie? So these are problems, questions that we have to establish standards for.

So what types of communication standards are needed? There are transmission standards that define how information is exchanged. Since the focus is on V2V, there are radio system standards and involves the capability for the over-the-air transmission. IEEE 802.11 standards define the physical and medium access control communications protocols that can be used for ITS. In addition, the IEEE 1609 family defines the rules and procedures on how data will be exchanged between two devices. For example, an analogy would be the English language. English consists of a grammar defining rules and procedures on how to exchange information.

There are also interface standards that define the characteristics necessary to allow the exchange of information between two systems or devices. SAE J2945 is an interface standard that defines the operations, performance, and functional requirements for one or more applications. For example, the SAE J2945 is proposed to define how often data must be broadcast so the safety applications can make the decisions or provide the data to the drivers for crash avoidance. There are also standards that define the data to be exchanged. SAE J2735 defined a message format, stated content, and data dictionary, the words that will be used to exchange data between two devices. An analogy is that message formats are sentences, while the data elements are individual words. In the next several slides, we will discuss each standard in a little bit more detail. Although the slides will contain detailed descriptions, we will only review the highlights of each standard.

As mentioned earlier, although not by standard ID, ASTM 2213 introduced the term DSRC. It was a source for the FCC rule that led to the report order for the 5.9 gigahertz ITS radio band. In ASTM 2213-03, the physical layer deals with the DSRC radio chips, transmitter and the receiver, and the intervening environment in between, while the MAC deals with the middle layer, or the messaging protocols, that allow applications to connect to the physical. Again, just to reemphasize, it is important to note that DSRC is only one possible communications means for vehicle-to-vehicle communications, but it is likely to be used for vehicle-to-vehicle communications in the near future because of its low latency. Also to note, ASTM 2213-03 is no longer used. However, it was the basis for the

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IEEE 802.11P-2010 amendment, Wireless Access in Vehicular Environment, that we will discuss in the next slide.

The IEEE 802.11 family of standards provide the wireless connectivity between different devices within a local area. For example, there is a section of 802.11 that makes up the Wi-Fi standard. The 802.11P amendment which is commonly referenced is now part of the 802.11 family and defines the wireless connectivity in vehicular environments. It specifies the channel bandwidth, the operating classes, the transmit power classifications, the transmission mask, and alternate channel requirements in the 5.9 gigahertz spectrum.

The IEEE 1609 family defines the rules and procedures on how data will be exchanged between two devices in the Connected Vehicle Environment. IEEE 1609.0 is the guide describing the architecture and services necessary for WAVE, which is the acronym for wireless access and vehicular environment, devices to communicate in Connected Vehicle Environment. IEEE 1609.2 defines the secure message formats and processing for use by WAVE devices, including methods to secure WAVE management messages and application messages. It also describes administrative functions necessary to support the core security functions. Note that IEEE 1609.2 may have applicability in other communication devices besides wireless broadcasts used in the 5.9 gigahertz system. That is, there are potential uses for the standard that is not ITS or connected vehicles related.

IEEE 1609.3 defines the services operating at the network and transport layers. It manages how communications are initiated and ended, and how messages are exchanged. The services are in support of wireless connectivity among vehicle-based devices using the 5.9 gigahertz DSRC/WAVE mode. Recalling that there are seven channels available for DSRC communications.

IEEE 1609.4 describes the multi-channel wireless radio operations and supports channel switching and routing, priority access, and the management services for multi-channel operations. For example, it allows information to be exchanged on different channels in case one channel is congested. IEEE 1609.11 specifies how over-the-air electronic payment transactions between a mobile device and a roadside unit, for example, occurs. It's not pertinent to V2V communications, but we include it in this slide for completeness.

1609.12 specifies allocation of wave identifiers defined in the IEEE 1609 series of standards. Services offered by a roadside unit are assigned an identifier by wave. This

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document identifies the specified goal's values. As a note, 1609.3 specifies the format of the identifiers.

The previous slides represented the communication protocol standards that will likely be used for V2V communications. Now let's talk about the data standards or the dictionary that will be used. That dictionary is the SAE J2735. The current approved version is 2009, although a 2015 version is expected to be released in the spring of 2015. The standard defines message formats and data elements. The basic safety message or BSM, is the primary message set that is expected to be used for V2V communications. The BSM consists of two parts, Part I and Part II. Part I data elements are considered basic information needed for safety applications and thus are mandatory when this message is broadcasted. Part I data elements are expected to be broadcasted by a vehicle on a frequent basis, although SAE J2735 does not define how frequently or when the message should be transmitted. It's only the dictionary. Part II data elements are optional. They may be broadcasted along with the Part I data elements as needed or as requested. For example, the BSM has a flag to indicate a vehicle is braking hard. Although the flag is a Part II data, it is an important piece of data that may impact safety and would be broadcasted along with the Part I elements.

This slide summarizes the information provided for BSM Part I. This information provides critical information needed about the movement of the vehicle for applications, whether safety and mobility or for environmental purposes. It provides information about where the vehicle is and where it is headed. Again, in an interest of time, I'm not going to read the entire list. However, positional accuracy is the quality of the accuracy for the location determination along all three axes. If the GPS receiver on the vehicle has a full view of the sky, the accuracy is likely to be high, but if it's in a canyon, the accuracy may be lower. Transmission allows other vehicles to know if the vehicle is in neutral, park, forward, or reverse. The steering wheel angle lets others receiving the data know if the vehicle is deviating from a straight line or projected turn. Direction about using directional signals. Acceleration is along all three axes, plus yaw rate. The vertical acceleration might be used to determine if there's a pothole in the road and the yaw rate may be used to determine if a car is overturning. Brake system status indicates if the brakes are being applied. It could even be anti-lock brakes, traction control, stability control, or parking brakes are engaged or not. Message Count is a counter to track the sequence of the message, so remote vehicles can track the message, which is received or in case a later message is received before an earlier message, which is possible depending on the communications media. Temporary IDs are identified so vehicles can determine the source of the message. Note that this is a transient identifier, which is expected to change every several minutes. How and when the ID changes will be defined in a different standard, specifically SAE J2945. Time is measured in milliseconds within a

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minute. There's the assumption that the vehicle's clock is accurate. This time is actually a time sample when the basic safety message was broadcasted.

This slide summarizes some of the data elements now contained in Part II, which might be of interest for vehicle-to-vehicle communications. It is not a complete list of all of the parts or data elements. But parts and data elements include event flags. Event flags are data elements that are broadcasted with the Part I data elements when some condition is met. These flag conditions generally have something to do with safety that might be of interest to other vehicles. So they could, when the hazard lights are on, when a brake system is activated or a stability control is activated. If someone's braking hard. Expected to violate a stop sign. When the external lights change. For example, someone makes a left turn, turns on the left turn blinker, or turns on a headlight. When the wiper rates have changed. If it's got a flat tire. If the vehicle is disabled or if the airbag has deployed. The event flag also indicates if the vehicle is an emergency vehicle on a service call or the vehicle is placated for carrying hazardous materials. Although event flags are optional, all standards, other standards and possibly a rule, may make it mandatory, for automobile manufacturers to support event flags. Other Part II data elements include a path history, a path prediction, which are expected to be required, to be supported by a standard or a rule. Other Part II data elements include the vehicle bus information such as tire information, axle information, vehicle identification, which includes the VIN number and the vehicle type. These latter are data elements primarily intended for commercial vehicles. And here are some additional Part II data elements that might be of interest.

While we have discussed basic safety message, there are other messages in the SAE J2735 that might be of interest. The common safety request message is intended for a vehicle to request additional information from other vehicles, usually for safety applications that the requested vehicle is running. It is important to note, however, that another device could request data from the vehicle, but there is currently no requirement or rule that says the receiving vehicle has to provide the requested data. Emergency vehicle alert message is intended to be broadcasted by emergency vehicles to indicate that emergency vehicle is operating in vicinity and additional caution is required. Again, note that the SAE J2735 data dictionary does not define when the message to be broadcasted is supportive in the application. This slide summarizes some of the other messages that might be of interest, but not necessarily for the vehicle-to-vehicle communications. However, I will mention that the latter two messages, the NMEA and RTCM correction messages, are used to calibrate GPS locations for vehicles and mobile devices to increase the absolute and relative accuracy.

The next family of standards we want to introduce is the SAE J2945 family of standards. This family of standards is still under development and expected to define the operational and performance requirements for connected vehicles, that is, how a vehicle is to be

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exchanged between two devices or two systems. This dictionary, for example, contains the words we use but it does not describe how those words are to be communicated. A similar analogy can be used for SAE J2735. It contains the message of the data elements but does not define what messages or when a message should be exchanged to support application. SAE J2945 is expected to do that. In addition to possibly specifying the transmission standards to use and how to use it, the family will define it before its requirements for specific J2735 messages. How often the message is sent, what data elements must be sent, and the quality requirements necessary before a data element is sent. For example, it may define how accurate the position of the vehicle is. If the position, the vehicle position, is of poor quality, perhaps because the GPS receiver is damaged, the performance requirements state that the vehicle not broadcast its position, which is better than providing a position that is of questionable accuracy. Most J2945 standards are expected to contain systems engineering content. That is it will include a concept of operations, describing the user needs and features that the standard will support, the requirements, and the design content in the form of messages of data elements most likely defined in SAE J2735 that will be required to fulfill the requirements. So right now at J2945/0 standard has been proposed that will provide generic content and requirements that are applicable to all applications.

The next two standards for the J2945 family/1 and /2 are expected to define the minimum performance requirements for vehicle-to-vehicle safety applications. This includes how often the BSM Part I message is expected to be broadcasted, how often Part II portions of the BSM will be broadcasted, which parts, and the conditions on when and how often the temporary ID of the vehicle will change and the minimum accuracy required before a value is broadcasted. For example, what allowable tolerance quality should a vehicle's speed be before it is broadcasted to other vehicles? It may also point to other standards to be used or implemented, such as IEEE 802.11 or IEEE 1609, so interoperability can be achieved. Other standards for a J2945 family have been discussed, but the focus right now for the vehicle-to-vehicle environment is on J2945/1 and J2945/2.

This slide summarizes the SAE J3067 information report. SAE J3067 was a comment submitted by USDOT to the DSRC Technical Committee, which oversees the SAE J2735 and J2945 standards. They expanded on the 2009 version of the SAE J2735, added systems engineering content to include tools for selecting the point of the standard and had extensive stakeholder direction in its development. It expanded support for user needs related to functional areas that were not addressed in the 2009 version of SAE J2735, including USDOT's Road Weather Management program, the AERIS program, transit user needs, and freight user needs, commercial vehicle operations. More specifically content that was added included a concept of operations requirement specification included before its requirements, accessibility matrices between user needs, requirements and design content. Although SAE J3067 is not in ITS standards, it

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provides insight on how the SAE J2735 and SAE J2945 standards will be structured and can be used for implementation.

Now that we've reviewed, the relevant standard, let's revisit an earlier slide that where we asked the question, "What is needed for the vehicle-to-vehicle to environment to be realized?" We now have our answers. This slide depicts the standards that answers the different questions we had and what is needed for an interoperable vehicle-to-vehicle environment, regardless of the vehicle make and model. How do we communicate? That's defined by the IEEE 802.11, IEEE 1609.3 standards. What language are we using? That's defined by SAE 2735, and SAE J2945, try and define some of the rules on how we use the language. How many people are talking in the room? That could be defined by IEEE 1609.4, which handles the channel switching. And how do we trust each other? IEEE 1609.2 enables it. It's a security standard.

The standards that we've presented are all communication standards, but how are those standards being used to specify today? USDOT through the Joint Program Office has established several test beds in the U.S. for testing applications and environment using the latest standards at the time of its implementation. Note that not all test beds are supporting the vehicle-to-vehicle safety application. As part of the testing, USDOT has developed several device specifications to be used and tested on the test beds. This slide lists the device specifications that are on the research qualified products list for onboard units currently being used in the Southeast Michigan test bed. Each of these specifications, based on the standards that were presented in this module. To support the test beds, USDOT also developed a certification process and tested programs for qualified devices for the test beds. The goal of the certification process is to verify and validate performance to the reference to the standards. When devices conform to the standards there is a high degree of certainty that broadcast data can be received and used.

We've reached another poll. So this poll asks, "Which is not a benefit of using ITS standards?" Go ahead. Answer choices are: a) supports interoperability; b) eliminate institutional issues; c) makes testing easier; d) makes procurement easier. So the correct answer is b) eliminates institutional issues. Standards alone cannot eliminate institutional issues. Interoperability is a key benefit of using standards. The standards can make testing easier since what you're testing against is defined by the standard and that procurements can be made easier with specifying standards, because some attributes have already been defined by the standard.

There's a second poll, and this poll asks, "Which of the following is a data standard?" Your answer choices are: a) IEEE 802.11-2012; b) IEEE 1609.x family of standards; c)

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SAE J2735; and d) USDOT FHWA vehicle awareness device specification. The correct answer is c. It is c, SAE J2735. A and b are communications and transmission standards while b is not a standard but really a specification that may reference the standards. So the correct answer is c, SAE J2735, which is a data standard.

So to summarize what we've learned, standards will support interoperability. The interoperability systems are able to maximize its benefits. The vehicle-to-vehicle environment is a standards based to support the goal of interoperability. There are several standards that have been developed or are being developed to support communications in a vehicle-to-vehicle environment. They include IEEE 802.11, which defines the physical medium access control communications protocol that can be used for ITS. The IEEE 1609 family of standards defines security in networking services, as well as multi-channel operations for IEEE 802.11-based devices in the 5.9 giga ITS radio band. Today's standard that is being used for the vehicle-to-vehicle is SAE J2735, which defines the data dictionary, while the SAE J2945/N standards defines the performance requirements for specific applications. USDOT has also developed the hardware specifications for its test beds based on these ITS standards.

Now that we've introduced the standards that have been developed or are in development to support communication in a vehicle-to-vehicle environment, this section introduces some of the existing barriers, both technical and institutional, to deploy in a vehicle-to-vehicle environment from the perspective of the deployer. The August 2014 ANPRM, Advanced Notice Proposed Rulemaking, released by NHTSA included a supporting research report. The report determined that the standards for a vehicle-to-vehicle environment were not mature yet. The standards needed refinement, more work was needed in security, and that there were a couple of areas that required clarification and needs to be addressed to enable interoperability between devices. Based on the agency's understanding of how these prototype safety applications operate, preliminary effectiveness estimates indicated a V2V safety application offered a substantial ability to mitigate crashes, injuries, or fatalities in these crash scenarios. Institutional issues were a major concern, but NHTSA has determined that it did have the legal authority to mandate vehicle-to-vehicle devices in light vehicles. The report also indicated that certification test procedures were important, including defining the minimum performance measures for vehicle-to-vehicle communications.

So what are some of the technical challenges deployers are facing to deploying vehicle-to-vehicle? Well, the vehicle-to-vehicle environment is envisioned to be an interoperable environment, which will provide the ability to broadcast standards-based messages and reliably exchange data regardless of the service provider or the manufacturer. However, new standards are still evolving. Requirements are still being added or tweaked as we learn more from the prototypes and field devices that are being conducted. NHTSA has

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also recognized this and sent letters to the standards development organizations encouraging that the standards be stable by September 2015, before the rulemaking. Some standards may also have to be updated to align with the final NHTSA rule when it is released, expected in 2016. There are also efforts right now to harmonize standards of each other, whether it is within North America or with other international efforts. Thus early adopters of initial standards should be aware of potential for changes, building means to cope with changes both planned and unforeseen. Plan for changes with contingency planning, including risk assessment and recovery techniques, and avoid complacency when all is sailing smoothly. There are also some potential challenges with implementation of the standards that are still being researched. For example, BSM Part II there is no assurance that the automobile manufacturers will support Part II in the short-term because of their V2V focus and concerns about channel congestion. As a defective mode of operations, all basic safety messages for a vehicle's safety applications are being broadcasted on Channel 172. Because of that, there is concern about congestion on Channel 172, thus a vehicle may not receive all the basic safety messages that are broadcasted from nearby vehicles. Basic safety messages may also be transmitted on any of the other channels of the application being implemented, requires the information included in control channel, however, automobile manufacturers are not pursuing that implementation. They're only focusing on Channel 172 right now. Finally, there is very little, if any, guidance documents currently available on deploying products conforming to these standards. Other implementation issues that project managers should be aware of? Vehicles need to be equipped to gain the benefits. At least one vehicle must be able to broadcast and the other must be able to receive. Also be aware of the challenges during the rollout, as some vehicles are equipped and some are not. There may be adjustment to driver behaviors when rollout occurs. BSM is also unencrypted, so near field tracking is possible. The vehicle IDs and MAC addresses are randomized, but we can still track them for a short distance in a short period of time. Perhaps about two minutes. Again, once vehicle-to-vehicle is deployed it opens the door to other V2X implementations, such as V2I.

Testing and certification is not a technical issue. The testing and certification needs to describe what test and by whom and for what purpose? Not all performance tests are the same. They can be self-tests, conformance certification tests to standards, or for interoperability. Interoperability testing can be viewed as connecting devices to the same network with other devices made by different manufacturers in attempting to exchange basic safety messages. Compliance testing is another set of testing to determine if our product is in compliance with the program regulation. For example, radio characteristics are in compliance with the various parts of the FCC regulation. Notice a procurement specification is also a legal requirement. Also we have to be aware of different versions of a standard. Also recall, that there will be aftermarket devices, devices that someone can purchase at an autoparts store or perhaps an app on a mobile phone. Who will certify the

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device is mounted properly so that the vehicle location is broadcast correctly, for example.

There are also some regulatory issues, not really a standards issue, but deployers have to be aware. In February of 2013, FCC released a notice of proposed rulemaking for changes to several frequencies in the 5.0 GHz band to allow others to use the 5.9 GHz band. The allocation for ITS is currently co-primary with satellite downlink in military radars, meaning that we have priority. But the proposed changes will allow other users to broadcast and transmit in the 5.9 GHz area. Primary users have to be able to sense other users and co-exist with other co-primary users, so this issue is still outstanding.

In addition to technical challenges, there are institutional challenges. Privacy's a key challenge. Issues of privacy with respect to user data and with respect to communications stack. Sensitivity to data collection, data use, data distribution, and relationship to data sources needs to be addressed. Note that the situation for data about vehicles differ from authorization needed to access the integrated information about the vehicles, such as for commercial vehicle credentialing. Privacy context differs and the differences should be noted for the project managers. The standards do address it in two ways. IEEE 1609.3 makes it difficult to track a vehicle using its radio MAC address by changing it at regular intervals. J2945 is expected to address it with temporary IDs. This provides some assurance of privacy between users and third parties because an agency or a private party, can track a vehicle to its source and destination without appropriate authorization such as electronic payments. Security is another concern. The difference between privacy and security is privacy is the use of data to identify something. With security it's the exchange of trusting unauthenticated data. The message may have the correct content but it can't be authenticated. Concept and context of data integrity and what is trusted is not likely to be found in standards, but with the systems being developed for a certificate management system. The current plan is for a security certificate system where certificates from a trusted source is broadcasted along with the messages. The standards would support the security systems. For example, IEEE 1609.2 defines how to use, revoke, and repress certificates in a certificate management system. To support how the security credential management system is currently envisioned, an infrastructure may be needed to support renewing security credential certificates on a periodic basis. This requires that the vehicle be able to manage, create, store, distribute, and revoke security certificates that accompany and validate each basic safety message. The infrastructure consists of a certificate authority to issue a verified certificates, a registration authority to verify a certificate authority, a certificate distribution and management system, which includes the communication system. A distribution system is the problem. It may need to involve distribution points along the roadway infrastructure to allow a vehicle to renew their vehicle's credentials and certificates. So

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although V2I is outside the scope of this module, project managers should be aware that some type of infrastructure may be needed to support the security.

We've reached another poll. What is the current challenge to deploying connected vehicles? Your answer choices are: a) security; b) privacy; c) evolving standards; or d) all of the above. The correct answer is d, all of the above. All three, security, privacy, and evolving standards are all current challenges to the connected vehicle environment.

So in the last several slides we've seen that the standards are evolving. The standards are still being updated based on the evaluation of pilot tests and field tests, and due to harmonization of each other and international efforts. There are also some potential implementation issues that need to be resolved, including testing and certification. Institutional issues include privacy and security are still being researched and tested. And a security system currently being envisioned requires infrastructure and may need support for the transportation infrastructure and systems.

In the last section we introduced some of the challenges to deployment. In this section, the module will review the status of the standards' activities and research activities underway that will address these challenges. The slides will provide additional resources for further reading information about these standards, activities, and deployment. And note that these statements, these upcoming slides, are as of March 2015.

To review, we've introduced what the connected vehicles and V2-vehicle environment is and what benefits they bring. We've also introduced potential applications that identify the standards that will support the vehicle-to-vehicle environment. Finally, we've described some of the challenges to deploying a V2V environment. What standards and research activities are currently being performed in anticipation of NHTSA's proposed rulemaking?

First, a revision of IEEE 802.11 is being considered to harmonize with the lessons learned from the safety pilots and to align with the proposed rulemaking. This revision is currently scheduled for review and comment in March 2016. This hopefully will allow the group to assess any potential changes needed to align with the proposed rulemaking for V2V communications in light vehicles.

For IEEE 1609 overall, there are research studies that are being done by CAMP, which is a consortium of vehicle manufacturers that are currently testing vehicle-to-vehicle safety applications. Based on those research projects, the IEEE 1609 working group is getting recommended changes from CAMP. There are also attempts to harmonize through international standards mark. Work items deemed critical to the NHTSA decision are

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being given priority and other items, will be addressed on a time-allocated basis. A revision for the entire IEEE 1609 family's plan for 2015 with or without harmonization results. The SAE DSRC technical committee is responsible for SAE J2735, and SAE 2945, as this is the data performance and included performance—excuse me—as this is the data standard and includes the performance requirement, NHTSA has asked that DSRC Technical Committee accelerate their efforts. For SAE J2735 related to the vehicle-to-vehicle environment, improvements are being considered to better support emergency vehicles and trucks. Work has also already started for J2945/1 and will be based on CAMP's findings. There is also work being considered for vehicle-to-pedestrians or mobile devices, or vulnerable users such as smartphones that a pedestrian or cyclist may be carrying.

Security. USDOT is still researching a security credential management system. In October 2014, NHTSA released an RFI, request for information, seeking information about the security system to support vehicle-to-vehicle operations. The RFI noted that the security system will not be established by NHTSA regulation. What is being looked at is developing a security management system that fits the requirements of how the certificates should be used, revoked, or repressed in 1609.2. In the meantime, USDOT and CAMP have separately been testing and designing a security credential management system as part of their efforts.

Certification testing. USDOT released a request for applications in June 2014 to establish a certification environment for connected vehicle devices and applications. The current intent is to enter into a cooperative agreement with one or more existing facilities to conduct qualification and certification testing. The RFA has proposed an approach for certification that includes the security certificate management system. In that approach, all basic physical connected devices will be certified for their environmental abilities and communications protocol abilities. An application, on the other hand, will have to be certified for all four abilities listed if it resides under basic device. So it will have to include interface abilities and will also have to be tested for overall application abilities. This approach allows for multiple applications to be hosted on one physical device. This slide contains only a couple of examples of some of the test beds and research that is being performed right now. Each of these test beds and research are using the latest standards at the time of their implementation with the intent to verify that the standards are complete and effective and to look for any ambiguities or holes in the standards, both in the real-world environment, as in the case of the Southeast Michigan test bed or the CAMP research or in a controlled environment, such as the Connected Vehicle PlugFests, where developers can bring in the devices and they can be tested for interoperability in a laboratory. Note that sometimes modifications are made to the implementation standards in the test beds to address known problems. A final note about CAMP. CAMP is performing the majority, if not all, the vehicle-to-vehicle safety tests.

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This slide summarizes some of the key scheduled milestones for the connected vehicle environment. I will note that a decision on a similar V2V rulemaking for heavy for vehicles such as transit vehicles and commercial vehicles, freight vehicles, was expected at the end of 2014, but nothing has been announced yet.

A little bit more about connected vehicle reference implementation architecture. CVRIA is a reference framework that identifies the key interfaces of a connected vehicle environment. It was also used as an input to create a standards development plan to identify gaps in the ITS standards and to prioritize the standards needed to support the connected vehicle implementation. The CVRIA can also be used as a resource for planning and deployment. It includes an application list, which will include emerging application requirements and standards to be considered for deployment for each application. We added the list, the link, to the website again. The CVRIA development team is currently working on version 2.0 and that's expected toward the end of spring 2015. But the CVRIA is expected to be merged into the National ITS architecture in 2016.

This on the next slide provides a link to the standards that were introduced in this module. IEEE 1609.0 is the architecture description document that provides a connective view of the 5.9 GHz radio system. So we have here the IEEE 802.11 and IEEE 1609 link. These are the links for the SAE documents. As I mentioned earlier, an updated version of SAE 2735 is expected in spring of 2015. The primary change to that version's standards is with the MAP and SPAT message. Recall that SAE J3067 is not an ITS standard, but an information report, provides insight on how the J2735 and the J2945 standards will be structured and can be used for implementation. And finally the student supplement work will contain some additional resources on connected vehicles and standards.

We've reached our last poll question. Which of the following is not a current connected vehicle activity? Revising ITS standards based on lessons learned; b) USDOT will be operating new certification laboratories for connected devices; c) developing a security system to authenticate messages; or d) revising the CVRIA for emerging application requirements. The correct answer is b, USDOT plans to develop a cooperative agreement with one or more existing facilities to conduct certification testing for connected devices. USDOT will not be operating ability recertification laboratories. The standards are currently being revised based on lessons learned. USDOT is seeking to establish a security certificate management system manager, and the CVRIA is a living document and will be revised to include emergency application requirements.

So in summary, the standards for the last couple of slides, standards development and maintenance is ongoing as research activities continue. NHTSA is working on a regulatory proposal to require vehicle-to-vehicle devices and capability in new light

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vehicles, and work is ongoing to develop a security system and certification process. The slides in the student supplement provides a list of resources and links where additional information can be found on the standards, the CVRIA, and other connected vehicle activities.

So what have we learned in this module? The connected vehicle environment involves vehicles wirelessly broadcasting data about itself. The vehicle-to-vehicle environment consists of onboard units or equipment, broadcasts the information to support safety applications, mobility applications, and environmental applications. Connected vehicle standards are critical to support interoperability. Some of the institutional issues that we are facing are security, privacy, and data ownership. And standards maintenance is continuing to include new requirements and to incorporate lessons learned.

Some questions that we received for this module include, "How does connectivity work with modules?" Excuse me, with motorcycles. Having a motorcycle unexpectedly brake or turn to avoid something could be catastrophic to the rider and passenger. So there have been tests in some of the test beds, including Michigan, and perhaps some other test beds where motorcycles have been equipped with an OBE. They would transmit the basic safety message like a regular vehicle and will receive basic safety messages from other vehicles. "Is there a potential opening door warning of a parked car, both on the roadside and the sidewalk side when parallel parked?" So, so far there has been no request for a vehicle to transmit that it has doors open, but this highlights that it is likely that there will be requests for new data on this as the vehicle-to-vehicle environment develops and matures. So that is it for the questions that we have received, and I thank you for viewing this module. And this is the end of this module.

End of Vehicle-to-Vehicle ITS Standards for Project Managers