



SURFACE VEHICLE STANDARD

J2945®

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Dedicated Short Range Communication (DSRC) Systems Engineering Process
Guidance for SAE J2945/X Documents and Common Design Concepts™

RATIONALE

This is an "interim progress release" which provides a snapshot of in-work content. It is intended to provide an opportunity for TC input and guidance, and to support overall coordination among the set of standards currently in development.

Please note that this document is intended to be cross cutting, and should serve the goal of stating a great many common aspects of DSRC that the DSRC TC often takes for granted. New developers will need this information. While it is a normative document for some common aspects of DSRC, it also provides informative material on both the exchanged messages, on DSRC systems, and many aspects of ITS work that together form a complex system.

This standard is dedicated to the memory of Peter Byk, who provided support and guidance in the evolution of the DSRC standards. He fostered the collaborative effort among SAE International, Federal and State governments, and the ITS industry that enabled a team of stakeholders and subject matter experts to create the DSRC message standards which will improve transportation safety and mobility.

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1. GENERAL [INFORMATIVE]

1.1 Scope

This SAE Standard serves as the guidance document for the J2945/x family of standards as illustrated in [Figure 7](#). It contains cross-cutting material which applies to the other J2945/x standards, including recommended practice for the use of Systems Engineering (SE) and generic DSRC interface requirements content.

The scope for the DSRC system environment is to provide for the information exchange between a host vehicle and another DSRC enabled device, a device worn by or otherwise attached to a traveler, a roadside device, or a management center, to address safety, mobility, and environmental system needs.

The audience for this document includes the technical teams of developers of the J2945/x documents and the implementers of the applications which are based on the J2945/x documents.

1.1.1 Applicable Documents [NORMATIVE]

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.

1.1.1.1 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.

- | | | |
|-----|-------------|--|
| [1] | SAE J2540 | Messages for Handling Strings and Look-Up Tables in ATIS Standards |
| [2] | SAE J2540-2 | ITIS Phrase Lists (International Traveler Information Systems) |
| [3] | SAE J2735 | Dedicated Short Range Communications (DSRC) Message Set Dictionary |
| [4] | SAE J2945/1 | On-Board System Requirements for V2V Safety Communications |
| [5] | SAE J2945/9 | Vulnerable Road User Safety Message Minimum Performance Requirements |

1.1.1.2 IEEE Publications

This standard is intended to be independent of the underlying lower layer protocols, though early deployments are expected to use the "DSRC-WAVE" technology operating at 5.9 GHz.

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

- | | | |
|-----|----------------------|--|
| [6] | IEEE Std 1609.0-2013 | IEEE Guide for Wireless Access in Vehicular Environments (WAVE) – Architecture |
| [7] | IEEE Std 1609.2-2016 | IEEE Standard for Wireless Access in Vehicular Environments - Security Services for Applications and Management Messages |
| [8] | IEEE Std 1609.3-2016 | IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Networking Services |
| [9] | IEEE Std 1609.4-2016 | IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Multi-channel Operation |

- [10] IEEE Std 1609.12-2016 IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Identifier Allocations
- [11] IEEE Std 802.11-2016 Standard for LAN/MAN - Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications

1.1.2 Related Publications

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

1.1.2.1 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.

- [12] SAE J1939 Serial Control and Communications Heavy Duty Vehicle Network - Top Level Document
- [13] SAE J3067 Candidate Improvements to Dedicated Short Range Communications (DSRC) Message Set Dictionary [SAE J2735] Using Systems Engineering Methods

1.1.2.2 ISO Publications

Copies of these documents are available online at <http://webstore.ansi.org/>.

- [14] ISO 16460 Intelligent transport systems -- Communications access for land mobiles (CALM) — Communication protocol messages for global usage
- [15] ISO 21217 Intelligent transport systems — Communications access for land mobiles (CALM) — Architecture
- [16] ISO 29281-1 Intelligent transport systems — Communication access for land mobiles (CALM) — Non-IP networking — Part 1: Fast networking & transport layer protocol (FNTP)
- [17] ISO 21215 Intelligent transport systems — Communications access for land mobiles (CALM) — M5
- [18] ISO 17419 Intelligent transport systems — Cooperative systems — Classification and management of ITS applications in a global context
- [19] ISO 19091 Intelligent transport systems -- Cooperative ITS -- Using V2I and I2V communications for applications related to signalized intersections

1.1.2.3 US Department of Transportation, National Transportation Library

Available on-line from the National Transportation Library at <http://ntl.bts.gov>.

- [20] Cooperative Intersection Collision Avoidance System Limited to Stop Sign and Traffic Signal Violations (CICAS-V), Task 10 Final Report Dated 09-30-2008 which is available at http://ntl.bts.gov/lib/38000/38600/38631/Appendix_G_CICAS-V_Task_10_Final_Report_4-29-10_FHWA-JPO-10-068_.pdf

1.1.2.4 US Department of Transportation

- [21] FHWA-JPO-11-089 Applying Systems Engineering Principles to the Development of Transportation Communication Standards, Dated April 22, 2011, which is available at http://ntl.bts.gov/lib/43000/43100/43152/ASEP_Dev_TCStandards_v2.pdf
- [22] *Instructions for Conducting Consistency Check Assessment on ITS V2V and V2I Information Level Standards*, Noblis, Inc., Dated April 13, 2012

- [23] National ITS Architecture, Available online at <http://www.iteris.com/itsarch/>
- [24] Systems Engineering Concepts for ITS Standards Development, Blake Christie, November 4, 2015, Noblis, Inc.
- [25] US Department of Transportation Systems Engineering for Intelligent Transportation Systems An Introduction for Transportation Professionals, January 2007

ITS Courses and Training

Available at https://www.pcb.its.dot.gov/stds_modules.aspx

- [26] ITS Courses and Training: Module 3. A102: Introduction to User Needs Identification, ITS-JPO, which is available at <https://www.pcb.its.dot.gov/StandardsTraining/Modules.aspx?ModuleID=13#mod13>
- [27] ITS Courses and Training: Module 4. A103: Introduction to ITS Standards Requirements Development, ITS-JPO, which is available at <https://www.pcb.its.dot.gov/StandardsTraining/Modules.aspx?ModuleID=14#mod14>
- [28] ITS Courses and Training: Module 7. A202: Identifying and Writing User Needs When ITS Standards Do Not Have SEP Content, ITS-JPO, which is available at <https://www.pcb.its.dot.gov/StandardsTraining/Modules.aspx?ModuleID=17#mod17>
- [29] ITS Courses and Training: Module 8. A203: Writing Requirements When ITS Standards Do Not Have SEP Content, ITS-JPO, which is available at <https://www.pcb.its.dot.gov/StandardsTraining/Modules.aspx?ModuleID=18#mod18>

1.1.2.5 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

- [30] ASTM E2213 -03 Standard Specification for Telecommunications and Information Exchange Between Roadside and Vehicle Systems - 5 GHz Band Dedicated Short Range Communications (DSRC) Medium Access Control (MAC) and Physical Layer (PHY) Specifications

1.1.2.6 IEEE Publications

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

- [31] IEEE Std 1012-2012 IEEE Standard for System and Software Verification and Validation
- [32] IEEE Std 1028-2008 IEEE Standard for Software Reviews and Audits
- [33] IEEE Std 1220-2005 (R2011) IEEE Standard for Application and Management of the Systems Engineering Process
- [34] IEEE Std 1233-1998 (R2002) IEEE Guide for Developing System Requirements Specifications (Replaced by ISO/IEC/IEEE 29148:2011 (<https://www.iso.org/obp/ui/#iso:std:iso-iec-ieee:29148:ed-1:v1:en>))
- [35] IEEE Std 1362-1998 (R2007) IEEE Guide for Information Technology - System Definition - Concept of Operations (ConOps) Document
- [36] IEEE Std 1471-2000 IEEE Recommended Practice for Architectural Description for Software-Intensive Systems

- [37] IEEE Std 610.12-1990 (R2002) Standard Glossary of Software Engineering Terminology ([Superseded by ISO/IEC/IEEE 24765:2010\(E\)](#))
- [38] IEEE Std 830-1998 (R2009) IEEE Recommended Practice for Software Requirements Specifications
- 1.1.2.7 NTCIP Publications
- [39] NTCIP 1202 v02.19r Object Definitions for Actuated Traffic Signal Controller (ASC) Units
- [40] NTCIP 1203 v3.05 Object Definitions for Dynamic Message Signs (DMS)
- [41] NTCIP 1204 v3.08 Environmental Sensor Station Interface Standard
- [42] NTCIP 8002 Annex B1 v01 *Content Outline for NTCIP 1200-Series Documents*, Dated April 17, 2007
- 1.1.2.8 INCOSE Publications
- [43] INCOSE Systems Engineering Handbook v3.2.2
- 1.1.2.9 Security References
- [44] Federal 24 Information Processing Standard (FIPS) 186-4 [ECDSA]
- [45] IEEE Std 1363a-2004 [ICIES] Standard Specifications For Public Key Cryptography- Amendment 1: Additional Techniques
- [46] IETF RFC 4301 Security Architecture for the Internet Protocol
- [47] National Institute for Standards and Technology (NIST) Special Publication (SP) 800-38C [AES-CCM]
- 1.1.2.10 Other References
- [48] Kazimierz Siwiak (1998), Radiowave Propagation and Antennas for Personal Communications, Second Edition. Norwood, MA: Artech House
- [49] Federal Communications Commission (FCC) 47 Code of Federal Regulations (CFR) Parts 0, 1, 2, 90 and 95 amendments for Dedicated Short Range Communications Services and Mobile Service for Dedicated Short Range Communications of Intelligent Transportation Service in the 5.850-5.925 GHz Band (5.9 GHz Band)
- [50] 3GPP TS 36.300, LTE; Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2
- [51] Specification of the Bluetooth® System (Bluetooth Core Specification), Bluetooth SIG
- [52] Systems Engineering Principles and Practice, Second Edition, Alexander Kossiakoff, William N. Sweet, Samuel J Seymour, Steven M. Biemer; Wiley, 2011
- [53] Xiaohui Wang, Eric Anderson, Peter Steenkiste, Fan Bai, Improving the Accuracy of Environment-Specific Vehicular Channel Modeling, WiNTECH, 2012. (BibTeX).
- [54] Xiaohui Wang, Kevin Borries, Eric Anderson, Peter Steenkiste, Network-Scale Emulation of General Wireless Channels, Vehicular Technology Conference (VTC) 2011-Fall, 2011
- [55] IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, VOL. 9, NO. 2, JUNE 2008 235 Vehicle-Vehicle Channel Models for the 5-GHz Band Indranil Sen, Member, IEEE, and David W. Matolak, Senior Member, IEEE.

- [56] Guillermo Acosta and Mary Ann Ingram, "Doubly Selective Vehicle-to-Vehicle Channel Measurements and Modeling at 5.9 GHz," Proceedings 2006 Wireless Personal Multimedia Communications Conference (WPMC'06), San Diego, CA, September 17-20, 2006.
- [57] G. Acosta and M.A. Ingram, "Six Time- and Frequency-Selective Empirical Channel Models for Vehicular Wireless LANs," (Best Paper Award) 1st IEEE International Symposium on Wireless Vehicular Communications, Vehicular Technology Conference, (VTC 2007), Sept 30 - Oct 1, 2007.
- [58] M.A. Ingram and G. Acosta, "WAVE Motion-Related Channel Model Development," doc.: IEEE 802.11-06/1017r1, San Diego, CA, July 18, 2006.
- [59] Measurement and Analysis of Wireless Channel Impairments in DSRC Vehicular Communications, Electrical Engineering and Computer Sciences University of California at Berkeley, Technical Report No. UCB/EECS-2008-33, <http://www.eecs.berkeley.edu/Pubs/TechRpts/2008/EECS-2008-33.html>, April 9, 2008, Laberteaux et al.

1.2 General Statements

This document is intended to provide the common elements that support the DSRC standards including the J2735 data dictionary and all J2945/x standards. It is intended that the J2735 and J2945/x standards will reference the common design elements, as needed to provide a single definition within the DSRC standards to avoid duplication of information. This will allow changes to be made in one document rather than propagating the changes across all of the J2945/x documents.

1.3 Terms and Definitions

For the purposes of this standard, the definitions, abbreviations and acronyms found in SAE J2735 also apply. The following additional definitions, abbreviations and acronyms supersede those found in J2735 in the case of conflict.

1.3.1 ACTOR

An entity that has an active role or interest in a use case, e.g., driver.

1.3.2 CERTIFICATE AUTHORITY (CA)

A Back-Office Infrastructure entity that interacts with the Host Vehicle (HV) and the RA to enter into a dialog with the HV and provide certification services. A primary goal of the CA is to manage the collection of certificates for DSRC devices.

1.3.3 CERTIFICATE MANAGEMENT

The public key infrastructure that issues certificates and manages other security functions.

1.3.4 CONCEPT OF OPERATIONS DOCUMENT

A user-oriented document that describes a system's operational characteristics from the end user's viewpoint. [34]

1.3.5 CONNECTED VEHICLE

A vehicle equipped with devices enabling interoperable network wireless communication. The devices can communicate with other equipped vehicles, infrastructure, and personal communications devices.

1.3.6 CONTEXT DIAGRAM

A context diagram is a block diagram, showing a system as a whole, and its inputs and outputs from/to external factors. This diagram is the highest-level view of a system. It shows the borders, actors, and interaction between systems and the major information flow in and out of the system. It can also be referred to as a system context diagram (SCD) [51]

1.3.7 CONTROL CHANNEL (CCH)

The radio channel typically used in IEEE 1609 for transmitting service announcements and other control information in WAVE protocol. This is used in DSRC implementations.

1.3.8 DATA PLANE

The data plane is the component of an abstract telecommunications architecture containing the entities that exchange protocol data units that contain application data units with their peers at the various layers in the protocol stack.

1.3.9 DEDICATED SHORT RANGE COMMUNICATIONS

DSRC is a low latency, multi-channel wireless form of communication enabling vehicle-to-vehicle and vehicle-to/from-infrastructure devices. The protocol is based on the IEEE Standard 802.11 and the IEEE 1609 family of standards, and it operates in the 5.9 GHz band.

1.3.10 DIALOG

A sequence of two or more messages which are exchanged in a known format (typically of a request followed by one or more replies) between the parties.

1.3.11 DRIVER

The human operating a vehicle (equipped or non-equipped) used in any role. Drivers may be actors in a use case.

1.3.12 ENCOUNTER

In the context of this Standard, an encounter is an exchange of messages between two or more DSRC equipped devices (OBUs, RSUs or other DSRC types).

1.3.13 ENTITY

Anything of interest (such as a person, place, process, property, object, concept, association, state, event, etc.) within a given domain of discourse (in this case within the ITS domain of discourse).

1.3.14 GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

GNSS is a satellite system that is used to determine the geographic location of a user's receiver. Two examples include the United States' Global Positioning System (GPS) and the Russian Federation's Global Orbiting Navigation Satellite System (Globalnaya Navigazionnaya Sputnikovaya Sistema or GLONASS)

1.3.15 HEAVY VEHICLE

Vehicles with a FHWA vehicle classification of 5 to 13.

1.3.16 HOST VEHICLE (HV)

The primary equipped vehicle of concern that is running a specific application about which a given use case may be constructed. The Host Vehicle (HV) can be a transmitting vehicle, a receiving vehicle, or both – this distinction is made clear in the use case description. There is typically only one Host Vehicle in any use case.

1.3.17 INFRASTRUCTURE

Any roadside devices which support V2V/V2I/V2X communications flows (message exchanges), including but not limited to DSRC RSU devices.

1.3.18 INTELLIGENT TRANSPORTATION SYSTEM (ITS)

An ITS is a system that applies information technology to transportation challenges. ITS improves transportation safety and mobility and enhances productivity through the integration of advanced communications technologies into the transportation infrastructure and in vehicles. ITS encompasses a broad range of wireless and wire line communications-based information and electronics technologies. - See more at: <http://www.its.dot.gov/index.htm>.

1.3.19 INTEROPERABILITY

The ability of two or more systems or components to exchange information and to use the information that has been exchanged. [36]

1.3.20 INTERNATIONAL TRAVELER INFORMATION SYSTEMS (ITIS)

The term commonly associated with the SAE J2540-2 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 (i.e., a traffic crash) and is 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. ITIS phrases can also be freely mixed with text and used to describe incidents, crashes, weather reports, roadway signage, and other content types.

1.3.21 LIGHT VEHICLE

A class 2 or class 3 vehicle as defined by FHWA https://www.fhwa.dot.gov/policyinformation/tmguid/tmg_2013/vehicle-types.cfm excluding ambulances, law enforcement vehicles, fire department vehicles and construction vehicles.

1.3.22 LINK (RF)

A communications channel being used in support of application data transfer needs.

1.3.23 MANAGEMENT INFORMATION BASE

Set of objects describing the attributes, properties and controllable features of devices on a network, which can be remotely monitored, configured and controlled. The information is provided in a format called Abstract Syntax Notation. 1 (ASN.1), which is an international standard for defining objects.

1.3.24 MESSAGE

A well-structured set of data elements and data frames that can be sent as a unit between devices to convey some semantic meaning in the context of pre-defined applications.

1.3.25 MESSAGE SET

A collection of messages based on the functional area to which they pertain.

1.3.26 NETWORKING SERVICES

The collection of management plane and data plane functions at the network layer supporting WAVE communications.

1.3.27 NOTIFICATION

An indication of an event sent to an application. Also, a term used by lower layers to inform upper layers of an event in a protocol stack.

1.3.28 ON-BOARD UNIT

An On-Board Unit (OBU) is a vehicle-mounted DSRC device used to transmit and receive a variety of message traffic to and from other DSRC devices (other OBUs and RSUs). Among the message types and applications supported by this process are vehicle safety messages used to exchange information on each vehicle's dynamic movements for coordination and safety. An OBU contains a station (STA).

1.3.29 PROVIDER SERVICE CONTEXT (PSC)

A field associated with a PSID containing supplementary information related to the service. PSC is defined in IEEE Standard 1609.3.

1.3.30 PUBLIC SAFETY VEHICLE

An equipped vehicle actively engaged in Public Safety operations and announcing so to others. When not engaged in Public Safety operations, this role reverts to the behaviors associated with its basic vehicle class and type (typically a passenger vehicle). This type of vehicle is presumed to be equipped with an On-Board Unit specialized for Public Safety ("PSOBU") device.

1.3.31 RECEIVING VEHICLE

An equipped vehicle receiving DSRC messages from other nearby vehicles, personal (VRU) devices, or from nearby infrastructure (e.g., an RSU).

1.3.32 REFERENCE LANE

A reference lane is a lane drivable by motorized vehicle traffic which also contains a detailed path definition of the lane's geometry (a center line path and width) as well as basic attributes (such as the allowed maneuvers) about the lane. The provided path data may optionally be reused with another nearby lane (a "computed lane") in the same intersection.

1.3.33 REMOTE VEHICLE (RV)

The equipped vehicle (or vehicles) which play supporting roles in the use case by interacting with the Host Vehicle in some way. Each Remote Vehicle (RV) can be a transmitting vehicle, or a receiving vehicle, or both – this distinction is made clear in the use case description. There is typically more than one Remote Vehicle in any use case.

1.3.34 REPORTING VEHICLE

An equipped vehicle which is providing data to other Remote Vehicles or to the roadside Infrastructure.

1.3.35 REVERSING VEHICLE

An equipped vehicle in which the transmission is engaged to propel the vehicle backwards.

1.3.36 ROADSIDE DEVICE (RD)

Any Roadside Infrastructure device which is equipped with an RSU and which is used to communicate with equipped vehicles. Further distinctions among RDs may be made for devices which are co-located or in proximity with other roadside devices (such as an advanced signal controller) for some use cases.

1.3.37 ROADSIDE UNIT (RSU)

A DSRC device used to transmit to, and receive from, DSRC equipped vehicles (OBUs) and personal devices. The RSU transmits from a fixed position on the roadside (which may be either a permanent installation or "temporary" equipment brought on-site for a period of time associated with an incident, road construction, or other event). Some RSUs have the ability to transmit signals with greater power than OBUs and some may have connectivity to other nodes or the Internet. An RSU contains a station (STA).

1.3.38 SAFETY VEHICLE

A vehicle used for emergency or incident management.

1.3.39 SERVICE CHANNEL

A DSRC channel used for exchange of information relevant for ITS applications, in contrast to CCH, which carries control information.

1.3.40 STANDARDS DEVELOPING ORGANIZATION

An organization whose primary activities are developing, coordinating, promulgating, revising, amending, reissuing, interpreting, or otherwise producing technical standards that are intended to address the needs of some relatively wide base of affected adopters.

1.3.41 STATION

Any device that contains an IEEE 802.11 conformant medium access control (MAC) and physical layer (PHY) interface to the wireless medium. Both an RSU and an OBU contain stations (STA).

1.3.42 SYNTAX

The structure of expressions in a language, and the rules governing the structure of a language.

1.3.43 SYSTEM

INCOSE Systems Engineering Handbook describes a system as “A combination of interacting elements organized to achieve one or more stated purposes.” It further states that a system is “an integrated set of elements, subsystems, or assemblies that accomplish a defined objective. These elements include products (hardware, software, firmware), processes, people, information, techniques, facilities, services, and other support elements.” [\[42\]](#)

1.3.44 SYSTEMS ENGINEERING PROCESS

An interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with design synthesis and system validation while considering the complete problem: operations, cost and schedule, performance, training and support, test, manufacturing, and disposal. Systems Engineering (SE) considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs. [\[42\]](#)

1.3.45 SYSTEM OF SYSTEMS

System of systems applies to a system-of-interest whose system elements are themselves systems; typically, these entail large scale inter-disciplinary problems with multiple, heterogeneous, distributed systems. Another appropriate definition can be found in Wikipedia, “System of systems is a collection of task-oriented or dedicated systems that pool their resources and capabilities together to create a new, more complex system which offers more functionality and performance than simply the sum of the constituent systems.” [\[42\]](#)

1.3.46 TRANSACTIONS

Bi-directional data exchanges between devices (RSUs and OBUs).

1.3.47 TRANSIT VEHICLE

An equipped vehicle engaged in Transit operations, e.g., a bus.

1.3.48 UN-EQUIPPED VEHICLE

A vehicle which is not equipped with an OBU device.

1.3.49 USER NEEDS

A user requirement for a system that a user believes would solve a problem experienced by the user.

1.3.50 VALIDATION

Assurance that the system fulfills its business or mission objectives and stakeholder requirements (user needs in ITS), achieving its intended use in its intended operational environment.

1.3.51 VERIFICATION

(A) The process of evaluating a system or component to determine whether the products of a given development phase satisfy the conditions imposed at the start of that phase. (B) The process of providing objective evidence that the system, software, or hardware and its associated products conform to requirements (e.g., for correctness, completeness, consistency, and accuracy) for all life cycle activities during each life cycle process (acquisition, supply, development, operation, and maintenance); satisfy standards, practices, and conventions during life cycle processes; and successfully complete each life cycle activity and satisfy all the criteria for initiating succeeding life cycle activities.

1.3.52 WAVE Device

A Device which is conformant to Wireless Access for Vehicular Environment communication protocol.

1.3.53 WAVE Management Entity (WME)

The set of management functions, as defined in IEEE Standard 1609 documents.

1.3.54 XML

A common mark-up language used for exchanging messages made up of tags and values organized in a data structure and typically transported over common Internet formats such as HTTP. XML can be implemented in the types of heterogeneous systems often found in ITS deployments.

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.

ACR	Adjacent Channel Rejection
AIFSN	Arbitration Interframe Space Number
ASC	Advanced Signal Controller
ASN	Abstract Syntax Notation revision One, Also: ASN.1
ASTM	American Society for Testing and Materials
ATIS	Advanced Traveler Information Systems
ATMS	Advanced Transportation Management Systems
BIM	Basic Infrastructure Message
BSM	Basic Safety Message
BSS	Basic Service Set
CAMP	Crash Avoidance Metrics Partners (CAMP LLC)
CAN	Controller Area Network
CACC	Cooperative Adaptive Cruise Control
CCH	Control Channel
CICAS-V	Cooperative Intersection Collision Avoidance System – Violation
CMS	Certificate Management System
ConOps	Concept of Operations
CRL	Certificate Revocation List
CV	Connected Vehicle
DE	Data Element
DF	Data Frame
DoD	Department of Defense
DSRC	Dedicated Short Range Communications

EDCA	Enhanced Distributed Channel Access
EVA	Emergency Vehicle Alert
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
FIPS	Federal Information Processing Standards
GHz	Gigahertz
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
Hv	Heavy Vehicle
HV	Host Vehicle
I2V	Infrastructure-to-Vehicle
ID	Identifier
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
INCOSE	International Council on Systems Engineering
IP	Internet Protocol
IPv6	Internet Protocol version 6
ITIS	International Traveler Information Systems
ISO	International Organization for Standardization
ITE	Institute of Transportation Engineers
ITIS	International Traveler Information Systems
ITS	Intelligent Transportation System
JPO	Joint Program Office
LAN	Local Area Network
LLC	Logical Link Control
LOS	Line of Sight
LSB	Least Significant Bit
LTE	Long Term Evolution – 4G wireless broadband technology
LV	Light Vehicle (also shown as Lv)
MAN	Metropolitan Area Network
MAC	Medium Access Control
MAP	SAE J2735 Map Data Message
MDC	Major Desired Capability
MIB	Management Information Base
MPDU	MAC Protocol Data Units
MSB	Most Significant Bit
MSG	Message
NHTSA	National Highway Traffic Safety Administration
NIST	National Institute for Standards and Technology
NTCIP	National Transportation Communications for ITS Protocols
NRTM	Needs to Requirements Traceability Matrix
OBE	On-Board Equipment
OBU	Onboard Unit
OEM	Original Equipment Manufacturer

OTA	Over-The-Air
PDM	Probe Data Management Message
PDU	Protocol Data Unit
PER	Packed Encoding Rules
PH	Path History
PHY	Physical Layer
PP	Path Prediction
PSC	Provider Service Context
PSID	Provider Service Identifier
PSN	Probe Segment Number
PVD	Probe Vehicle Data Message
RA	Registration Authority
RSA	Road Side Alert
RSU	Roadside Unit
RTCM	Radio Technical Commission for Maritime Services or RTCM Corrections Message
RTM	Requirements Traceability Matrix
RV	Remote Vehicle
SAE	Society of Automotive Engineers
SAP	Service Access Point
SC-104	RTCM's Sub-Committee 104
SCD	System Context Diagram
SCH	Service Channel
SDH	Sensor Data Handler
SDO	Standards Developing Organizations or Standards Development Organization
SE	Systems Engineering
SEP	Systems Engineering Process
SoS	System of Systems
SP	Special Publication
SPaT	Signal Phase and Timing Message
SRM	Signal Request Message
SRS	Safety Restraint System or Supplemental Restraint System
SSM	Signal Status Message
SSP	Service Specific Permissions
STA	Station
Std	Standard
TCIP	Transit Communications Interface Profiles
TCP	Transmission Control Protocol
TF	Task Force
TIM	Traveler Information Message
TMDD	Traffic Management Data Dictionary
TXOP	Transmission Opportunity
UC	Use Case
UDP	User Datagram Protocol
UML	Unified Modeling Language

UP	User Priority
URL	Uniform Resource Locator
USDOT	United States Department of Transportation
UTC	Universal Coordinated Time
V&V	Verification and Validation
V2D	Vehicle-to-Device
V2Hv	Vehicle-to-Heavy Vehicle
V2I	Vehicle-to-Infrastructure
V2P	Vehicle-to-Pedestrian
V2Sv	Vehicle-to-Safety Vehicle
V2Tv	Vehicle-to-Transit Vehicle
V2V	Vehicle-to-Vehicle
V2X	Vehicle to any DSRC equipped object
VRU	Vulnerable Road User
WAVE	Wireless Access in Vehicular Environments
Wi-Fi	Wireless Fidelity
WME	WAVE Management Entity
WMH	Wireless Message Handler
WSM	WAVE Short Message
WSMP	WAVE Short Message Protocol
XML	eXtensible Markup Language

2. INTRODUCTION TO DSRC STANDARD SERIES [INFORMATIVE]

2.1 Connected Transportation Eco System (System of Systems)

The Connected Transportation System of Systems (SoS), as shown in [Figure 1](#), consists of a collection of systems. Each system is comprised of various connected devices including vehicles (V), infrastructure (I), and other devices (D). Interactions between the devices within the system include Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I), Vehicle to Device (V2D), and Device to Infrastructure (D2I). Additionally, systems that may be included in the SoS are developed to address more specific varieties of devices, as an example, with vehicles there are light vehicles (Lv), heavy vehicles (Hv), transit vehicles (Tv), and safety vehicles (Sv). Other devices such as Vulnerable Road Users (VRU) are examples that are not vehicles. The following context diagrams are intended to be for instructive and illustrative purposes and are not to be considered to be complete or exhaustive.

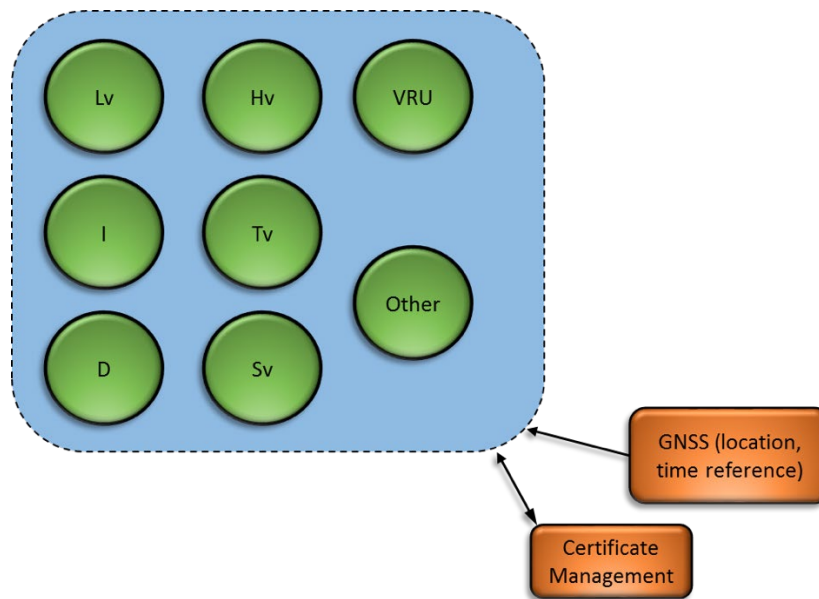


Figure 1 - Connected transportation (system of systems)

Systems

- Vehicle System ($V \leftrightarrow V$)
- Infrastructure System ($V \leftrightarrow I$)
- Device System ($V \leftrightarrow D$, $D \leftrightarrow I$)
- Light Vehicle (Lv) System ($V \leftrightarrow Lv$, $Lv \leftrightarrow I$)
- Heavy Vehicle (Hv) System ($V \leftrightarrow Hv$, $Hv \leftrightarrow I$)
- Transit Vehicle (Tv) System ($V \leftrightarrow Tv$, $Tv \leftrightarrow I$)
- Safety Vehicle (Sv) System ($V \leftrightarrow Sv$, $Sv \leftrightarrow I$)
- Vulnerable Road User System ($V \leftrightarrow VRU$, $VRU \leftrightarrow I$)
- Others

It is important to note that for example purposes, only a few of the vehicle types have been shown at the point in time when this standard was published. There are many additional types of vehicles. For reference, [Figure 2](#) illustrates the FHWA vehicle classifications. These classifications are used to help differentiate the vehicle types specified in the connected systems. This classification is used in subsequent context diagrams.

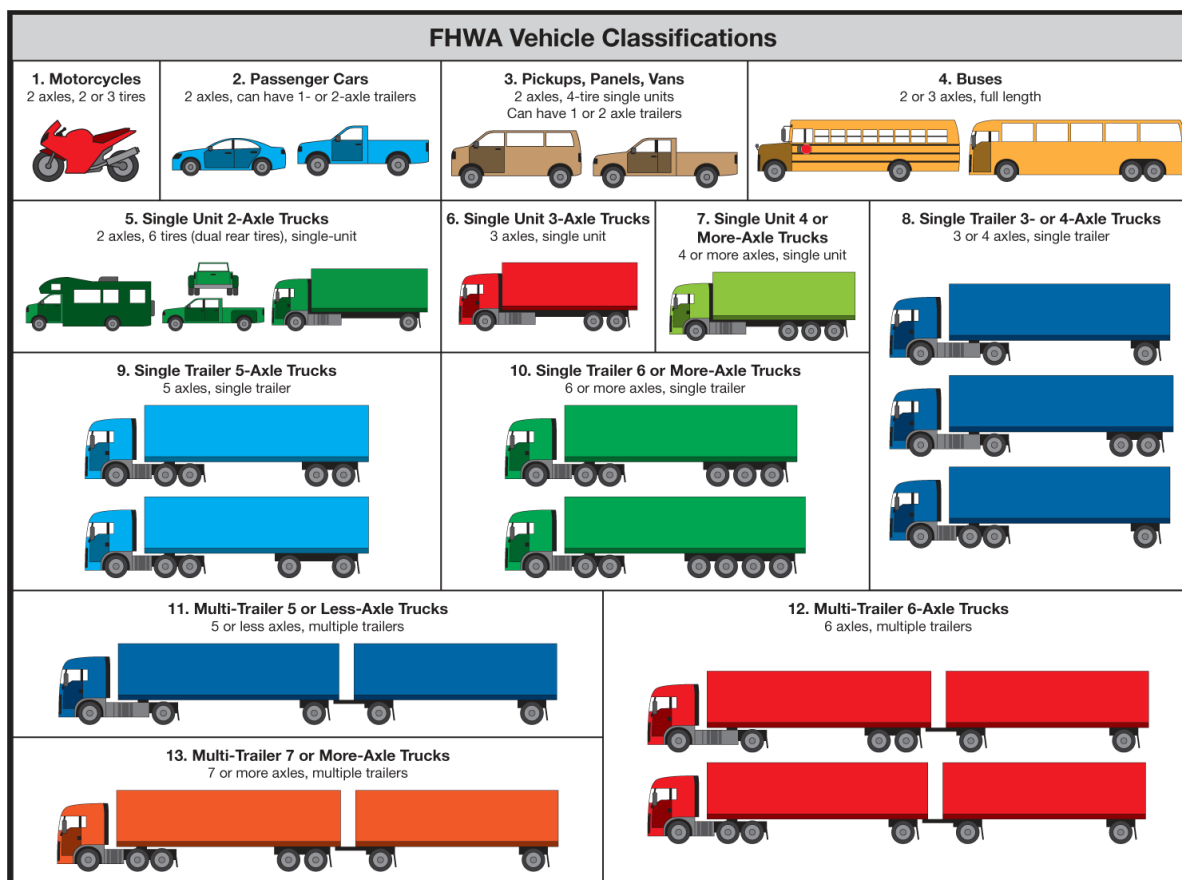


Figure 2 - Vehicle classification using FHWA 13 - category scheme

2.2 Connected Transportation System Context Diagrams

The context diagrams are further illustrated by expanding on two of the systems, the V2V vehicles and the V2I systems. In order to develop the specific system context diagrams (SCD) a block diagram is created showing the system as a whole, and its inputs and outputs from/to external factors. These context diagrams are the highest-level view of a system and are included in the concept of operation. The diagrams show the borders, actors, and systems interacting with the specified system and the major information flow in and out of the system. These interfaces and interdependencies will drive the system design. The SCD typically describes the flow of information in the system with labeled communication arrows drawn between the system components. If there are different types of information, one arrow may be used per information type. This distinguishes between the input and output of information. The objective of the system context diagram is to focus attention on external factors and events that should be considered in developing a complete set of systems requirements and constraints. The following context diagrams are intended to be for instructive and illustrative purposes and are not to be considered to be complete, normative, or exhaustive.

2.2.1 V2V System Motorized Vehicle Context Diagram

The V2V system, as shown in [Figure 3](#), consists of on-board units (OBU) installed in the vehicles. The OBU broadcasts and receives vehicle safety and status information. Applications reside on the OBU for notifying the vehicle occupants of specific situations. The OBU communicates with the other vehicles and interfaces with GNSS and a certificate management system, in addition to other devices.

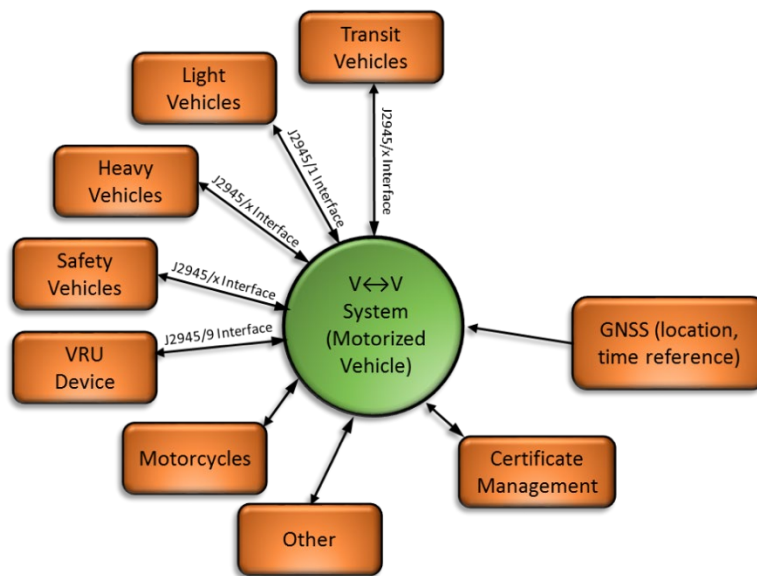


Figure 3 - Connected vehicle (V2V) context diagram

GNSS - The OBU interfaces with one or more GNSS for location and time data.

Certificate Management - In order to authenticate the source of a message, the OBU may interface with a certificate management system (CMS). The OBU messages that include a valid certificate indicate to the receiver that the sending device has been granted permission from a mutually trusted authority.

Light Vehicle - A vehicle with a FHWA vehicle classification of 2 and 3, as described in [Figure 2](#), can include factory installed devices, after-market devices, or retrofit devices that interface with systems installed on other vehicles to improve safety and movement within the road system. Taxis, while possibly being light vehicles, may be considered as shared passenger transport service vehicles and therefore transit vehicles.

Transit Vehicle – A shared passenger-transport service which is available for use by the general public which is equipped with a device that can interface with other equipped devices to improve safety and movement within the transportation system. Buses, FHWA vehicle classification 4, are treated as transit vehicles instead of heavy vehicles as they are considered to be a shared passenger-transport service

Heavy Vehicle – Heavy vehicles, those with the FHWA vehicle classification of 5 through 13 can have V2V systems installed to assist in their movements and safety. These larger vehicles have unique needs due to their size and weight.

Safety Vehicle – Emergency and incident management vehicles such as police vehicles, ambulances, and motorist assist vehicles can have devices installed to communicate within the V2V systems to assist in their response and safety during operations. Safety Vehicles are made up of other physical vehicle types (Light, Heavy, Transit, Motorcycle, etc.), but operate in the role of Safety Vehicles when using a certificate granting them the additional rights and privileges.

VRU Device – A road user who is not using a motorized vehicle is particularly vulnerable to serious injury or death when involved in a motor-vehicle-related collision. These users include pedestrians, cyclists, and road workers. The V2V systems in motorized vehicles can communicate with these users via the VRU devices.

Motorcycle – Motorcycles are vehicles with a FHWA vehicle classification of 1. They have more safety concerns than other vehicle types. They can have OBUs installed to allow them to communicate with other vehicles to improve their safety and to improve awareness of nearby vehicles in relation to themselves.

The specific vehicle roles will be defined in their appropriate J2945/x standard.

2.2.2 V2I Vehicle to Infrastructure Context Diagram

The V2I system, as shown in [Figure 4](#), interfaces with vehicles, other field devices, agencies, GNSS, a certificate management system, along with other external systems. The interfaces can utilize various standards including, but not limited to those standards developed by SAE and NTCIP.

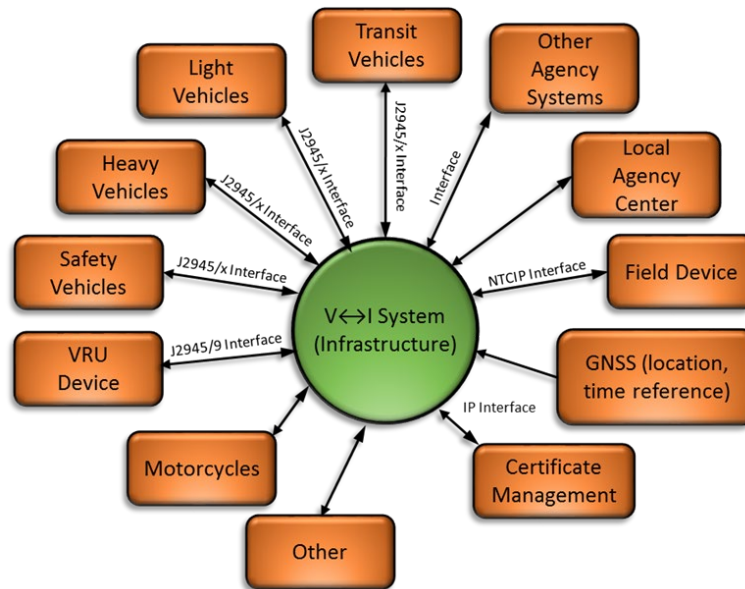


Figure 4 - Connected infrastructure context diagram

Definitions common between the context diagrams have not been repeated. Refer to the section above.

Agency Centers - The V2I infrastructure can communicate with agency centers to notify the agencies of the current state of the device and its environment, including vehicle mobility within its area.

Field Devices - The field devices can consist of, but are not limited to, road-side units, signal controllers, and other transportation regulating or monitoring devices.

2.3 SAE DSRC Standards Series Supporting the Connected Transportation Eco System

The SAE DSRC standards series, that supports the deployment of connected transportation eco system, are made up of two types of documents. First are the common documents including J2735 [\[3\]](#) and this document, J2945/0, which will be referenced by the other J2945/x documents. The second type will be the specific J2945/x documents which will include applications and provide their associated needs, requirements, and design, within the connected transportation eco-system. For illustrative purposes [Figure 5](#) shows the typical relationship between a system and its associated J2945/x standards. J2735 and J2945/0 are not shown in this figure.

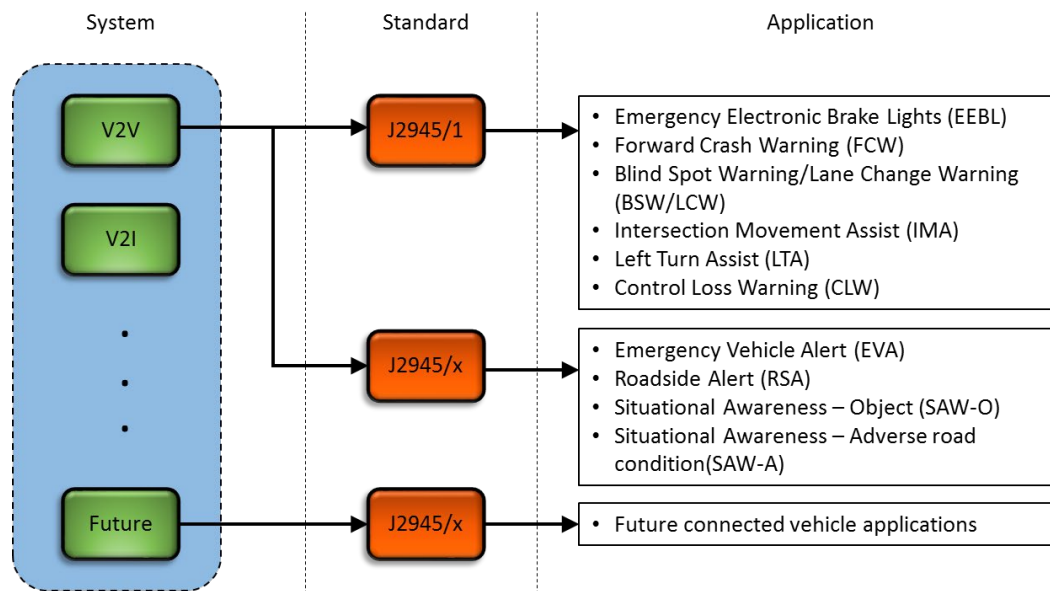


Figure 5 - Relationship of system and J2945/x standards¹

3. SYSTEMS ENGINEERING PROCESS (SEP) FOR J2945/X [INFORMATIVE]

This section is intended to assist the DSRC Technical Committee (TC) in the development of J2945/x standards. Using a Systems Engineering Process is beneficial as it enables the TC to produce high value, high quality documents for the operating agency's use. This section continues from the SoS view of the connected vehicle domain ([Section 2](#)) to provide context for stakeholders. This section provides more of the details and organization of references for a Systems Engineering Process that can be used to enable the TC to develop a J2945/x. Finally, it provides the TC a detailed Table of Contents for a new J2945/x document.

3.1 Systems Engineering Process and Guidance to Support J2945/x Development

3.1.1 Introduction

This section provides an overview of the Systems Engineering Process that can be used by J2945/x. It is based on work done by the USDOT to adapt the Systems Engineering Process for the US transportation industry, as referenced below.

Over the past decade, the transportation industry (e.g., American Association of State Highway and Transportation Officials (AASHTO), Institute of Transportation Engineers (ITE), National Electrical Manufacturers Association (NEMA), National Transportation Communications for ITS Protocol (NTCIP)) has worked with the systems engineering community to develop numerous guidance documents and material to assist the US transportation industry Standards Development Organizations (SDOs) in developing standards with SEP content and support the industry implementers deploying interoperable systems. The TC is utilizing the extensive resources developed by the transportation industry in the development of J2945/x standards with SEP.

The subsequent sections utilize the content of several documents authored by the transportation industry to provide an overview of the System Engineering Process that can be used by J2945/x. References and resources for the specific SEP guidance and training material are intended to support the TC in developing, reviewing, comment resolution, approval and balloting of the standards.

¹ The J2945/x applications listed in the figure have not completed ballot process at the time of this document's publication.

3.1.2 Fundamentals of Systems Engineering

The remainder of section 3 provides reference documents covering the SEP for a comprehensive system to provide context to how the SEP can be applied to the development of J2945/x documents. The Systems Engineering Process is based on the principles developed by the leading systems engineering organizations, INCOSE and IEEE. There are two primary SEP guidance references.

- a. INCOSE, Systems Engineering Handbook [\[43\]](#)
- b. IEEE Std 1220-2005 (R2011) IEEE Standard for Application and Management of the Systems Engineering Process [\[33\]](#)

In support of developing SEP documents for systems there are several relevant IEEE standards that provide guidance, they are as follows:

- a. IEEE Std 610.12-1990 (R2002) Standard Glossary of Software Engineering Terminology [\[36\]](#)
- b. IEEE Std 1362-1998 (R2007) IEEE Guide for Information Technology - System Definition - Concept of Operations (ConOps) Document [\[35\]](#)
- c. IEEE Std 1471-2000 IEEE Recommended Practice for Architectural Description for Software-Intensive Systems [\[36\]](#)
- d. IEEE Std 1233-1998 (R2002) IEEE Guide for Developing System Requirements Specifications [\[34\]](#)
- e. IEEE Std 830-1998 (R2009) IEEE Recommended Practice for Software Requirements Specifications [\[38\]](#)
- f. IEEE Std 1012-2012 IEEE Standard for System and Software Verification and Validation [\[31\]](#)
- g. IEEE Std 1028-2008 IEEE Standard for Software Reviews and Audits [\[32\]](#)

The transportation industry has worked with other SDOs to optimize the SEP for transportation related standards development. These efforts have built upon the SEP principles contained in the references provided above. To meet the needs of the SAE TC specifically for development of the J2945/x standards, several documents are referenced that incorporate the lessons learned by the standards development efforts of the USDOT and other transportation related SDOs. The documents are:

- a. US Department of Transportation Systems Engineering for Intelligent Transportation Systems An Introduction for Transportation Professionals [\[25\]](#)
- b. FHWA-JPO-11-089 Applying Systems Engineering Principles to the Development of Transportation Communication Standards [\[21\]](#)
- c. Systems Engineering Concepts for ITS Standards Development [\[24\]](#)
- d. NTCIP 8002 Annex B1 v01 Content Outline for NTCIP 1200-Series Documents [\[42\]](#)
- e. SAE J3067 Candidate Improvements to Dedicated Short Range Communications (DSRC) Message Set Dictionary [SAE J2735] Using Systems Engineering Methods [\[13\]](#)

The core concepts of the Systems Engineering Process that are illustrated in the SE Vee-Diagram as shown in [Figure 6](#). The diagram illustrates the complete lifecycle of a system from inception and concept of operations through system deployment and operations. The SAE DSRC TC J2945/x with SEP content documents can address a specific system and one or more applications that will meet the user's operational needs as illustrated in [Figure 5](#). Therefore, the SEP content covers the SE Vee-Diagram that addresses the concept of operations, requirements, and design as the SEP applies to standards development. Moving through the material concerning the SEP in this section, it is important to refer forward to [3.2](#), specifically [Figure 11](#) to understand how NTCIP 8002 Annex B1 and the SEP are applied to create the outline and content for a J2945/x standard.

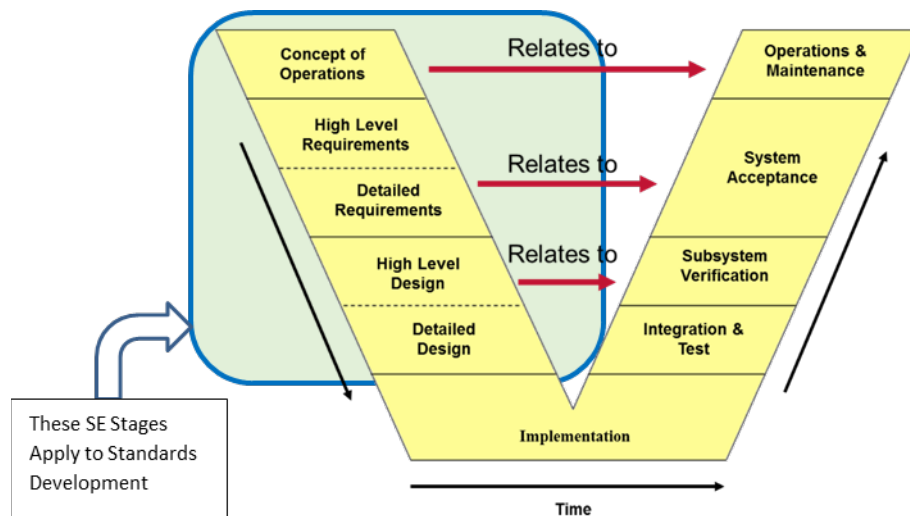


Figure 6 - Systems engineering vee-diagram lifecycle

Systems engineering at its most basic level aims to solve the right problem, in the right way, with the right tools, for the right cost. It should be noted that having the right group of stakeholders to identify the operational needs is the first step in identifying the right problem. Once the right stakeholders for the specific J2945/x and the Systems Engineering Process is engaged at the onset of the effort, the TC is able to assess the project risks, develop risk mitigation strategies, evaluate alternative solutions to technical problems, document the rationale for selecting a specific solution, control changes in scope, and finally enable the verification and validation of the system's implementation.

The Systems Engineering Process is concerned with the quality and traceability, both within each stage (e.g., concept of operation) and within the transitions between each stage (e.g., between concept of operations and requirements). Within each stage, the solutions should validly reflect the intent and content of the product(s) of the previous stage. In between the stages at the transitions, the stakeholders should verify the products that result from a stage are in fact complete and correct. [Figure 7](#) provides a graphical overview of the processes, their relationships, and the timing within the development of a J2945/x utilizing the Systems Engineering Process.

[Section 3.1.6](#) provides additional detail about how to achieve traceability through applying the SEP, but for now it is worth providing a set of truisms about the Systems Engineering Process to keep in mind throughout the development of the J2945/x documents.

- a. Every need must be addressed by at least one requirement
- b. Every requirement must relate to at least one need
- c. Any need that is not addressed by at least one requirement may be irrelevant or unsatisfied
- d. Every requirement that does not address at least one need is irrelevant
- e. Every requirement must be addressed by at least one "design element" (dialog, message, data frame, data element)
- f. Every "design element" must relate back to at least one requirement
- g. Any requirement that is not addressed by at least one "design element" is unfulfilled
- h. Any "design element" that does not address at least one requirement is unnecessary

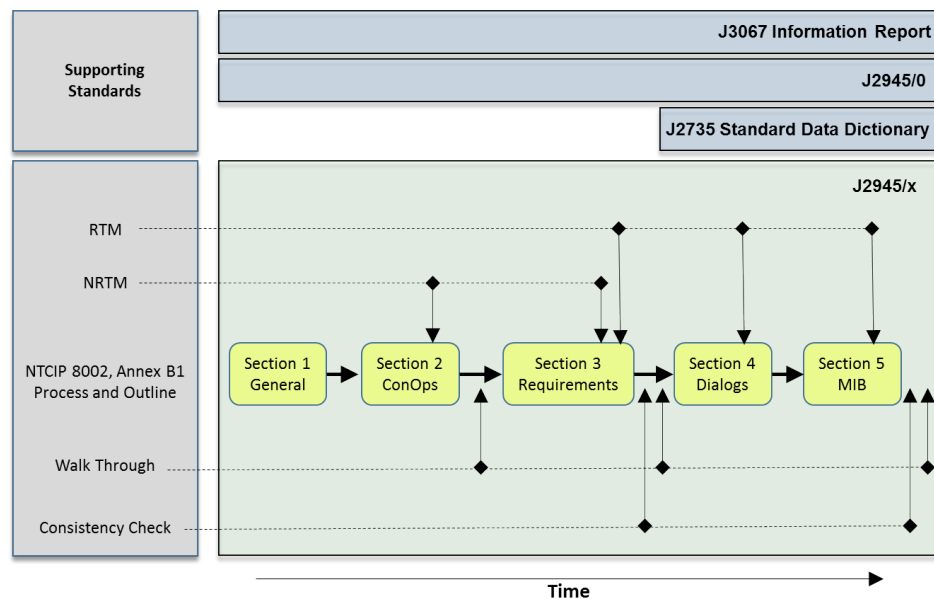


Figure 7 - J2945/x SEP relationships

Execution of the SEP results in attaining traceability throughout the stages of the process. [Figure 7](#) provides a graphical overview of the end product of the Systems Engineering Process. The connections describe the timing and how the processes interact throughout the SEP process. The Needs to Requirements Traceability Matrix (NRTM) provides the mapping of which requirements satisfy the specific user needs developed in the concept of operations. The NRTM provides a tool for completeness and correctness (V&V), can be used as a guide for procurement, gives the high-level picture of how needs and requirements map to the data dialogs and data concepts, and sets up the basis for design. The Requirements Traceability Matrix (RTM) tells the developers how specifically to fulfill a given requirement, it traces requirements with the design; dialogs and associated messages, data frames and data elements. The RTM explains to the developer the reason why a design element is needed and what requirement(s) it fulfills. The RTM also provides a tool for completeness and correctness checks (V&V) of the design, it specifies the “how” for development, it maps the requirements to design, it drills down to the lower levels of design and is the basis for verification testing, as shown in [Figure 8](#).

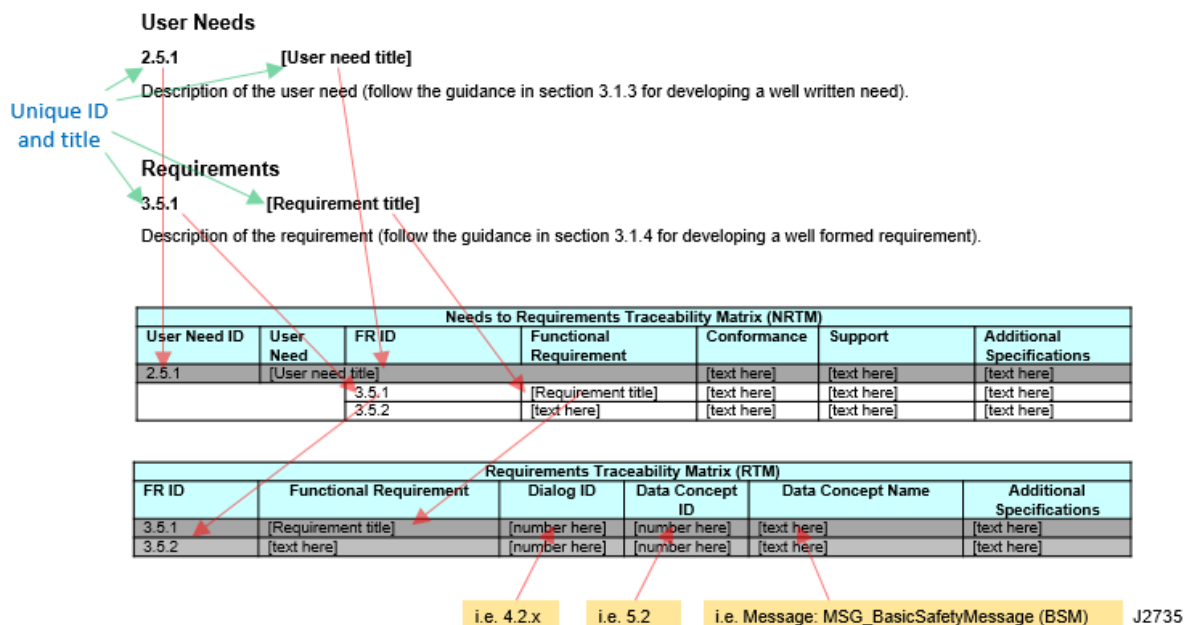


Figure 8 - Traceability matrices

The traceability is consistent with the process described in NTCIP 8002, Annex B1, but is not 100% compliant. For example, NTCIP 8002, Annex B1 includes Object ID and Object Name as column headings in the Requirements Traceability Matrix, but is called Data Concept ID and Data Concept Name for SAE J2945/0, because the design may be a message, data frame, or data element, not an object.

The SEP provides the J2945/x standards with a process to create high quality standards, validates that the standard meets the users' needs, verifies that it is complete, validates it is correct, and will reduce cost of interface development for the industry.

3.1.3 The Basics of the Concept of Operations

The concept of operations is the first major documentation step of the SE process as shown in [Figure 6](#). For additional general guidance refer to the IEEE 1362-1998, Guide for Information Technology - System Definition - Concept of Operations (ConOps) Document. It should be noted that IEEE 1362-1998 is oriented toward the development of a system, not a standard.

The table of contents for the Concept of Operations is shown in [Figure 11](#), which includes;

- a. Tutorial [Informative]
- b. Current Situation and Problem Statement [Informative]
- c. Reference Physical Architecture [Informative]
- d. Architectural Needs
- e. Features
- f. Security
- g. [Optional] Operational Policies and Constraints
- h. [Optional] Relationship to the ITS National Architecture
- i. [Optional] Operational Scenarios

The Concept of Operations defines the user needs in terms of the operations and maintenance of the system, which is the highest level of “whats”. The first and most critical step in developing the Concept of Operations is to assemble the correct and comprehensive set of stakeholders that will accurately describe the operational needs for which the systems will address. The stakeholders should first develop a reference physical architecture in the form of a context diagram as illustrated in [2.2](#).

The stakeholders should then identify the system features in terms of operational needs, which are user needs that describe what the users want to do operationally with the proposed system. Stakeholders may already know, through experience, their operational needs and document them directly. Operational Scenarios are used to give examples of how the user (or system) may operate with the desired capabilities. In some situations, the stakeholders may find it easier to develop use cases for the operational scenarios from which they can extract the user needs. A standardized template for development of use cases is provided in [Appendix B.1](#). It should be noted in some cases developers of a new J2945/x may have access to existing works that have been implemented prior to the standardization process. These works may influence how rapidly and in what order the components of the Concept of Operations can be developed.

The needs should be written to support the applications to be addressed by the standard. They are the highest level of “requirement” in the system. For specific examples, which were developed by another party, see reference document SAE J3067 Candidate Improvements to Dedicated Short Range Communications (DSRC) Message Set Dictionary [SAE J2735] Using Systems Engineering Methods [\[13\]](#). Other future J2945/x documents will also provide examples.