



SURFACE VEHICLE INFORMATION REPORT

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Candidate Improvements to Dedicated Short Range Communications (DSRC)
Message Set Dictionary [SAE J2735] Using Systems Engineering Methods

RATIONALE

This technical report is being stabilized because the technical committee has determined that the using community is moving towards newer technology and would like to alert users that this new technology exists which may want to be considered for new design.

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DOCUMENT REVISION HISTORY

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1. SECTION 1 - GENERAL [INFORMATIVE]

1.1 Scope

This document is not a standard, it is a candidate for a standard being submitted to SAE for their consideration as a comment to SAE J2735. The term SAE J2735 SE candidate is used within this document to refer to this submission.

This document specifies dialogs, messages, and the data frames and data elements that make up the messages specifically for use by applications intended to utilize the 5.9 GHz Dedicated Short Range Communications for Wireless Access in Vehicular Environments (DSRC/WAVE, referenced in this document simply as "DSRC"), communications systems. Although the scope of this Standard is focused on DSRC, these dialogs, messages, data frames and data elements have been designed, to the extent possible, to be of use for applications that may be deployed in conjunction with other wireless communications technologies. This standard therefore specifies the definitive message structure and provides sufficient background information to allow readers to properly interpret the message definitions from the point of view of an application developer implementing the messages according to the DSRC Standards.

1.2 References

The following standards (normative references) contain provisions that, through reference in this text, constitute provisions of SAE J2735 SE. Other documents and standards (other references) are referenced in these documents, which might provide a complete understanding of the entire protocol and the relations between all parts of the protocol. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on SAE J2735 SE are encouraged to investigate the possibility of applying the most recent editions of the standards listed below.

1.2.1 Normative References

Document Identifier	Document Title
FMCSA MCS-150	Federal Motor Carrier Safety Administration (FMCSA), Form MCS-150, Motor Carrier Identification Report (Revision 06/12/07)
FIPS Publication 5-2	Federal Information Processing Standards Publication 5-2, May 29 1987
IEEE Std 1609.2-2006	IEEE Trial-Use Standard for Wireless Access in Vehicular Environments - Security Services for Applications and Management Messages.
IEEE Std 1609.3-2010	IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Networking Services
IEEE Std 1609.4-2010	IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Multi-channel Operation
ISO 3166-2:2007	ISO 3166-2:2007, Codes for the Representation of Names of Countries and their Subdivisions - Part 2: Country Subdivision Code.
ISO 3780:2009	Road Vehicles - World Manufacturer Identifier (WMI) Code
NMEA 0183 Version 4.00	NMEA 0183 The Standard For Interface Marine Electronics
NTCIP 1202, v2.19f	National Transportation Communications for ITS Protocol - Object Definitions for Actuated Traffic Signal Controller Units, v02.19f
NTCIP 1204, v3.08r2	National Transportation Communications for ITS Protocol - Environmental Sensor Station Interface Protocol, Version v03
RTCM 10402.3	RTCM 10402.3 Recommended Standards for Differential GNSS (Global Navigation Satellite Systems) Service
RTCM 10403.1	Differential GNSS (Global Navigation Satellite Systems) Services - Version 3
SAE J2354	Message Set for Advanced Traveler Information System (ATIS)
SAE J2540/2	ITIS Phrase List (International Traveler Information Systems)
SAE J2735	Dedicated Short Range Communications (DSRC) Message Set Dictionary
Title 49 CFR 395.16 - Regulation for On Board Recorders, Appendix A	Title 49 CFR 395.16 - Regulation for On Board Recorders, Appendix A, April 5, 2010

1.2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

Document Identifier	Document Title
APTA TCIP-S-001 3.0.3	Transit Communications Interface Profiles - APTA, January 10, 2009
NHTSA 09-118	Cooperative Intersection Collision Avoidance System for Violation (CICAS-V) for Avoidance of Violation-Based Crashes, Michael Maile, Luca Delgrossi, NHTSA Paper Number 09-0118
Core System Concept of Operations Rev C	Core System Concept of Operations Rev C, Lockheed Martin Corporation, April 19, 2011.
DSRC Implementation Guidance:	DSRC Implementation Guidance: A guide to users of the SAE J2735 message sets over DSRC. [16-Feb-10]. Pp., 210.
FHWA-JPO-09-038 Final Report	Vehicle Infrastructure Integration (VII) Proof of Concept (POC) Test - Executive Summary. FHWA, February 2009
IEEE 830-1998	IEEE Recommended Practice for Software Requirements Specifications, June 25, 1998.
Final Report: Vehicle Infrastructure Integration Proof of Concept	Final Report: Vehicle Infrastructure Integration Proof of Concept, The VII Consortium, May 19, 2009.
Manual of Uniform Traffic Control Devices (MUTCD): 2009	Manual on Uniform Traffic Control Devices for Streets and Highways, 2009 Edition, U.S. Department of Transportation, Federal Highway Administration
NTCIP 1211 v01.38	Object Definitions for Signal Control and Prioritization - AASHTO / ITE / NEMA, May 2008.
SAE J1587	Electronic Data Interchange Between Microcomputer Systems in Heavy Duty Vehicle Applications
SAE J1708	Serial Data Communications Between Microcomputer Systems in Heavy-Duty Vehicle Applications
SAE J1939	Serial Control and Communications Heavy Duty Vehicle Network - Top Level Document
SAE DSRC Implementation Guide	SAE DSRC Implementation Guide, A guide to users of SAE J2735 message sets over DSRC, SAE International, February, 2010.
Vehicle Safety Communications-Applications Final Report (VSC-A)	Vehicle Safety Communications - Applications (VSC-A) Final Report, Ahmed-Zaid, F., et. al., CAMP Vehicle Safety Communications 2, April 26, 2011
VII Privacy Policies Framework	VII Privacy Policies Framework, Version 1.0.2 February 16, 2007, Institutional issues Subcommittee of the National VII Coalition

1.3 General Statements

Not Applicable

1.4 Terms

For the purposes of this candidate standard, the following terms and definitions apply.

Term	Description
Aftermarket Safety Device	A connected device in a vehicle that operates while the vehicle is mobile, but which is not connected to the data bus of the vehicle.
Allowed Movements	In the context of this standard, the directions of movement that are legally allowed at a specific point in time based upon the state of the intersection signals.
Application	A software program with an interface, enabling people to accomplish a specific task. In the context of this standard, it is a software program that provides functionality to realize safety, mobility, and environmental benefits.
BLOB	Binary Large Object, a term used in software to describe sequences of octets or bytes where any inner encoding or meaning is not visible.
Commercial Motor Vehicle	Commercial motor vehicle means any self-propelled or towed motor vehicle used on a highway in interstate commerce to transport passengers or property when the vehicle: (1) Has a gross vehicle weight rating or gross combination weight rating, or gross vehicle weight or gross combination weight, of 4,536 kg (10,001 pounds) or more, whichever is greater; or (2) Is designed or used to transport more than 8 passengers (including the driver) for compensation; or (3) Is designed or used to transport more than 15 passengers, including the driver, and is not used to transport passengers for compensation; or (4) Is used in transporting material found by the Secretary of Transportation to be hazardous under 49 U.S.C. 5103 and transported in a quantity requiring placarding under regulations prescribed by the Secretary under 49 CFR, subtitle B, chapter I, subchapter C. (Source: 49 U.S.C. 31132)
Commercial Motor Vehicle On-Board Unit	An OBU or ASD mounted on or in a vehicle moving goods, heavy equipment, or people. Includes motor coaches.
Connected Device	Any device used to transmit to or receive messages from another device. A connected device can be sub-categorized as an OBU, ASD, or RSU. In many cases the connected device will be a DSRC device, but other types of communications could be supported.
Connected Vehicle	A vehicle containing an OBU or ASD.
Control Channel	A single radio channel, not a service channel, intended for the exchange of management frames, including Wireless Access in Vehicular Environments (WAVE) Service Advertisements, and WAVE Short Messages. (Source: IEEE 1609.3)
Controller Area Network	A Controller Area Network (CAN) bus is a message-based protocol, designed specifically for automotive applications. The CAN bus is one of five protocols used in the OBD-II vehicle diagnostics standard. The OBD-II standard has been mandatory for all cars and light trucks sold in the United States since 1996.
Eco-Driving	The practice of driving in such a way as to minimize fuel consumption and emissions.
Eco-Lane	A dedicated lane(s) optimized for the environment similar to high-occupancy vehicle lanes; however, these lanes are optimized for the environment using connected vehicle data. These lanes would be targeted toward low-emission, high-occupancy freight, transit, and alternative-fuel vehicles (AFV). Drivers would be able to opt in to these dedicated eco-lanes to take advantage of eco-friendly applications such as eco-speed limits, eco-cooperative adaptive cruise control and connected eco-driving applications.
Electronic On-Board Recorders	A device on-board a commercial vehicle used to record driver information such as hours of service.
Event Snapshot	A snapshot generated when the connected vehicle when a sensor value exceeds a specific threshold.
Geoid	The equipotential surface of the Earth's gravity field which best fits, in a least squares sense, global mean sea level. (Source: National Geodetic Society)

Term	Description
Horizontal Dilution of Precision	The horizontal dilution of precision (HDOP) allows a person or application to more precisely estimate the accuracy of GPS horizontal (latitude/longitude) position fixes by adjusting the error estimates according to the geometry of the satellites used.
Host Vehicle	A connected vehicle that receives messages from a remote vehicle. [In this document, the host vehicle is also used to describe the originator of a vehicular transmission of information to the RSU.] (See Remote Vehicle)
Intelligent Transportation Systems (ITS)	Systems that apply data processing and data communications to surface transportation, to increase safety and efficiency. Another appropriate meaning of the ITS acronym is integrated transportation systems, which stressed that ITS systems will often integrate components and users from many domains, both public and private.
Interoperability	The ability of two or more systems or components to exchange information and to use the information that has been exchanged. (Source: IEEE 610.12-1990)
Intersection	In the context of this standard an intersection is a nexus where two or more approaches (links) meet and vehicles and other type users may travel between the connecting links. Typically this is a signalized intersection when considered by this standard, and as such the modes of allowed movement are reflected in the signal phases, the geometry of the intersection, and the local regulatory environment. The messages of this J2735 SE candidate convey some of this intersection information to the traveling public. Specifically, the MAP message conveys the relevant road geometry, while the SPaT message conveys the current allowed movements to control movement in the intersection.
Interval	The part of a signal cycle during which signal indications are stable and do not change. In the SPaT message the current timing value for the remaining interval time estimate as well as the anticipated interval for yellow change interval is provided for each lane. Because signal interval times commonly change based on triggering events in many types of signaling systems, the value provided in the SPaT message may represent a minimal value that is extended and updated as the message is re-issued each time.
Interval Sequence	The order of appearance of signal indications during successive intervals of a signal cycle.
ITIS	International Traveler Information Systems, the term commonly associated with the standard for incident phrases developed by the SAE ATIS Committee in conjunction with ITE TMDD and other standards. This work contains a wide variety of standard phrases to describe incidents and is expected to be used throughout the ITS industry. The codes found there can be used for sorting and classifying types of incident events, as well as creating uniform human readable phrases. In the capacity of classifying incident types, ITIS phrases are used in many areas. ITIS phrases can also be freely mixed with text and used to describe many incidents.
Lane	In the context of this standard a lane is a portion of the transportation network (typically a section of roadway geometry) which is being described (its paths and various attributes about it) or referred to. In the DSRC message set, the lane object is widely used. Lanes consist not only of sections of drivable roadway traversed by motor vehicles, but other types of lanes including pedestrian and bicycle walkways, trains and transit lanes, and certain types of dividers and barriers. When used in describing an intersection, a lane is defined for each possible path into and out of the intersection (in the MAP message). The current allowed movements then applicable to that lane or its approach is provided in the SPaT message.
Lane-use control signal	A signal face displaying signal indications to permit or prohibit the use of specific lanes of a roadway or to indicate the impending prohibition of such use.
Latency	A measure of time delay experienced in a system, the precise definition of which depends on the system and the time being measured. For a data element in this context, latency is the time difference between the time that data value is acquired by the source and the time the message is transmitted.
Link (RF)	A communications channel being used in support of application data transfer needs.
Link (traffic)	A segment of a road network. While highway links are generally separated by one data collection node (such as an RSU or a vehicle detector station), local road links tend to be limited by intersections with cross streets. Other common usages of the word "link," such as those used in telecommunications, may also appear in the document.
Low Emissions Zone	A geographically defined area that seeks to restrict or deter access by specific categories of high-polluting vehicles to improve the air quality within the geographic area. The low-emissions zone can be dynamic, allowing the operating entity to change the location, boundaries, or time of the low-emissions zone.

Term	Description
MAP	Map Data Message. In the context of J2735 SE, the MAP message provides the road geometry at an intersection.
On-Board Unit	A vehicle mounted device used to transmit and receive a variety of message traffic to and from other connected devices (other OBUs and RSUs). Among the message types and applications supported by this device are vehicle safety messages, a primary subject of this standard, used to exchange information on each vehicle's dynamic movements for coordination and safety.
Periodic Snapshots	Snapshots that are generated at fixed intervals (distance or time).
Point Speed	The velocity (of a device) at a specific point in time.
Power Unit	The control and pulling vehicle for trailers or semitrailers. Also includes straight trucks, and single-unit trucks.
Precondition	A condition that must exist or be established before something can occur or be considered.
Provider Service Context	A field associated with a Provider Service Identifier (PSID) containing supplementary information related to the service. The internal format of the PSC is PSID dependent.
Provider Service Identifier	An octet string that identifies a service provided by a higher layer entity.
Public Safety On-Board Unit	An OBU or ASD mounted or in an authorized public safety vehicle.
Remote Vehicle	A connected vehicle that periodically and dynamically broadcasts a message about its general situation to a host vehicle. (See Host Vehicle).
Road Sign	A physical traffic control device intended to communicate specific information to road users through a word, symbol, and/or arrow legend. Road signs do not include highway traffic signals, pavement markings, delineators, or channelization devices.
Roadside unit	A connected device that is only allowed to operate from a fixed position (which may in fact be a permanent installation or from temporary equipment brought on-site for a period of time associated with an incident, road construction, or other event). Some RSUs may have connectivity to other nodes or the Internet.
Roadway Segment	A section of a highway improved, designed, or ordinarily used for vehicular travel and parking lanes, or that portion of a highway improved, designed, or ordinarily used for vehicular travel and parking lanes, but exclusive of the sidewalk, berm, or shoulder even though such sidewalk, berm, or shoulder is used by persons riding bicycles or other human-powered vehicles. (MUTCD, 2009, Section 1A.13)
Service Channel	Any channel that is not the control channel, intended for management frames and higher layer information exchanges. There may be more than one service channel defined in a given spectrum.
Signal Indication	Illumination of a signal lens or equivalent device. The signal face of a signal indication is an assembly of one or more signal sections that is provided for controlling one or more traffic movements on a single approach. (MUTCD, 2009, Section 1A.13).
Signal Control Zone	A geo-physical area of an intersection used for an approaching vehicle to request a preempt or priority request of a traffic signal.
Snapshot	A report including one or more status elements in the vehicle at a single point in time, along with a set of position and heading elements.
SPaT	In the context of this standard, Signal Phase And Timing (SPaT), is a message type that describes the current state of a signal system and its phases and relates this to the specific lanes (and therefore to movements and approaches) in the intersection. It is used along with the MAP message to allow describing an intersection and its current allowed movements.
Speed	The rate of progress, or change in position, usually without regard to direction. The distance traveled divided by time (if speed is constant). A scalar quantity which refers to how fast an object is moving.
Start and Stop Snapshots	Snapshots generated when a connected vehicle is stopped, and when the connected vehicle starts up again.
Timing Advertisement frames	A management frame specified in IEEE Std 802.11p used to carry timing information. [IEEE Std. 1609.4]
Transit Vehicle On-Board Unit	An OBU or ASD mounted or in a transit vehicle.
Vehicle	A self-propelled transport device, along with any attachments (e.g., trailers), that is a legal user of the transportation network.

Term	Description
Vehicle Bus	A specialized internal communications network that interconnects components within a vehicle. A commonly used protocol on the vehicle bus is the Controller Area Network (CAN). CAN (or CAN-bus) is a vehicle bus standard designed to allow microcontrollers and devices to communicate with each other within a vehicle without a host computer.
Vehicle type	In the context of this standard the vehicle type is a data element used to define overall gross size and mass of a vehicle. Observe that this definition differs from the (multiple other) vehicle types defined elsewhere in other standards used in ITS.
Vendor Specific Action Frame	A management frame specified in IEEE Std 802.11. Despite the name, when the first 36 bits of the Organization Identifier are equal to 0x0050C24A4, the contents are specified within the 1609 standards for use in carrying IEEE 1609 management information including Wireless Access in Vehicular Environments (WAVE) Service Advertisements. [IEEE Std. 1609.4]
Wireless Access in Vehicular Environments (WAVE) device	A device that is compliant to IEEE Std 1609.3, IEEE Std 1609.4, and IEEE Std 802.11, operating outside the context of a basic service set. (See IEEE Std 802.11p specification of station [STA] transmission of data frames outside the context of a basic service set.)
Wireless Access in Vehicular Environments (WAVE) Management Entity (WME)	A set of management functions required to provide WAVE networking services. It is specified in IEEE Std 1609.3.
Wireless Access in Vehicular Environments (WAVE) Service Advertisement (WSA)	A data structure specified in IEEE Std 1609.3 containing information including the announcement of the availability of services.
Wireless Access in Vehicular Environments (WAVE) Short Message Protocol (WSMP)	A protocol for rapid exchange of messages in a rapidly varying radio frequency (RF) environment where low latency is also an important objective. It is specified in IEEE Std 1609.3.
Work Zone	An area of a highway with construction, maintenance, or utility work activities. A work zone is typically marked by signs, channelizing devices, barriers, pavement markings, and/or work vehicles. A work zone extends from the first warning sign or high-intensity rotating, flashing, oscillating, or strobe lights on a vehicle to the END ROAD WORK sign or the last Temporary Traffic Control device (MUTCD 2009, Section 6C.02).

1.5 Abbreviations

The abbreviations used in this Standard Publication are defined as follows:

ABS	Anti-lock Brake System
ADA	Americans with Disabilities Act
ALC	A La Carte
ASD	Aftermarket Safety Device
BER	Basic Encoding Rules
BLOB	Binary Large Object
BSM	Basic Safety Message
BSW	Blind Spot Warning
CAMP	Crash Avoidance Metrics Partnership
CAN	Controller Area Network
CFCW	Cooperative Forward Collision Warning
CICAS	Cooperative Intersection Collision Avoidance System
CICAS-V	Cooperative Intersection Collision Avoidance System - Violation
CLW	Control Loss Warning
CMV	Commercial Motor Vehicle
CVOBU	Commercial Motor Vehicle On-Board Unit
ConOps	Concept of Operations
CSR	Common Safety Request
DNPW	Do Not Pass Warning
DSRC	Dedicated Short Range Communications

EEBL	Emergency Electronic Brake Lights
EMV	Emergency Management Vehicle
EOBR	Electronic On-Board Recorders
FCC	Federal Communications Commission
FCW	Forward Collision Warning
FHWA	Federal Highway Administration
FIPS	Federal Information Processing Standard
FMCSA	Federal Motor Carrier Safety Administration
GPS	Global Positioning System
HAZMAT	HAZardous MATerial
HDOP	Horizontal Dilution of Precision
HMI	Human Machine Interface
HOT	High Occupancy Toll
HOV	High Occupancy Vehicle
HRI	Highway Rail Intersection
ICA	Intersection Collision Avoidance
ID	Identifier
IEEE	Institute of Electrical and Electronics Engineers
IMA	Intersection Movement Assist
ITIS	International Traveler Information Systems
ITS	Intelligent Transportation Systems
LCW	Lane Change Warning
MAC	Medium Access Control
MAP	Map Data Message
MH	Message Handler
mph	miles per hour
mSec	ms
MUTCD	Manual of Uniform Traffic Control Devices
NMEA	National Marine Electronics Association
NRTM	Needs to Requirements Traceability Matrix
NTCIP	National Transportation Communications for ITS Protocols
OBD	On-board Diagnostics
OBUE	On-Board Unit
OEM	Original Equipment Manufacturer
OER	Octet Encoding Rules
OTA	Over-The-Air
PER	Packed Encoding Rules
PHY	Physical Layer
PIN	Personal Identification Number
POC	Proof-of-Concept
PRL	Protocol Requirements List
PSC	Provider Service Context
PSID	Provider Service IDentifier
PSN	Probe Segment Number
PSOBU	Public Safety On-Board Unit
PTV	Public Transit Vehicle
RF	Radio Frequency
RITA	Research and Innovative Technology Administration
RSU	Roadside Unit
RTCM	Radio Technical Commission for Maritime Services
SAE	Society of Automotive Engineers
SCH	Service CHannel
SE	Systems Engineering
SME	Subject Matter Expert
SPaT	Signal Phase and Timing
SRS	Software Requirements Specification
TA	Basic Threat Arbitration Module

TC	Target Classification (module)
TCIP	Transit Communications Interface Profiles
TrVOBU	Transit Vehicle On-Board Unit
URL	Uniform Resource Locator
USDOT	United States Department of Transportation
UTC	Coordinated Universal Time
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
VII	Vehicle Infrastructure Integration
VIN	Vehicle Identification Number
VMT	Vehicle Miles of Travel
VSC-2	Vehicle Safety Communications II - (a consortium at CAMP)
VSC-A	Vehicle Safety Communications - Applications. (a joint effort of USDOT, Vehicle Safety Communications 2 (VSC2) and CAMP)
WAVE	Wireless Access in Vehicular Environments
WME	Wireless Access in Vehicular Environments (WAVE) Management Entity
WMI	World Manufacturer Identifier
WMO	World Meteorological Organization
WSA	Wireless Access in Vehicular Environments (WAVE) Service Advertisement
WSM	Wireless Access in Vehicular Environments (WAVE) Short Message
WSMP	Wireless Access in Vehicular Environments (WAVE) Short Message Protocol

2. SECTION 2 - CONCEPT OF OPERATIONS [NORMATIVE]

This Section 2 describes the Concept of Operations (ConOps) for the SAE J2735 SE candidate, which covers the information exchange between applications that may be deployed in conjunction with wireless communications related to the next generation intelligent transportation system, currently referred to as the *Connected Vehicle* program.

A ConOps describes the ways a proposed system will be used from the users' perspective. The ConOps is one of the first key outputs of the systems engineering process and forms the basis for the definition of requirements. The ConOps stage of the systems engineering process is used to ensure that the system developers document a thorough understanding of the users' needs.

For the SAE J2735 SE candidate, the ConOps identifies and documents the various operational needs (capabilities) that users may have for SAE J2735 SE information, and that subsequent sections within the SAE J2735 SE candidate will address.

The ConOps provides the reader with:

- A detailed description of the scope of the SAE J2735 SE candidate;
- An explanation of how the SAE J2735 SE candidate is expected to fit into the larger context of the Connected Vehicle environment;
- A starting point in the procurement process; and
- An understanding of the perspective of the designers of the SAE J2735 SE.

The ConOps is intended to be used by the following groups of users:

- Transportation Agencies;
- Transportation Enforcement Agencies;
- Systems Integrators;
- Vehicle Manufacturers; and

- Device Manufacturers.

Readers will find this section useful for understanding how the SAE J2735 SE candidate can be used in their system(s). It serves as the starting point in the procurement and specification process. Procurers and specification writers, such as the transportation agencies and transportation enforcement agencies, can become familiar with each capability addressed by the SAE J2735 SE candidate and determine whether that capability is appropriate for their implementation. If it is, then their implementation will require the capability and all of the mandatory requirements related to that capability.

The last three bulleted groups of users will find this section useful to gain a more thorough understanding as to why the more detailed requirements (as specified in later sections of this standard) exist.

2.1 Tutorial [Informative]

A concept of operations describes a proposed system from the users' perspective. Typically, a concept of operations is used on a project to ensure that the system developers understand the users' needs. Within the SAE J2735 SE candidate, the concept of operations documents the scope of the standard, the interfaces addressed by the standard, and various operational needs (features) that users may have for SAE J2735 SE information. The concept of operations also serves as the starting point for agencies to select those features that may be appropriate for a specific procurement.

The concept of operations starts with a discussion of the current situation and issues that have led to the need to deploy systems within the scope of the standard and to the development of the standard itself. This discussion permits both potential users and system developers to understand the situation.

The concept of operations then documents key aspects of the proposed system, including:

- Reference Physical Architecture (Section 2.3) - The reference physical architecture defines the overall context of the proposed system and defines which specific interfaces are addressed.
- Architectural Needs (Section 2.4) - The architectural needs discuss issues and needs relative to the system architecture.
- Features (Section 2.5) - The features identify and describe the various functions that users may want the system to perform. These features are derived from the high level user needs identified in the problem statement but are refined and organized into a more manageable structure that forms the basis of the traceability table contained in Section 3 (Functional Requirements).

Architectural needs and features are collectively called "user needs". In Section 3, these user needs are traced to the various functional requirements of the connected vehicles environment. Basic systems engineering requires that:

- Each user need traces to one or more functional requirement(s), and
- Each functional requirement derives from at least one user need.

This traceability is shown in the Protocol Requirements List (PRL) in Section 3.3.3.

The SAE J2735 SE is intended for use in a broad range of prospective implementations. Within the PRL, each user need and requirement is identified as mandatory, optional, or conditional, and users of this standard may complete the PRL to clearly define unique aspects of their implementation. Within the SAE J2735 SE, items marked mandatory are those that relate to the most basic functionality of connected devices. For specific implementations, the user identifies those optional or conditional needs appropriate for a specific implementation.

In Appendix A, each requirement is presented in a Requirements Traceability Matrix (RTM), which defines how the requirement is fulfilled through data concepts, such as dialogs, messages, and data element definitions.

NOTE: Off-the-shelf interoperability and interchangeability can only be obtained by using well documented user needs, along with their corresponding requirements and design, which are broadly supported by the industry as a whole. Users should be aware that designing a system that uses environments or features not defined in a standard or not typically deployed in combination with one another, may inhibit the goals of interoperability and interchangeability, especially if the documentation of these user needs is not available for distribution to system integrators. The standards allow implementations to support additional user needs in order to support innovation, which is constantly needed within the industry; but users should be aware of the risks involved with using such environments or features.

The concept of operations concludes by:

- Describing the degree to which security issues have been addressed by the standard (Section 2.6);
- Describing the extent to which policies or constraints relative to the operational environment have a direct impact on the implementation of this standard (Section 2.7);
- Providing a description of how the SAE J2735 SE candidate relates to the National ITS Architecture; (Section 2.8) and
- Presenting operational scenarios that demonstrate how a proposed system using the SAE J2735 SE candidate should operate and interact with its users under specific circumstances (Section 2.9).

2.2 Current Situation and Problem Statement [Informative]

2.2.1 Background

One of the key concepts of the original VII program was to use DSRC to provide vehicle-to-vehicle and vehicle-to-infrastructure connectivity for exchanging data that supported safety and mobility applications both in the vehicle and in the infrastructure. An interim version of the SAE J2735 standard was developed and tested as part of the Proof of Concept in Detroit. Following several years of effort, the current version of SAE J2735 was published in 2009. The scope of the current SAE J2735 is focused on the message set, data frames, and data elements exchanged between applications on vehicles and the roadside via wireless communications technologies. The current standard does not define its scope in more detail in the normative sections of the standard, but does contain a series of informational appendices that describe use and operation of the key messages defined in the standard.

The current standard does have a clear statement of objectives, which is:

“Public sector organizations throughout the world have identified the need to reduce fatalities and serious injuries that result from vehicle crashes, as well as the need to reduce traffic congestion. The use of wireless and computer technologies in vehicles, and on the roadway infrastructure, has been identified as promising areas to provide solutions for these needs. Intelligent Transportation System (ITS) planning in many regions of the world has therefore become focused on supporting applications that utilize a common platform to address three priorities:

- *Safety*
- *Mobility*
- *Commercial (or Private)*

Safety applications, in particular, must be interoperable between vehicles from different manufacturers and between vehicles and roadway infrastructure within all the areas where the vehicle is likely to travel. This requirement for interoperability is also relevant to contemplated mobility applications. This SAE Standard specifies messages, data frames and data elements that allow interoperability at the application layer without the need to standardize applications. This approach supports innovation and product differentiation through the use of proprietary applications, while maintaining interoperability by providing a standard message set that can be universally generated and recognized by these proprietary applications."¹ Note that an additional environment priority has also been defined by the USDOT, which is performing research to define connected vehicle applications relating to the environment.

To describe the needs and operations supported by SAE J2735, this document will use the following terminology, which have been taken from the proof-of-concept (POC) programs implemented by the Crash Avoidance Metrics Partnership (CAMP) and the Cooperative Intersection Collision Avoidance System (CICAS) project:

- **RSU - Roadside Unit.** A connected device that is only allowed to operate from a fixed position (which may in fact be a permanent installation or from temporary equipment brought on-site for a period of time associated with an incident, road construction, or other event).
- **OBU - On-Board Unit.** A vehicle-mounted device used to transmit and receive a variety of message traffic to and from other connected devices (other OBUs and RSUs).
- **Host vehicle².** A connected vehicle that receives messages from a remote vehicle. [In this document, the host vehicle is also used to describe the originator of a vehicular transmission of information to the RSU.]
- **Remote vehicle.** A connected vehicle that periodically and dynamically broadcasts a message about its general situation to a host vehicle.

2.2.2 Description of the Current Situation

Currently there are no operational deployments of DSRC for Vehicle-to-Vehicle (V2V) safety or mobility applications. However, there are widespread deployments of Vehicle-to-Infrastructure (V2I) applications using DSRC at 915MHz including electronic toll and transit signal priority. From a V2I perspective, there are only limited deployments of V2I applications using IEEE 1609 (DSRC at 5.9 GHz). One example of this is a recent tolling implementation in Oregon. Although there are initiatives under development to deploy widespread connected vehicle applications (using 5.9 GHz DSRC) in operational environments, to date, there are only a few controlled test beds that support the SAE J2735 SE environment. Select tests have been conducted in Ohio, California, and Virginia for V2I. The proof of concept tests conducted at the Michigan test bed used an earlier version of J2735 as did the demonstrations deployed in New York during the 2008 ITS World Congress.

The V2I field tests were conducted in conjunction with the CICAS project, which was a joint effort of the U.S. Department of Transportation (USDOT) and the CAMP Vehicle Safety Communications II (VSC-2) Consortium. The V2V field tests were conducted by the Vehicle Safety Communications - Applications (VSC-A) which is a joint effort of USDOT and the CAMP VSC-2.

The V2I tests conducted by the CICAS-V program implemented a system as depicted in Figure 1.

¹ SAE J2735, Dedicated Short Range Communications (DSRC) Message Set Dictionary, 2009-11-19, p. 23.

² Derived from CAMP definitions for Host and Remote (also called "target") vehicle roles. See for description of test and remote Vehicle Safety Communications-Applications Final Report (VSC-A) p6.

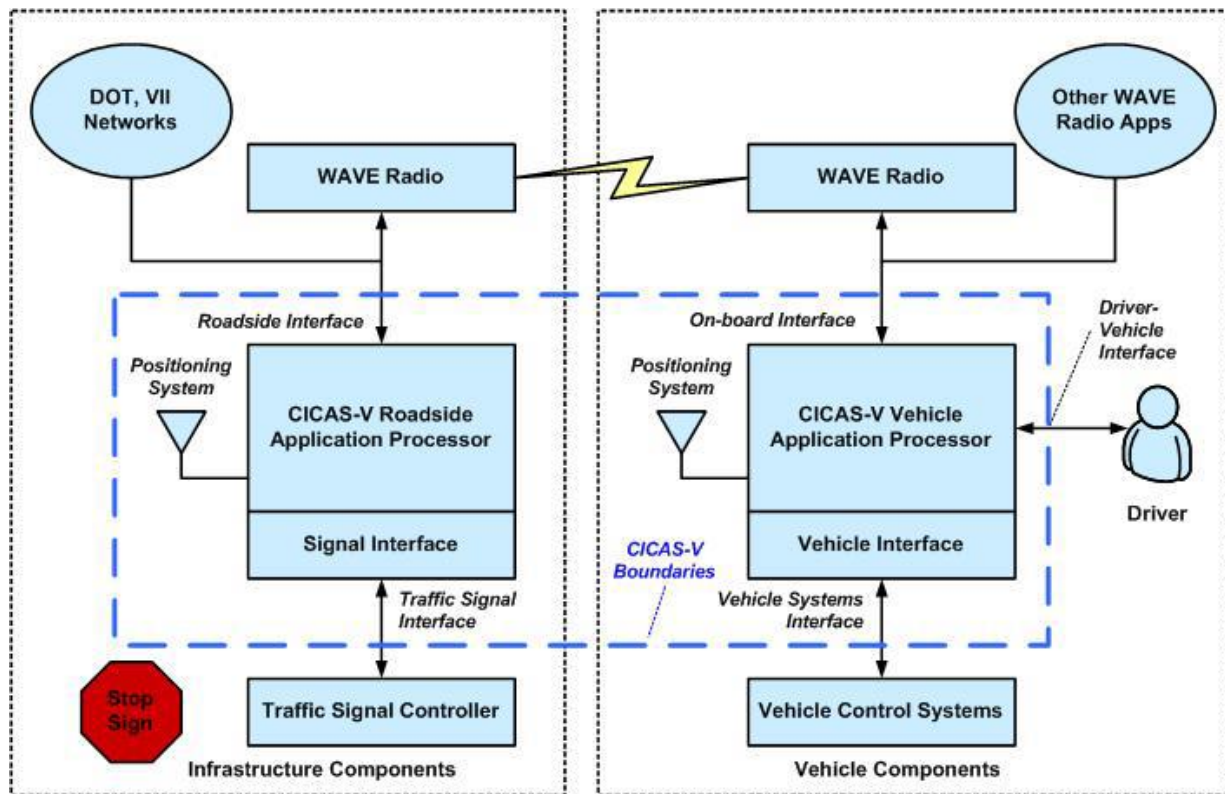


FIGURE 1 - CICAS-V SYSTEM WITH INTERFACES [FROM CICAS-09-0118.PDF]

The VSC-2 tests implemented a suite of standards as follows:

- The Basic Safety Message (BSM) as defined in the SAE J2735 Message Set Dictionary standard;
- The Full-Use 1609.3 and 1609.4 standards published in December 2010;
- The Full-Use 1609.2 draft standard; and
- The 802.11p amendment for the Medium Access Control (MAC) and Physical (PHY) layers as published in June 2010.

There has been no testing of the current SAE J2735 standard. However an earlier version was used in the Proof-of-Concept testing in Detroit in 2005. In this test, various services were provided to the vehicles. Those that are part of the SAE J2735 Message Set included: Probe Data; Probe Data Management and Advisory Message Delivery. The results are reported in FHWA-JPO-09-038 Final Report: Vehicle Infrastructure Integration (VII) Proof of Concept (POC) Test - Executive Summary. Booz Allen Hamilton. February 2009. The report states: "Booz Allen conducted the standards testing during all three phases of the VII test program. The scope of this testing included validating that the IEEE 1609 and 802.11p suite of standards as well as the SAE J2735 standards (POC DSRC Message Sets) function properly throughout the VII network, including in the 5.9 GHz band allocated for use with VII." The conclusions concerning J2735 included: "The usage descriptions and content of some SAE J2735 messages need to be updated to avoid uncertainty during development and implementation. A constant line of communications was open between POC developers and the SAE during development, resulting in the majority of the issues being addressed in SAE J2735 Version 2.0."

2.2.3 Stakeholders and Other Involved Personnel

This section describes the users who have needs to exchange information across the connected vehicle interfaces defined as part of SAE J2735 SE. In most standard development efforts, a user is a “person who will use the system that is developed”³. In the development of SAE J2735 SE user needs, the people who will use the system that is developed are certainly present, but due to the nature of the operational policies (Section 2.7), the definition of user includes a vehicle that is equipped as a connected vehicle system. In addition, stakeholders also include groups of users having needs relevant to SAE J2735 SE. The users that have defined needs relative to SAE J2735 interfaces include:

- **Vehicle Drivers.** Drivers of general vehicles, commercial vehicles, heavy vehicles (e.g., snowplows), and transit vehicles have a variety of needs that can be addressed by the interfaces defined in SAE J2735.
- **Vehicles (Remote Vehicle, Host Vehicle).** SAE J2735 is meant to support deployment of on-board vehicle systems operating in general, commercial, heavy, emergency, and transit type vehicles. These equipped vehicles can provide warnings to drivers, automatically perform related actions (e.g., collision avoidance), or provide other forms of travel related information. Because these equipped vehicles may operate without direct intervention by the driver or operator, and their operation is a key aspect of the overall user needs, the vehicles themselves are considered a user. This category also includes aftermarket safety devices (ASDs) and other mobile devices that can perform similar warning or travel information related functions when in the vehicle.
- **Transportation Agencies.** This type of user represents the staff at transportation agencies, which include traffic operations agencies at any level of government (e.g., national, state or local), transit agencies, toll authorities, or private companies operating a highway concession. It also includes private information service providers who might collect vehicle data to support traveler information capabilities. Finally, it includes commercial vehicle credentials and safety agencies, as well as maintenance personnel.
- **Emergency Responders.** This type of user represents the staff of providers of emergency services, including public safety providers. Examples include law enforcement, fire department, ambulances, or environmental protection agencies that respond to hazmat incidents. In some cases this user overlaps with the Vehicle Driver user listed above (for example when considering the driver of an emergency vehicle).
- **Vehicle Manufacturers and Fleet Operators.** This type of user represents companies that manufacture or operate automobiles, trucks, transit vehicles, or any other specialized vehicles. This type of user is included because of needs identified for the manufacturers or operators to provide data transfers to the vehicles, of which the data may be proprietary to the manufacturer or the fleet operator.

2.2.4 Objectives

The objectives of the proposed system have been articulated very well by the current SAE J2735 standard and are repeated below:

“Public sector organizations throughout the world have identified the need to reduce fatalities and serious injuries that result from vehicle crashes, as well as the need to reduce traffic congestion. The use of wireless and computer technologies in vehicles, and on the roadway infrastructure, has been identified as promising areas to provide solutions for these needs. Intelligent Transportation System (ITS) planning in many regions of the world has therefore become focused on supporting applications that utilize a common platform to address three priorities:

- Safety
- Mobility
- Commercial (or Private)

³NTCIP 1204 v03.06: National Transportation Communications for ITS Protocol Environmental Sensor Station Interface Standard – Version 03, December 2007

Safety applications, in particular, must be interoperable between vehicles from different manufacturers and between vehicles and roadway infrastructure within all the areas where the vehicle is likely to travel. This requirement for interoperability is also relevant to contemplated mobility applications. This SAE Standard specifies messages, data frames and data elements that allow interoperability at the application layer without the need to standardize applications. This approach supports innovation and product differentiation through the use of proprietary applications, while maintaining interoperability by providing a standard message set that can be universally generated and recognized by these proprietary applications."

The USDOT Research and Innovative Technology Administration (RITA), identifies the objective of the connected vehicle (technologies) as to:

"...tackle some of the biggest challenges in the surface transportation industry, in the areas of safety, mobility, and environment.

- **Safety:** In 2009, there were 5.5 million crashes, resulting in 33,808 fatalities and 2.2 million injuries. Our children and young people are particularly vulnerable. Motor vehicle crashes are the leading cause of death for ages 3 through 34. Connected vehicle technologies provide the tools to make transformational improvements in safety - to significantly reduce the number of lives lost each year through connected vehicle crash prevention applications.
- **Mobility:** U.S. highway users waste 4.8 billion hours a year stuck in traffic - nearly one full work week (or vacation week) for every traveler. The overall cost (based on wasted fuel and lost productivity) reached \$115 billion in 2009 - more than \$808 for every U.S. traveler. Delays in Truck operations alone result in \$33 billion. Connected vehicle mobility applications will enable system users and system operators to make choices that reduce travel delay.
- **Environment:** The total amount of wasted fuel topped 3.9 billion gallons in 2009 according to the Texas Transportation Institute - 130 days of flow in the Alaska Pipeline (nearly a third of the year). Connected vehicle environmental applications will enable system users and system operators to make choices that reduce the environmental impacts of surface transportation travel."⁴

To that end, the scope of the SAE J2735 SE system environment is the information exchange between a host vehicle and remote vehicles and between a host vehicle and the roadside, to address safety, mobility, and environmental system needs.

The SAE J2735 SE candidate is an information level standard that can be used to develop a system interface for information exchange with a connected vehicle. SAE J2735 SE will specify dialogs, messages, data frames, and data elements specifically for use by applications intended to utilize the 5.9 GHz Dedicated Short Range Communications for Wireless Access in Vehicular Environments (DSRC/WAVE, referenced in this document simply as DSRC). SAE J2735 SE is intended for use over DSRC as defined in the IEEE 1609 suite of standards. However the SAE J2735 SE messages can also be used over other media.

SAE J2735 SE is intended to define over-the-air messages that are transmitted to and from equipment located in vehicles traveling on the surface street and freeway network. The equipment in the vehicle will most likely be connected to the vehicle, but J2735 SE could also be used by equipment that is not connected to the vehicle.

SAE J2735 SE does not define applications, either in the vehicle or in the infrastructure.

⁴ USDOT, http://www.its.dot.gov/connected_vehicle/connected_vehicles_FAQs.htm, February 1, 2012.

2.3 Reference Physical Architecture

2.3.1 Typical Physical Architecture [Informative]

The SAE J2735 SE is part of a larger environment currently under development by the USDOT program and a variety of stakeholder groups. The SAE J2735 SE is limited to the over-air messaging between road vehicles (V2V), and between vehicles and roadside units (V2I). Note in this document the term V2I is meant to represent the interface between a vehicle and roadside unit, and unless specifically indicated V2I represents information going either direction on the interface. It covers the information exchange between the OBUs on vehicles of different modes, classes, and manufacturers, and between OBUs on vehicles and RSUs. Furthermore, the J2735 SE is intended for use over Dedicated Short Range Communications (DSRC) protocols. The current SAE J2735 standard requires that all messages can operate over DSRC as defined by the IEEE 1609 suite of standards. However, the SAE J2735 standard also indicates that the messages may be used over other communications technologies. The intention is to continue this approach with SAE J2735 SE.

Figure 2 shows the variety of users that may operate in the SAE J2735 SE environment.

A connected vehicle is a vehicle with an in-vehicle device sending the Basic Safety Message (BSM) for vehicle safety applications. In this document three (3) different in-vehicle systems are considered to be a connected vehicle. Those are:

- **Integrated Vehicles (IV).** Those vehicles have On-board Equipment (OBE) installed by an OEM. The OBEs in those vehicles have full access to all the vehicle information that is available on the vehicle bus.
- **Here I Am Devices (HIA).** Those devices are installed in the vehicle but do not have any safety applications running and are not connected to a vehicle bus.
- **Aftermarket Safety Devices (ASD).** Those devices are installed in the vehicle and have safety applications running. They may or may not have access to vehicle information through a vehicle bus.

Connected vehicles include the following types: passenger, commercial, transit, and emergency. OBUs may be embedded in the vehicle, or ASDs may be installed or operating within the vehicle. The RSU acts as a conduit to connect the *connected vehicles* in the SAE J2735 SE environment to other downstream users such as transportation organizations, centers, and operators or to other ITS roadside equipment. The Core Systems shown in Figure 2 represents center based systems that provide the support services and distribution mechanism to support connected vehicle operations.

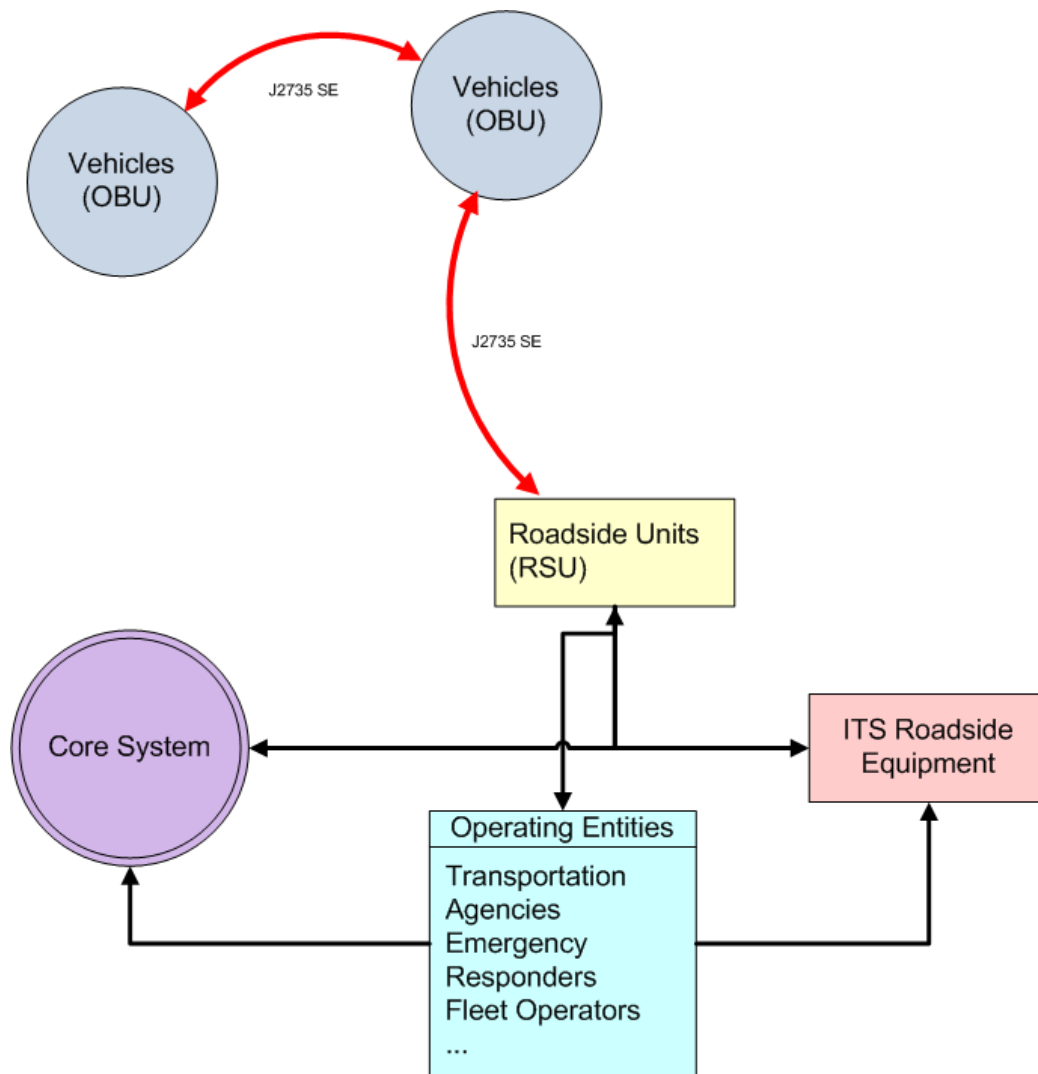


FIGURE 2 - CONNECTED VEHICLES SYSTEM OVERVIEW

2.3.2 SAE J2735 SE Device Characteristics [Normative]

A factor that complicates the development of SAE J2735 SE and that complicates the work of a specification developer is the fact that there are two different types of devices addressed by the SAE J2735 SE candidate - an OBU in a vehicle, and an RSU at the roadside. To promote interoperability among these devices, the J2735 SE must provide a single protocol that is compatible with both types of devices. However, the differences between these two types of (SAE J2735 SE) devices dictates that not all features defined within SAE J2735 SE are applicable to an RSU or an OBU. Thus, the user must categorize those features specific to an OBU or an RSU prior to determining which requirements are mandatory for a particular project.

The SAE J2735 SE recognizes two basic types of devices as described below. In addition, the SAE J2735 SE candidate recognizes there are some user needs that are specific to an On-Board Unit on a specific type of vehicle.

2.3.2.1 On-Board Unit (OBU)

A vehicle mounted device used to transmit and receive a variety of message traffic to and from other devices (other OBUs and RSUs).

2.3.2.2 Roadside Unit (RSU)

Device used to transmit to, and receive from, equipped moving vehicles (OBUs). The RSU transmits from a fixed position on the roadside (which may in fact be a permanent installation or from temporary equipment brought on-site for a period of time associated with an incident, road construction, or other event).

2.3.2.3 Public Safety On-Board Unit (PSOBU)

An OBU or ASD mounted or in an authorized public safety vehicle.

2.3.2.4 Transit Vehicle On-Board Unit (TrVOBU)

An OBU or ASD mounted or in a transit vehicle.

2.3.2.5 Commercial Motor Vehicle On-Board Unit (CVOBU)

An OBU or ASD mounted or in a vehicle moving goods, heavy equipment or people (includes motor coaches).

2.4 Architectural Needs

2.4.1 Fundamental Needs Driving Connected Vehicles Deployment

The provision of timely and reliable information between connected vehicles and between connected vehicles and roadside units is used to support applications to address safety, mobility, and environmental needs.

2.4.2 Operational Environment

SAE J2735 SE addresses the over-the-air interface between connected vehicles, and between a connected vehicle and a roadside unit. Each connected device needs to establish communications with other connected devices within its operational range.

This communications system must support the operation of secure wireless communications between the authorized connected devices. Applications will utilize this communications system to provide a variety of services to different users, including drivers, roadway operators, transit operators, public safety agencies, and maintenance personnel.

2.5 Features

Highway safety efforts over the past few decades have been focused on the reduction of crashes and the amelioration of their effects. Improvement in crash rates over the years have resulted from better education, improved legislation, traffic engineering improvements, and safer vehicles design. While these measures have resulted in reduced traffic fatalities over the past decade, the improvements have shown signs of leveling off in recent years. The connected vehicle program, which is supported by development of SAE J2735, has as one of its goals, a significant reduction in collisions on the roadways, which will translate to a significant improvement in road safety.

The operation of transportation networks and the vehicles that use them has historically been one where little information is known about the traffic flow and levels of congestion. Real-time data has been collected on only a small portion of the interstate network and virtually none of the arterial streets. This lack of data has resulted in the development of traffic operations that includes a lot of guesswork. Information given to drivers is often inefficient and not focused, little or no information is available on alternate routes and the operators who provide the data have no feedback on the efficacy of their actions. The potential exists for connected vehicles to make transformational changes to the way transportation networks operate. By allowing the ubiquitous monitoring of the transportation network, the connected vehicle program will enable new operational strategies. Operators will be able to provide focused, location-based traffic information to drivers prior to congestion points, and to see and measure the consequences of their actions.

Historically in the US, the effects of transportation on the environment have not been a driving factor but this is changing. The connected vehicle program has the ability to use data from vehicles to estimate fuel consumption and emissions. Combining this with transportation operations strategies and other data will allow operations that are optimized for environmental benefits.

The connected vehicle benefits for safety, mobility, and the environment cannot occur without a standardized way of communicating between vehicles and between the vehicles and the infrastructure. These communications must be interoperable and manufacturer-independent to work with the variety of connected devices that are likely to be deployed. This is a formidable task that requires a standardized solution that defines the various communication layers and the data to be sent. The lower level communications layers are defined in IEEE 802.11p and IEEE 1609; the data to be sent is defined in SAE J2735.

Thus, the nature of the changes between the current situation and a future with connected vehicles is extensive. It will impact all drivers, vehicles, and transportation agencies. It will open new fields for innovative applications in the vehicle, in transportation agencies, and in mobile devices.

2.5.1 Introduction to User Needs

Section 2.5 contains specific information on the user needs for the SAE J2735 SE environment. The first step in the development of the revision to the standard is to identify the user operational needs that the proposed SAE J2735 SE candidate will address.

There were two primary sources of user needs for this project. The first source of user needs was a literature review of relevant documentation including the existing SAE J2735 Standard, the outputs of the Core System for Connected Vehicles, and other relevant ongoing research related projects and programs, including other programs similar in concept to Connected Vehicles outside of the United States.

The second source of user needs was interviews with subject matter experts (SMEs) to obtain their inputs on operational needs related to connected vehicle applications. Contributors to these user needs are documented in a User Needs Report.

The user needs provide an expression of the end users' operational needs that can be met by information that goes into or out of a connected vehicle, either from one connected vehicle to another connected vehicle, or from one connected vehicle to the infrastructure (or the reverse).

The following criteria will be used as the basis for documenting well-written needs:

1. **Uniquely Identifiable.** Each need must be uniquely identified (i.e., each need shall be assigned a unique number and title).
2. **Major Desired Capability (MDC).** Each need must express a major desired capability in the system, regardless of whether the capability exists in the current system or situation or is a gap.
3. **Solution Free.** Each need must be solution free, thus giving designers flexibility and latitude to produce the best feasible solution.
4. **Capture Rationale.** Each need must capture the rationale or intent as to why the capability is needed in the system.

The User Needs are divided into two major sets:

- Vehicle-to-vehicle (V2V)
- Vehicle-to-infrastructure (V2I)

Vehicle-to-infrastructure is assumed to be bi-directional that is, vehicle-to-infrastructure and infrastructure-to-vehicle.

The user needs were divided into groups to reflect the differences in the types of information exchanged and to mirror the USDOT connected vehicle program. The needs are further divided into other classes of information needs, some related to the end users as described in Section 2.2.3 Stakeholders and Other Involved Personnel

These classes are grouped as follows:

- V2V
 - Crash Prevention Safety
 - Situational Awareness
 - Emergency Vehicle Alert
 - Vehicle Emergency Response
 - Mayday Request
- V2I
 - Safety Related User Needs
 - Mayday Forward
 - Mayday Request to Infrastructure
 - Commercial Vehicle Operations User Needs
 - Data Capture and Management Needs
 - Vehicle Data for Traffic Operations
 - Vehicle Data for Highway Maintenance and Design
 - Vehicle Data for Environment Monitoring
 - Vehicle Data to Determine Hazardous Road Conditions
 - Vehicle Data for Weather Forecasting
 - Vehicle Data for Emergency Response
 - Vehicle Data for Transit Operations
 - Traveler Related User Needs
 - Emergency Response Needs
 - Transit Operations Needs
 - Vehicle Manufacturers and Fleet Operators User Needs

The sections below list the user needs (in *italics*) followed by a summary of the rationale for the need.

2.5.2 V2V User Needs

2.5.2.1 Crash Prevention Safety

2.5.2.1.1 Forward Collision Prevention

The host vehicle needs to determine that the conditions of a remote vehicle indicate that a collision with the host vehicle is imminent in order to perform crash prevention actions. Prevention is defined as, “<an> action of stopping something from happening or arising.” This capability is intended to help drivers avoid a collision with an equipped vehicle ahead in traffic in the same lane and direction of travel and can be applied to all types of vehicles. This capability covers a range of actions from warnings to the driver to actions taken automatically by the vehicle to avoid an imminent forward collision (e.g., automatically applying the brakes) and is particularly useful when the driver’s line of sight is obstructed by other vehicles, bad weather conditions, or roadway geometry. One type of warning that could be provided is that remote vehicles are performing emergency braking. The host vehicle must take into account the unique characteristics of the size and weight of the remote vehicles, such as commercial vehicles and transit vehicles, which may help determine stopping distances and the distance between the vehicles.

2.5.2.1.2 Intersection Movement Assist

The host vehicle approaching an intersection needs to determine the conditions of remote vehicles entering or currently in the intersection in order to perform intersection crash prevention actions. This capability enables the host vehicle to anticipate impacts where vehicle paths cross and then perform crash prevention actions to reduce the likelihood of crashes at intersections.

2.5.2.1.3 Pre-crash Actions

The host vehicle needs to determine that the conditions of remote vehicles indicate that a collision with the host vehicle is imminent in order to perform actions just before the impact occurs. This capability enables the host vehicle to determine that the crash is about to happen, then to mitigate the injuries in a crash by activating countermeasures in the vehicle. This information would supplement other information within the host vehicle. These countermeasures could include air bag pre-arming, pyrotechnic and non-pyrotechnic seat belt pre-tensioning, bumper extension or lowering, and emergency brake assist.

2.5.2.1.4 Control Loss Warning

The host vehicle needs to *determine* when a nearby remote vehicle is experiencing a loss of control that may result in an unsafe condition for the host vehicle. This capability enables a remote vehicle to broadcast a self-generated, control loss event to surrounding vehicles. Upon receiving such event information, a host vehicle can determine the relevance of the event and take appropriate actions, such as providing a warning to the driver.

2.5.2.1.5 Lane Change Warning

The host vehicle needs to determine that the conditions of nearby remote vehicles make it unsafe for the driver to perform a lane change maneuver. This capability enables the host vehicle to determine if the area into which the host vehicle intends to switch is, or will soon be, occupied by another vehicle traveling in the same direction. The host vehicle can use this information to take appropriate actions, such as warning the driver of the vehicle conflict.

2.5.2.1.6 Do Not Pass Warning

The host vehicle needs to determine if the conditions of nearby remote vehicles make it unsafe for the driver to initiate a passing maneuver past a remote vehicle ahead in its lane. This capability enables a host vehicle to determine if a passing maneuver of a slower moving vehicle, ahead and in the same lane, cannot be safely attempted using a passing zone which is occupied or will be occupied by vehicles with the opposite direction of travel. The host vehicle can use this information to take appropriate action, such as warning the driver of the potential vehicle conflict.

2.5.2.1.7 Blind Spot Warning

The host vehicle needs to determine that the conditions of nearby remote vehicles indicate that a nearby remote vehicle is in the blind spot area of the host vehicle. This capability enables the host vehicle to determine if the area on either side of the host vehicle is occupied by another vehicle traveling in the same direction. The host vehicle can use this information to take appropriate actions, such as warning the driver of the vehicle conflict.

2.5.2.1.8 Facilitate Development and Testing

During development and testing, it is preferable to have information exchanged in a format that contains some amount of redundant formatting so that any informational or encoding errors can more easily be detected.

2.5.2.2 Situational Awareness

The host vehicle needs to determine if the road conditions measured by remote vehicles represent a potential safety hazard for the host vehicle. This capability enables relevant road condition information, such as fog or icy roads, to be broadcast from a remote vehicle and received by the host vehicle. This capability allows connected vehicles to share situational awareness information even in areas where no I2V infrastructure exists. This can be useful to host vehicles that are not fully equipped with sensors, or host vehicles entering an area with hazardous conditions.

2.5.2.3 Emergency Vehicle Alert

The host vehicle needs to receive information about the location and status of nearby emergency vehicles responding to an incident. This capability enables the host vehicle to alert the driver about the location of and the movement of public safety vehicles responding to an incident so the driver does not interfere with the emergency response.

2.5.2.4 Vehicle Emergency Response

Emergency responders need information about remote vehicles involved in a crash to respond safely and effectively to a vehicle crash. Because this information has privacy considerations, drivers need the ability to opt in to this capability. This capability enables public safety vehicles to receive information concerning the vehicles involved in accidents. Information such as HAZMAT data can assist the responders on-board the responding public safety vehicle to prepare. Information about air bag activations can provide useful input to ambulance staff.

2.5.2.5 Mayday Request

The remote vehicle, if involved in an accident, needs to be able to transmit its circumstances to public safety agencies. One capability would be to enable a host vehicle to receive automated mayday requests from remote (disabled) vehicles, so the host vehicle can forward mayday requests to emergency response services. Remote vehicles would automatically transmit these mayday requests when it detects indications of a crash, such as the deployment of airbags. This capability allows a host vehicle to forward mayday requests even in areas where no V2I infrastructure exists. Because this information has privacy considerations, drivers need the ability to opt in to this capability.

2.5.2.6 Transit Vehicle Crash Warning

A connected transit vehicle needs to determine that the conditions of nearby remote vehicles indicate that a nearby remote vehicle is pulling in front of the transit vehicle to make a turn. This capability enables the transit vehicle to determine if the area in front of it will not be occupied as it begins to pull away from a transit stop.

2.5.3 V2I User Needs

2.5.3.1 Safety and Eco Driving Related User Needs

2.5.3.1.1 Data to Determine Stopline Violations at Unsignalized Intersections

A connected vehicle needs the data to determine that a stopline violation may occur at an unsignalized intersection. This capability enables a connected vehicle to receive information from the infrastructure regarding the geometry of the intersection. This capability allows a connected vehicle to predict if the speed and acceleration profile of the vehicle makes it appear likely that the vehicle will enter the intersection in violation of a stop sign.

2.5.3.1.2 Data to Determine Stopline Violations at Signalized Intersections and Grade Crossings

A connected vehicle needs the data to determine that a stopline violation may occur at a signalized intersection or a railroad grade crossing. This capability enables a connected vehicle to receive information from the infrastructure regarding the signal timing and the geometry of the intersection. This capability allows a connected vehicle to predict if the speed and acceleration profile of the vehicle makes it appear likely that the vehicle will enter the intersection in violation of a traffic signal. Another usage may be at a railroad crossing where the violation may include gate crossings.

2.5.3.1.3 Signal Movement at Intersections: Eco-Driving

A connected vehicle needs to receive signal movement information at a signalized intersection or at an active railroad crossing for eco-driving capabilities. This capability enables the vehicle to perform actions to improve the efficiency of vehicle operations (e.g., by making engine adjustments that provide increased fuel efficiency).

2.5.3.2 Infrastructure Restriction Warnings

A connected vehicle needs to receive information about upcoming infrastructure restrictions such as height or weight restrictions. This capability allows transportation agencies to warn vehicles of upcoming infrastructure restrictions, which may result in damage to the vehicle or the roadway infrastructure. Such damage may result from a vehicle that is too high or too wide to travel under a bridge, an overweight vehicle approaching a crossing, or a vehicle making a turning movement that may hit a roadway lighting fixture. This capability also enables transportation agencies to provide route restriction warnings and alternate routes to the vehicle.

2.5.3.2.1 Warnings about Hazards in a Work Zone

Maintenance personnel within a work zone need to be warned about potential hazards within the work zone. This capability enables vehicles or the infrastructure to provide warnings to workers in a work zone when a vehicle is moving in a manner that appears to create an unsafe condition (e.g., moving at high speed or entering the work zone).

2.5.3.2.2 Warnings about Upcoming Work Zone

A connected vehicle needs to receive information about the conditions that exist in a work zone that the vehicle is approaching. This capability provides approaching vehicles with information about work zone activities that may result in unsafe conditions to the vehicle, such as obstructions in the vehicle's travel lane, lane closures, lane shifts, speed reductions or vehicles entering/exiting the work zone.

2.5.3.2.3 Restricted Lane Warnings

A connected vehicle needs to receive information to determine if it is in a restricted lane, such as HOV, eco-lanes, transit, or emergency vehicle only lanes. This capability provides the vehicle with restriction information about the travel lane, such as if the lane is restricted to high occupancy vehicles (HOV), transit, or public safety vehicles only or has defined eco-lane criteria.

2.5.3.2.4 Roadway Hazards Information

A connected vehicle needs to receive information about the current road hazard conditions. This capability enables the vehicle to advise the driver who may take appropriate actions, such as slowing down the vehicle, to reduce the risk of a crash based on the vehicle's location, speed, trajectory and the road conditions. Examples of hazardous roadway conditions include fog, high winds, ice, objects in the road and other poor pavement conditions.

2.5.3.2.5 Pedestrian and Turning Vehicle Crash Warning

The connected vehicle driver needs to know if there are pedestrians in the crosswalk when the vehicle is making a right or left turn at an intersection. This capability would provide to the vehicle information from the infrastructure that indicates the possible presence of pedestrians in a crosswalk into which the vehicle is about to turn. The infrastructure based indication could include the outputs of pedestrian sensors or simply an indication that the pedestrian call button has been activated. This capability was initially defined for transit vehicles, but can be applicable to any class of vehicle.

2.5.3.3 Mayday Forward

A connected vehicle needs to forward to the infrastructure a mayday request received from a disabled vehicle. This capability enables a host vehicle to forward automated mayday requests from remote vehicles to the infrastructure, where the requests are then routed to emergency response services. Remote vehicles automatically transmit these mayday requests when the vehicle detects indications of a crash, such as the deployment of airbags. The mayday would include additional information about the vehicle, such as fuel type vehicle make and model that might impact the emergency response. For example, different car makes require differing responses due to variation in manufacturing materials; this information is used by fire truck crews when working on cutting open cars.

2.5.3.4 Mayday Request to Infrastructure

A connected vehicle needs to transmit a mayday request to the infrastructure. This capability enables a connected vehicle to send automated mayday requests to the infrastructure, where the requests are then routed to emergency response services. Connected vehicles automatically transmit these mayday requests when the vehicle detects indications of a crash, such as the deployment of airbags.

2.5.3.5 Commercial Vehicle Operations User Needs

2.5.3.5.1 Commercial Vehicle Credentialing and Permitting

The commercial vehicle credentials agency needs commercial vehicle information to support credentialing and permitting functions. This capability enables commercial vehicles to provide identifying information to the infrastructure to allow the credentials or permitting to be verified without requiring the commercial vehicle to stop. The commercial vehicle would transmit its identifying information to the infrastructure, where the commercial vehicle agency can verify the proper fees have been paid and the permits are valid. The commercial vehicle may also transmit driver identification, duty logs, trailer data and cargo data to the infrastructure. As this service uses sensitive information, commercial vehicle drivers have to opt-in for these services.

2.5.3.5.2 Safety Inspection Data

Commercial vehicle safety agencies need to access the electronic safety inspection data from a commercial vehicle. This capability allows commercial vehicle inspectors to electronically download inspection data from the vehicle via the infrastructure without requiring the commercial vehicle to stop. This capability allows the commercial vehicle agencies to inspect more commercial vehicles and saves the commercial vehicle drivers' time. This capability also allows commercial vehicle agencies to select those vehicles that are of interest for physical inspections at an inspection site. Note: For the purpose of this project it is assumed that the power unit will have all data pertaining to the trailers. As this service uses sensitive information, commercial vehicle drivers (or fleet operators) have to opt-in for these services.

2.5.3.5.3 Vehicle Clearance

The commercial vehicle driver needs to know if the commercial vehicle has received electronic clearance at an inspection site. This capability enables the commercial vehicle and inspection agencies to transmit clearance via the infrastructure to the commercial vehicle, allowing the commercial vehicle to bypass inspection and wayside stations. Clearance may be provided after all the electronic safety inspections, weight inspections, tariff payments, credentials, permits, etc. have been checked and verified. This capability allows a commercial vehicle driver to continue on his trip without needing to stop at the inspection station, saving the driver time. A toll booth may be used to implement this feature. As this service uses sensitive information, commercial vehicle drivers (or fleet operators) have to opt-in for these services.

2.5.3.5.4 Receive Parking Space Availability and Service Information

Commercial vehicle drivers need the availability of parking spaces and services at upcoming parking lots or rest area facilities. This capability provides commercial vehicle drivers with information about the availability of parking and services information, including availability times and parking space dimensions. This capability has a safety aspect to it since commercial vehicle drivers that exceed hours of service requirements represent a safety hazard on the roads.

2.5.3.6 Data Capture and Management User Needs

2.5.3.6.1 Vehicle Data for Traffic Operations

2.5.3.6.1.1 Vehicle Data for Traffic Data Collection

Transportation agencies and private traveler information companies need to collect vehicle data to support traffic data collection. This capability enables transportation agencies to obtain data from vehicles in the network to determine network performance measures such as speed and travel times.

2.5.3.6.1.2 Vehicle Data for Incident Detection

Transportation agencies need to collect vehicle data to support incident detection. This capability enables transportation agencies to determine the location of potential incidents so the agencies can respond more quickly to the incident and mitigate any negative impacts to the transportation network. Vehicle data that can be used to detect potential incidents include changes in vehicle speeds indicating the disruption of traffic flow, when a vehicle's safety systems have been activated or deployed, or sudden vehicle turns or deceleration at a specific location (indicating a potential obstacle in the roadway).

2.5.3.6.1.3 Vehicle Data for Traffic Operations Strategies

Transportation agencies need to collect vehicle data to support the implementation of operations strategies. This capability enables transportation agencies to use vehicle data to optimize traffic operations through the implementation of localized operational strategies. One example of optimizing traffic operations include knowing what vehicles are approaching a signalized intersection and their trajectories to minimize delay, improve traffic flow, and improve safety. Another example involves knowing how many vehicles are on a freeway mainline and on a freeway ramp to optimize the ramp metering rate or to employ speed harmonization.

2.5.3.6.2 Vehicle Data for Highway Maintenance and Design

Transportation agencies need to collect vehicle data to support performance monitoring and other uses of historical data including transportation planning, safety analyses, and research. This capability enables transportation agencies to collect transportation data to support performance monitoring of the transportation infrastructure, for transportation planning, condition monitoring, and to improve safety.

2.5.3.6.3 Vehicle Data for Environmental Monitoring

Transportation agencies need to gather data from the vehicles to support environmental monitoring. This capability enables transportation agencies to collect vehicle and emissions data to improve forecasting models, to measure the effectiveness of transportation strategies, and to provide input to real-time operations strategies that can be implemented when environmental conditions dictate. Vehicle data collected includes the type of vehicle(s), engine(s), and fuel type used by each vehicle on the roadway, emissions from each vehicle, vehicle weight and speeds, and vehicle operating data.

2.5.3.6.4 Vehicle Data to Determine Hazardous Road Conditions

Transportation agencies need to collect data from vehicles to support detection of weather-related hazardous road conditions. This capability enables transportation agencies to determine road conditions based on vehicle status data collected from the vehicle. Vehicle status data such as slippage detected by the vehicle, status of windshield wipers, vehicle (front) lights, fog lamps and hazard lights can be used by transportation agencies to determine road conditions such as low visibility, icy roads, heavy rains, or flooding.

2.5.3.6.5 Vehicle Data for Weather Forecasting

Transportation agencies need to collect vehicle data to enhance weather forecasting. This capability enables transportation agencies to determine current or forecasted road weather condition on a link-by-link basis using environmental data collected by vehicles, such as slippery road conditions, temperature, air pressure, and the presence of precipitation. This information can augment the road weather information collected from fixed environmental sensor systems, provide input into traveler information systems, and enhance the operations of snow plows and maintenance vehicles.

2.5.3.7 Traveler Related User Needs

2.5.3.7.1 Speed Advisories

Transportation agencies need to provide vehicle speed advisories directly to vehicles for safety and to encourage progression through arterial signal systems. This capability allows transportation agencies to provide speed advisories to drivers. Potential scenarios include encouraging vehicles to lower their vehicle speeds due to poor roadway conditions (e.g., ice, fog), upcoming work zones, or to encourage vehicle platoons on the roadway thereby improving vehicle density and reducing delays and emissions. The variable speed limits can also be used by in-vehicle navigation systems to update estimated travel times.

2.5.3.7.2 Location-Based Traveler Information and Advisories

The driver needs to receive traveler information and advisories based on the vehicle's current position and heading. This capability allows the driver to receive focused transportation related traveler information of interest. Such information could include travel advisories, warnings on upcoming road conditions (including weather and speed limits), and toll information. This information could also include availability and location of electrical charging stations or alternative fueling stations to support eco driving.

2.5.3.7.3 Vehicle Restrictions

Transportation agencies need to provide travel restriction or route restrictions relevant to all or to specific types of vehicles as part of the implementation of travel demand strategies. This capability enables transportation agencies to restrict travel for certain types of vehicles (or for all vehicles) based on demand strategies that may be implemented due to some predetermined set of environmental or security conditions.

2.5.3.7.4 Curve Speed Warning

The vehicle needs to receive information that it is approaching a curve along with the recommended speed for the curve. This capability allows the vehicle to provide a warning to the driver regarding the curve and its recommended speed. In addition, the vehicle could perform additional warning actions if the actual speed through the curve exceeds the recommended speed.

2.5.3.8 Emergency Response Needs

2.5.3.8.1 Minimize Delay to Emergency Vehicles at Traffic Signals

Emergency responders need to have their trip through the traffic network expedited. This capability allows emergency responders to more quickly and safely go through a signalized intersection (or follow a planned route) in response to an incident or emergency. The potential scenarios include an emergency vehicle requesting traffic signal pre-emption and the traffic signal providing the emergency responder with an indication that the preemption action has been taken.

2.5.3.9 Transit Operation Needs

2.5.3.9.1 Transit Signal Priority

Transit operators need transit signal priority to assist transit vehicles in maintaining their schedules. This capability allows transit schedules to be more predictable, improving transit service for transit users, and allowing transit operators to reduce their fleet size and operating costs. This capability includes feedback to the transit driver if the signal priority has been granted or not, and how to manage conflicting priority requests. This capability can also contribute to improved operating performance of the transit vehicles by reducing the time spent stopped at a red light.