



SURFACE VEHICLE STANDARD	J2945™/1B	OCT2024
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(R) On-Board System Requirements for V2V Safety Communications by Non-Light-Duty Vehicles and Motorcycles		

RATIONALE

This revision coincides with the 2024 revision of SAE J2735. Explanatory text has been added as well as clarifications regarding how to use corresponding SAE J2735 ASN.1 entities.

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Documents



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1. SCOPE

This SAE Standard specifies the system requirements for vehicle-to-vehicle (V2V) safety system for Federal Highway Administration (FHWA) vehicle classes 1 (motorcycles) and 6 through 13 (non-light-duty vehicles), including functional requirements and performance requirements. The system can transmit and receive the SAE J2735-defined Basic Safety Message (BSM) over a wireless communications interface; the communications interface itself is outside the scope of this document. This document provides the specifications necessary to build interoperable systems that support V2V safety applications for non-light-duty vehicles, as well as motorcycles which rely on the exchange of BSMs. The document covers vehicle classes not addressed in SAE J2945/1 and SAE J3161/1.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J2735	V2X Communications Message Set Dictionary
SAE J2945	Dedicated Short Range Communication (DSRC) Systems Engineering Process Guidance for SAE J2945/X Documents and Comment Design Concepts™
SAE J2945/C	Requirements for Probe Data Collection Applications
SAE J2945/1	On-Board System Requirements for V2V Safety Communications
SAE J2945/1C	On-Board System Requirements for V2V Safety Communications by School Buses
SAE J3067	Candidate Improvements to Dedicated Short Range Communications (DSRC) Message Set Dictionary [SAE J2735] Using Systems Engineering Methods
SAE J3161	LTE Vehicle-to-Everything (LTE-V2X) Deployment Profiles and Radio Parameters for Single Radio Channel Multi-Service Coexistence
SAE J3161/1	On-Board System Requirements for LTE-V2X V2V Safety Communications

2.1.2 Code of Federal Regulations (CFR) Publications

Available from United States Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-1800, www.gpo.gov.

49 CFR § 571.121 Standard No. 121; Air brake systems

2.1.3 FHWA Publications

Available from Federal Highway Administration, 1200 New Jersey Ave, SE, Washington, DC 20590, Tel: 202-366-4000, <https://www.fhwa.dot.gov/>.

FHWA Traffic Monitoring Guide, Appendix B - Vehicle Types

2.1.4 IEEE Publications

Available from IEEE Operations Center, 445 and 501 Hoes Lane, Piscataway, NJ 08854-4141, Tel: 732-981-0060, www.ieee.org.

IEEE Std 1609.2 IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Security Services for Applications and Management Messages

2.1.5 Other Publications

NTCIP 8002 National Transportation Communications for ITS Protocol. (2016). *Content outline for NTCIP 1200-series documents (for standards engineering process [SEP] content)* (Report No. NTCIP 8002 Annex B1 version v01). American Association of State Highway and Transportation Officials (AASHTO).

3. DEFINITIONS

For the purposes of this standard, the definitions, abbreviations, and acronyms found in SAE J2735 and SAE J2945/1 also apply. In the case of conflict, the following additional definitions, abbreviations, and acronyms supersede those found in SAE J2735. The definitions in SAE J2945 are incorporated by reference.

3.1 LEAN ANGLE

Lean angle is defined as the angle a motorcycle's frame makes around the longitudinal axis in the direction of travel without considering the position of the rider.

3.2 HARD BRAKING

A class 7 to 13 or a class 4 vehicle is decelerating at a level greater than 0.2 g. For all other classes, the level is greater than 0.4 g.

3.3 NON-LIGHT-DUTY VEHICLE

An FHWA class 1 or 6 through 13 vehicle. Note that classes 2 through 5 are addressed in SAE J2945/1 and SAE J3161/1.

4. ABBREVIATIONS

The additional abbreviations and acronyms cited below are terms related to this standard (and of the other companion volumes and guides), unless specifically cited otherwise.

ARC-IT	Architecture Reference for Cooperative and Intelligent Transportation
ASN.1	Abstract Syntax Notation One
BSM	Basic Safety Message
BSW	Blind Spot Warning
CAN	Controller Area Network
CFR	Code of Federal Regulations
CLW	Control Loss Warning
CRL	Certificate Revocation List
CVRIA	Connected Vehicle Reference Implementation Architecture

DE	Data Element
DF	Data Frame
DNPW	Do Not Pass Warning
DSRC	Dedicated Short Range Communications
DTI	Distance-to-Intersection
DVI	Driver-Vehicle Interface
ECU	Electronic Control Unit
FCW	Forward Collision Warning
FHWA	Federal Highway Administration
FR	Functional Requirement
GNSS	Global Navigation Satellite System
HV	Host Vehicle
ID	Identifier
IEEE	Institute of Electrical and Electronics Engineers
ITS	Intelligent Transportation Systems
IMA	Intersection Movement Assist
LCW	Lane Change Warning
LTE-V2X	LTE Vehicle-to-Everything
NRTM	Needs to Requirements Traceability Matrix
OBE	On-Board Equipment
PV	Pulling Vehicle
RF	Radio Frequency
RTM	Requirements Traceability Matrix
SCMS	Security Credential Management System
SSP	Service Specific Permission
TTC	Time-to-Collision
TTI	Time-to-Intersection
UV	Unequipped Vehicle

V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
WGS	World Geodetic System

5. CONCEPT OF OPERATIONS

5.1 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 application standards, the concept of operations documents the purpose of each feature for which an application standard supports an application. The concept of operations also serves as the starting point for users to select those features that may be appropriate for a specific application.

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 a 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:

- a. Reference physical architecture: The reference physical architecture defines the overall context of the proposed system and defines which specific interfaces are addressed.
- b. Architectural needs: The architectural needs discuss issues and needs relative to the system architecture.
- c. Features: The features identify and describe the various capabilities the users may want that are not currently covered in other standards. 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 tables contained in [6.3.3](#).

Architectural needs and features are collectively called "user needs." In [6.4](#), these user needs lead to the definition of the various requirements. Basic systems engineering requires that:

- a. Each user need traces to one or more functional requirements
- b. Each functional requirement derives from at least one user need

This traceability is shown in the Needs to Requirements Traceability Matrix (NRTM) in [6.3.3](#).

SAE J2945/1B is intended to be used in vehicle classes 1 (motorcycles) and 6 through 13 (non-light-duty vehicles), as defined by FHWA, to ensure that the exchange of BSMs in V2V safety communications provides the desired interoperability and data integrity to support the performance of the envisioned safety applications. SAE J2945/1B is a complementary standards document to SAE J2945/1 and SAE J3161/1 and provides additional requirements for vehicle classes 1 and 6 through 13.

Within the NRTM, each user need and requirement is identified as mandatory, optional, or conditional, and users may complete the NRTM to clearly define unique aspects of their implementation. Within SAE J2945/1B, items marked mandatory are those that relate to the most basic functionality required in meeting the identified user needs. For specific implementations, the user identifies those optional or conditional needs appropriate for a specific implementation.

Each requirement is presented in the Requirements Traceability Matrix (RTM) in [Appendix A](#), which defines how the requirement is fulfilled through the standardized dialogs and data entities defined in [Sections 7](#) and [8](#).

A conformant system may support additional features, as long as it is conformant with the requirements of SAE J2945/1B.

5.2 Current Situation and Problem Statement (Informative)

SAE J2945/1 (for dedicated short range communications [DSRC]) and SAE J3161/1 (for LTE-V2X) address vehicle-safety communications for FHWA classes 2 through 5, and the safety communications needs for school buses are covered in SAE J2945/1C. With other classes of vehicles on the roads today expecting to have V2V capabilities, it is necessary to address the unique needs of the remaining classes of vehicles.

SAE J2945/1B is a complementary standard to SAE J2945/1 and/or SAE J3161/1, providing the extra requirements for vehicle classes 1 (motorcycles) and 6 through 13 (non-light-duty vehicles). Motorcycles and vehicles as described in this document must comply with both SAE J3161/1 and SAE J2945/1B.

This document specifies the functional and performance requirements for V2V safety communications for FHWA classes 1 and 6 through 13 (non-light-duty), which are not covered in SAE J2945/1 and SAE J3161/1. These specifications provide the requirements necessary to build interoperable systems that support V2V safety applications for non-light duty vehicles and motorcycles that rely on the exchange of BSMs. The system can transmit and receive the SAE J2735-defined BSM over a wireless communications interface; the communications interface itself is outside the scope of this document.

As shown in [Figure 1](#), motorcycles are class 1 vehicles. Motorcycles, similar to passenger cars, can be represented as a rectangle with certain length and width; however, because of the potential for leaning by the rider, the actual surface space taken up by the vehicle and its rider varies. The information provided from a motorcycle about its physical space on the road is therefore a function of its position on the road and its varying lean angle, which is the angle between the center plane of the motorcycle and the vertical plane. To make the necessary data available to other vehicles, SAE J2945/1B sets the requirements for information provided by class 1 vehicles to other connected vehicles and devices.

Like classes 2 through 5, classes 6 and 7 are all single unit vehicles (see [Figure 1](#)). Although the size of these vehicles and their number of axles vary from one class to another, they can all be represented using fixed width and length rectangles. Except for the possibility of towing a trailer or another vehicle, this group—designated as “Rigid Body Group”—does not represent any new requirements beyond those identified in SAE J2945/1.

Vehicles used to pull one or more trailers, including many of the Rigid Body Group classes and vehicle classes 8 to 13, are hereafter referred to as being members of the Trailer Group. Typically, the motorized section houses a V2V device (including the positioning devices), while trailers (for the purposes of SAE J2945/1B) are assumed not to be equipped with V2V technology. For this group of vehicles, there is a need to provide a means of conveying information about pulling trailers to support safety-related applications and providing information that is critical to the surrounding vehicles. Information provided by this class of vehicles includes the trailer-related data to inform other drivers about:

- Emergency electronic brake lights
- Forward collision warning
- Blind spot warning/lane change warning
- Intersection movement assist
- Control loss warning

For the purposes of defining the user needs, vehicles that are receiving and acting on BSMs from this group of vehicles are referred to as host vehicles (HVs), vehicles that are part of this group and transmitting the required data using BSMs are designated pulling vehicles (PVs), and trailers that are not active providers of information are simply referred to as “trailers.”

Note that other path constrained vehicles are supported by this document via the trailer data that is available in the BSM. For example, for articulated buses, the vehicle class would still be class 4, but its BSM would include the trailer data to represent the rear section of the articulated bus.

Class 1 Motorcycles		Class 7 Four or more axle, single unit	
Class 2 Passenger cars		Class 8 Four or less axle, single trailer	
			
			
			
Class 3 Four tire, single unit		Class 9 5-Axle tractor semitrailer	
			
			
Class 4 Buses		Class 10 Six or more axle, single trailer	
			
			
Class 5 Two axle, six tire, single unit		Class 11 Five or less axle, multi trailer	
			
			
Class 6 Three axle, single unit		Class 12 Six axle, multi-trailer	
			
			
			
		Class 13 Seven or more axle, multi-trailer	
			
			

Figure 1 - FHWA vehicle classes (see [2.1.3](#))

5.3 Reference Architecture

[Figure 2](#) illustrates the components of the V2V system and its interfaces, which is based on the reference physical architecture of SAE J3161/1 and SAE J2945/1.

NOTE: SAE J2945/1 was originally developed for DSRC, and V2V safety communications were extended to LTE-V2X in SAE J3161/1. While SAE J3161/1 may eventually also contain all requirements originally in SAE J2945/1, both documents are referred to herein for completeness.

An infrastructure-based Security Credential Management System (SCMS) is responsible for generating and delivering the security certificates that are used in the message verification process. The SCMS can also revoke certificates that cannot be trusted (e.g., the associated device may have been tampered with or is misbehaving) by placing them on a Certificate Revocation List (CRL) that the SCMS distributes to all systems.

The V2V on-board equipment (OBE), which is the on-board V2V safety communications system defined in this standard (hereafter referred to as “the System”), typically consists of multiple subsystem components, which may be discrete or integrated depending on the implementation:

- V2X radio subsystem: Transmits and receives BSMs. The OBE can include one or more radio subsystems.
- Positioning subsystem: The subsystem that includes a Global Navigation Satellite System (GNSS) receiver and provides vehicle position, heading, speed, and time information. The System may augment and enhance positioning using additional information and components, which are not shown in [Figure 2](#). Examples of these are speed data from the controller area network (CAN) bus, dead reckoning sensors, optical/camera-based systems, and pivot data.

- c. OBE control processor electronic control unit (ECU): Executes software that generates BSMs for transmission according to the requirements in this standard.
- d. Antennas: Support radio frequency (RF) links for the V2X radio and GNSS receiver. A second diversity antenna for the V2X radio subsystem is recommended to improve performance. GNSS and radio subsystem antennas may be integrated (dual band).

Systems communicate among themselves using the V2X radio subsystem as an interface. The System (OBE) can interface to a Safety Application ECU that detects threats and issues alerts through a driver-vehicle interface (DVI). The DVI can provide visual, audio, and/or haptic alerts. The OBE can also interface with the vehicle CAN bus to obtain vehicle status information. The safety application ECU, CAN bus, and DVI are outside the scope of this document.

NOTE: The Safety Application ECU is anticipated to support interfacing to other sensing systems and use data fusion techniques to implement related applications. Those sensors and the interfaces to them are outside the scope of this document.

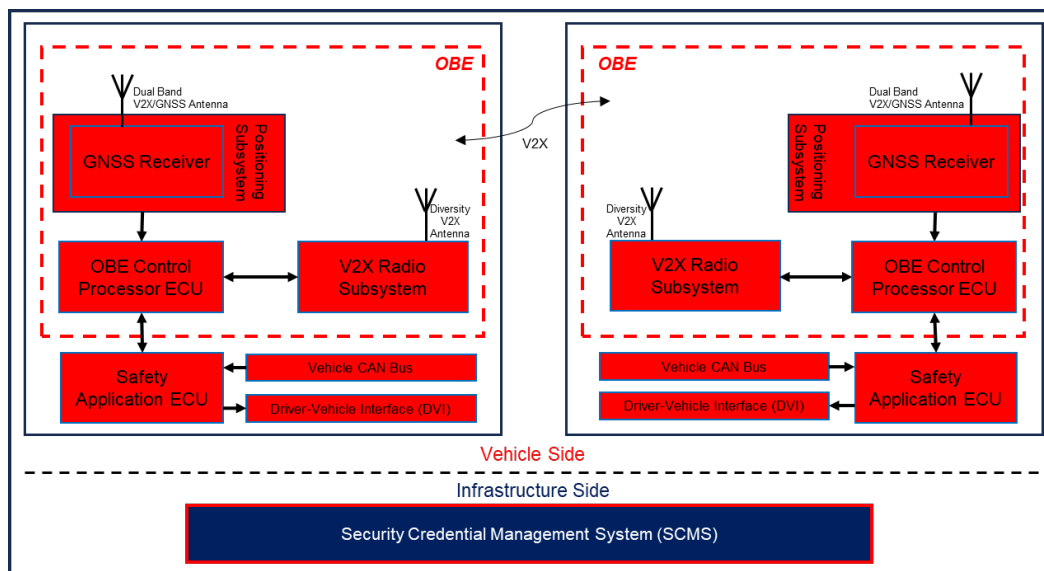


Figure 2 - Reference physical architecture

5.4 Architectural Needs

5.4.1 V2V Communications Interface

Refer to 5.2.1 of SAE J2945/1 for DSRC and SAE J3161/1 for LTE-V2X.

5.4.2 Positioning and Timing

Refer to 5.2.3 of SAE J2945/1 and SAE J3161/1. Note that positioning as described in those documents applies to the pulling vehicle in the case of vehicles with trailers.

5.5 Features

The System needs to provide relevant information so that the following applications, described in SAE J3067, can be supported:

- Forward collision prevention, as described in 2.5.2.1.1 of SAE J3067
- Intersection movement assist, as described in 2.5.2.1.2 of SAE J3067
- Pre-crash actions, as described in 2.5.2.1.3 of SAE J3067
- Control loss warning, as described in 2.5.2.1.4 of SAE J3067
- Lane change warning, as described in 2.5.2.1.5 of SAE J3067
- Do not pass warning, as described in 2.5.2.1.6 of SAE J3067
- Blind spot warning, as described in 2.5.2.1.7 of SAE J3067

5.5.1 Vehicle Class

The System needs to provide the class of vehicle for the vehicle classes 1 and 6 through 13.

5.5.2 Dimensions of a Motorcycle in Motion

The area covered by a motorcycle in motion varies based on the height of its rider and the angle the motorcycle makes around the longitudinal axis in the direction of motion. The System is to provide information needed to estimate the footprint of a motorcycle in motion. The data includes:

- The lean angle
- Approximate height of a motorcycle in motion

5.5.3 Indication of the Presence of Trailers

The System needs to provide an indicator if the vehicle is pulling one or more trailers. For an articulated bus, the rigid sections following the engine section can be described as trailers. Note that a motorcycle with a trailer can also be represented using the features in this document.

5.5.4 Indication of Jackknife Condition

A jackknifed vehicle-trailer condition is hazardous to incoming traffic. The System needs to report if a trailer-pulling vehicle encounters a jackknife condition. The conditions that define a jackknife are left to implementers, but initial research suggests that a pivot angle greater than 90 degrees is a good starting point.

5.5.5 Data Related to Pulling Vehicle

The System needs to provide attributes of the pulling vehicle that are necessary in calculating the position of trailers.

5.5.5.1 Indication of the Direction of Movement

The estimation of a trailer's position is calculated based on the position of the pulling vehicle (see [5.5.6](#)). The direction of travel is needed in estimating the position of the trailers. The System needs to provide an indicator of the movement of a vehicle, forward, neutral, or reverse.

5.5.5.2 Details of Pulling Vehicle Point of Connection

The System needs to provide the physical details that identify its point of connection to a trailer. The information includes:

- Position of the point of connection
- Ability of the point of connection to pivot

5.5.6 Trailer Data for Estimation of a Trailer's Position

The System needs to provide physical trailer attributes of one to eight trailers for a receiving entity to calculate the position of the trailers of a class 4 to class 13 vehicle, including:

- Length of each trailer
- Indicator of the ability for the front of a trailer to pivot
- Indicator of the ability for the rear of a trailer to pivot
- Length of the front connection point with respect to the front edge of the trailer
- Length of the rear connection point with respect to the rear edge of the trailer
- Angle a trailer makes with respect to another trailer or vehicle directly in front of it

5.5.7 Other Details for Pulling Vehicle and Its Trailers

For the vehicle and each trailer, the System needs to provide:

- Vehicle and trailer height
- Vehicle and trailer width
- Trailer weight
- Vehicle and trailer front and rear bumper height
- Vehicle and trailer total number of axles, and number of front and rear axles

5.6 Security

All vehicle classes need to implement security as specified in 6.5 and 6.6 of SAE J2945/1. The security solution also needs to include certificate permissions to operate as a class 1 or classes 6 through 13 vehicles, as well as public safety vehicles, as described in SAE J3161/1.

5.7 Operational Policies and Constraints

The System must be equipped with a radio communications interface that enables it to send and receive BSMs to and from other vehicles.

5.8 Relationship to the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) (Informative)

ARC-IT incorporates all the connected vehicle applications of the Connected Vehicle Reference Implementation Architecture (CVRIA). Physical objects such as vehicles are defined to represent the major physical components of the Intelligent Transportation Systems (ITS) Architecture. SAE J2945/1B addresses the communications and processing of certain classes of vehicles equipped with platforms aware of their location and their status and capable of communicating with other equipped vehicles.