

Performance Requirements for Cooperative Adaptive Cruise Control (CACC) and Platooning

RATIONALE

This standard is the first edition of the Performance Requirements for Cooperative Adaptive Cruise Control and Platooning. It provides the information necessary to build interoperable systems that support CACC, which rely on the exchange of the Cooperative Control Message.

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1. GENERAL [INFORMATIVE]

1.1 Scope

This standard provides the guideline for enhancements to adaptive cruise control (ACC) by the addition of wireless communication from relevant vehicles (V2V) and/or the infrastructure (I2V) to augment the ACC active sensing capability. The CACC system operates under driver responsibility and supervision and is limited to the following:

- Does only longitudinal control of the vehicle.
- Uses time gap control strategy similar to ACC.

Motor vehicles covered in the scope of this document include light and heavy vehicles. The message elements to realize CACC and platooning are part of the scope.

The initial release covers definitions for CACC and platooning and requirements for CACC, while a subsequent release will cover the platooning requirements.

1.2 References

1.2.1 Normative References

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.

1.2.1.1 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 J2399	Adaptive Cruise Control (ACC) Operating Characteristics and User Interface
SAE J2735	V2X Communications Message Set Dictionary
SAE J2945	Dedicated Short Range Communication (DSRC) Systems Engineering Process Guidance for J2945/X Documents and Common Design Concepts™
SAE J2945/1	On-Board System Requirements for V2V Safety Communications
SAE J2945/5	Service Specific Permissions and Security Guidelines for Connected Vehicle Applications
SAE J3016	Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles
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

1.2.1.2 IEEE Publications

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

Please note this report incorporates certain IEEE specifications by reference. ESSENTIAL IPRs (Intellectual Property Rights) have been declared to IEEE. All information statements and licensing declarations of ESSENTIAL IPRs received by IEEE are publicly available via the IEEE IPR Online Database found at <https://standards.ieee.org/about/sasb/patcom/patents/>.

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
IEEE Std 1471-2000	IEEE Recommended Practice for Architectural Description for Software-Intensive Systems
IEEE Std 802.11™-2016	Standard for LAN/MAN - Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications
IEEE Std 1609.2™-2016	IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Security Services for Applications and Management Messages
IEEE Std 1609.3™-2016	IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Networking Services
IEEE Std 1609.4™-2016	IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Multi-channel Operation
IEEE Std 1609.12™-2019	IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Identifier Allocations

It should be noted that there are additional standards in the 1609 suite which are not directly referenced here but which may also be of assistance to implementers.

1.2.1.3 ISO Publications

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

Please note that this report incorporates certain ISO specifications by reference. ESSENTIAL IPRs (Intellectual Property Rights) have been declared to ISO. All information statements and licensing declarations of ESSENTIAL IPRs received by ISO are publicly available via the ISO IPR Online Database found at <https://www.iso.org/iso-standards-and-patents.html>.

ISO 15622:2018	Intelligent transport systems - Adaptive cruise control systems - Performance requirements and test procedures
ISO 20035:2019	Intelligent transport systems - Cooperative adaptive cruise control systems - Performance requirements and test procedures
ISO/IEC 8824-1:1998	Information technology - Abstract Syntax Notation One (ASN.1): Specification of basic notation.
ISO/IEC 8824-2:1998	Information technology - Abstract Syntax Notation One (ASN.1): Information object specification.
ISO/IEC 8824-3:1998	Information technology - Abstract Syntax Notation One (ASN.1): Constraint specification.
ISO/IEC 8824-4:1998	Information technology - Abstract Syntax Notation One (ASN.1): Parameterization of ASN.1 specifications.

1.2.2 Other References

All documents cited here are considered informative with respect to SAE J2945/6.

Meier, J.-N., Kailas, A., Abuchaar, O., Abubakr, M., Adla, R., Ali, M., Bitar, G., Deering, R., Ibrahim, U., Kelkar, P., Kumar, V.V., Moradi-Pari, E., Parikh, J., Rajab, S., Sakakida, M., and Yamamoto, M. (2018). On Augmenting Adaptive Cruise Control Systems with Vehicular Communication for Smoother Automated Following. *Transportation Research Record*, 2672(22), 67-77. <https://doi.org/10.1177/0361198118796375>.

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Lu, X.-Y. and Shladover, S.E. (2017, May 24-26). *Integrated ACC and CACC development for heavy-duty truck partial automation*. 2017 American Control Conference (ACC-17), Seattle, WA, United States.

Lu, X.-Y., Shladover, S.E., and Bergquist, S. (2019). Truck CACC implementation and test to verify control performance. *Transportation Research Record: Journal of the Transportation Research Board*, 2637(8). <https://doi.org/10.1177/0361198119842122>.

Shladover, S.E., Nowakowski, C., Lu, X.-Y., and Ferlis, R. (2015). Cooperative adaptive cruise control: Definitions and operating concepts. *Transportation Research Record: Journal of the Transportation Research Board*, 2489(1), 145-152. <https://doi.org/10.3141/2489-17>.

Federal Communications Commission. (2015). Guidelines for determining the effective radiated power (ERP) and equivalent isotropically radiated power (EIRP) of an RF transmitting system. Federal Communications Commission.

U.S. Department of Transportation (2016). *Privacy impact assessment: National Highway Traffic Safety Administration notice of proposed rulemaking (NPRM) on V2V communications*. U.S. Department of Transportation and National Highway Traffic Safety Administration.

2. TERMS AND DEFINITIONS

For the purposes of this standard, the definitions, abbreviations, and acronyms found in SAE J2735, SAE J2945/1, and SAE J3161/1 also apply. The following additional definitions, abbreviations, and acronyms supersede those found in SAE J2735, SAE J2945/1, and SAE J3161/1 in the case of conflict.

2.1 General Terms

2.1.1 CRITICAL EVENT FLAG

Refer to 3.1.2 in SAE J2945/1.

2.1.2 CRITICAL EVENT CONDITION

Refer to 3.1.3 in SAE J2945/1.

2.1.3 HARD BRAKING

A vehicle is decelerating at level greater than 0.4 g (vehicle classes of 2 and 3 in Annex D) or 0.3 g (vehicle classes of 5 through 13 in Annex D).

2.1.4 SECURITY CREDENTIAL MANAGEMENT SYSTEM

Refer to 3.1.8 in SAE J2945/1.

2.2 Cooperative Vehicle Control Systems

This section provides definitions of terms relevant to cooperative vehicle control systems.

2.2.1 COOPERATIVE VEHICLES CONTROL

Vehicles that send or receive information wirelessly to and/or from other vehicles or from roadside devices to automatically adjust their driving behavior. These driving behavior adjustments could include changes in speed or initiation of maneuvers such as lane changes.

2.2.2 COOPERATIVE ADAPTIVE CRUISE CONTROL (CACC)

An enhancement to ACC by the addition of wireless communication from preceding vehicles and/or the infrastructure to augment the ACC active sensing capability. In common with ACC, it typically uses a longitudinal controller for constant time gap vehicle following strategy.

2.2.3 V2V CACC

Cooperative adaptive cruise control that uses wireless communication with other vehicles to augment the ACC active sensing capability. The system is anticipated to use direct communication but other communication interfaces such as cellular networks may be possible.

2.2.4 I2V CACC

Cooperative adaptive cruise control that uses wireless communication with the infrastructure to augment the ACC active sensing capability. The system is anticipated to use direct communication but other communication interfaces such as cellular networks may be possible.

2.2.5 PLATOON (or AUTOMATED PLATOON)

A group of vehicles that closely follow the speed changes of a leader vehicle automatically and whose maneuvers are automatically coordinated by the leader vehicle.

NOTE: Additional supervisory or coordination functions may be performed by an off-board entity. The following vehicles in the platoon typically use a constant clearance gap criterion to govern their separation. If the clearance gap between the vehicles is very small, they may also employ automated steering control. The following strategies could be adopted in platooning:

Depending on the platooning strategy, the vehicles in platoon may follow various spacing policies:

- A constant headway (time gap) policy.
- A constant clearance distance policy.

- Variable headway (time gap) policy.
- Nonlinear or hybrid strategies.

Depending on the spacing policy and the control approach, various measurements could be used as controller inputs:

- Position, and/or velocity, and/or acceleration of leader vehicle.
- Position, and/or velocity, and/or acceleration of vehicle ahead.
- Position, and/or velocity, and/or acceleration of multiple vehicles in platoon.
- Other variables of the platooning vehicles may also be used, such as their local control commands or planned trajectories.

2.2.6 CACC STRING

A group of consecutive vehicles using CACC to govern their vehicle following behavior.

2.2.7 ELECTRONIC TOWBAR CONTROL

A form of cooperative automated vehicle following control in which the subject vehicle's steering is also controlled to automatically follow the lateral motions of the rear end of the preceding vehicle. This is a form of Level 2 (refer to SAE J3016) automation that can be implemented on one or more vehicles following the same leader vehicle.

2.2.8 LOOSELY COUPLED VEHICLE CLUSTER

A group of neighboring vehicles driving in the same direction in adjacent lanes using wireless communications to coordinate their maneuvering, including manually driven vehicles as well as vehicles operated by various levels of driving automation systems.

2.3 Definitions Specific to Adaptive Cruise Control

This section provides definitions of terms relevant to adaptive cruise control.

2.3.1 ADAPTIVE CRUISE CONTROL (ACC)

Enhancement to conventional cruise control systems (see Conventional Cruise Control), that allows the subject vehicle to follow the preceding vehicle at a pre-selected time gap by controlling the propulsion system and/or the service brake, up to a maximum speed, set by the driver. This control system is comprised of two main functions:

- Speed control: The subject vehicle travels at a driver-set speed.
- Spacing/time gap control: The subject vehicle maintains a desired distance/time-gap from the lead vehicle.

Refer to SAE J2399.

2.3.2 CONVENTIONAL CRUISE CONTROL (CCC)

System capable of controlling the speed of a vehicle, as selected by the driver without consideration of in-path forward vehicles (refer to SAE J2399).

2.3.3 FULL SPEED RANGE ACC (FSRA)

A class of adaptive cruise control systems (see Adaptive Cruise Control), which allows the subject vehicle to follow the preceding vehicle at an appropriate distance by controlling the engine and/or power train and the brake down to standstill (refer to ISO 15622).

2.3.4 LIMITED SPEED RANGE ACC (LSRA)

A class of adaptive cruise control systems (see Adaptive Cruise Control), which allows the subject vehicle to follow the preceding vehicle at an appropriate distance by controlling the engine and/or power train and the brake above a certain minimum velocity (refer to ISO 15622).

2.3.5 AUTONOMOUS ADAPTIVE CRUISE CONTROL (AACC)

Adaptive cruise control that does not rely on use of wireless communication as an information source (and therefore is not cooperative adaptive cruise control).

2.4 Specific Vehicle Roles

This section provides definitions of terms relevant to vehicle roles in cooperative system.

2.4.1 SUBJECT VEHICLE

Vehicle equipped with the CACC system in question (refer to SAE J2399).

2.4.2 FORWARD VEHICLE

Vehicle in front of, moving in the same direction, and travelling on the same roadway path as the subject vehicle (refer to SAE J2399).

2.4.3 PRECEDING VEHICLE

The vehicle immediately in front of the subject vehicle and following the same path (generally in the same lane).

2.4.4 LEADER VEHICLE

The first vehicle in the platoon or CACC string.

2.4.5 MASTER VEHICLE

The vehicle that takes on special responsibilities for coordinating the behaviors of other vehicles in its vicinity. In an automated platoon this role is normally taken by the leader vehicle, but in some cases, it may be taken by a vehicle in a different location.

2.5 Elemental Maneuvers

This section provides definitions of terms for maneuvers relevant to cooperative vehicles.

2.5.1 JOIN

The maneuver by which a cooperative vehicle is added to a CACC string or platoon and thereby switches to cooperative vehicle following control.

2.5.2 LEAVE

The maneuver by which a cooperative vehicle departs from a CACC string or platoon and switches out of cooperative vehicle following control.

2.5.3 MERGE

The maneuver by which a vehicle enters a highway and changes lane from the on-ramp to a mainline lane. If and only if the subject vehicle is a cooperative vehicle and the adjacent vehicles in the mainline lane are driving in a CACC string or a platoon the merge could also represent a join.

2.5.4 CUT-IN

A lane change maneuver by a non-cooperative vehicle inserting itself between cooperative vehicles that are driving in a CACC string or platoon.

2.5.5 CUT-OUT

A lane change maneuver by the forward vehicle.

2.5.6 LATERAL VEHICLE MOTION CONTROL

Refer to SAE J3016.

The dynamic driving task (DDT) subtask comprising the activities necessary for the real-time, sustained regulation of the y-axis component of vehicle motion.

2.5.7 LONGITUDINAL VEHICLE MOTION CONTROL

Refer to SAE J3016.

The DDT subtask comprising the activities necessary for the real-time, sustained regulation of the x-axis component of vehicle motion in which x-axis points forward from the vehicle in a coordinate system anchored to the midpoint of rear axle.

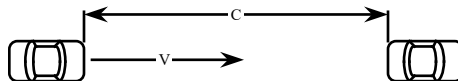
2.6 Supporting Terms for Vehicle-Following Control

This section provides definitions of terms relevant to vehicle-following maneuvers.

2.6.1 HEADWAY

The time interval defined between the passage of the forward surfaces of two consecutive vehicles by a fixed location along their path.

2.6.2 TIME GAP



Time interval for traveling a distance equal to the clearance 'c' to the preceding vehicle, given the current vehicle speed 'v.'

2.6.3 CLEARANCE GAP

Distance from the preceding vehicle's trailing surface to the subject vehicle's leading surface (refer to SAE J2399).

2.7 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.

ASN Abstract Syntax Notation revision One (also ASN.1)

BSM Basic Safety Message

CACC Cooperative Adaptive Cruise Control

CCM Cooperative Control Message

ConOps	Concept of Operations
CRL	Certificate Revocation List
CV	Connected Vehicle
C-V2X	Cellular Vehicle to everything
DE	Data Element
DF	Data Frame
DSRC	Dedicated Short Range Communications
FCC	Federal Communications Commission
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
ISO	International Organization for Standardization
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation System
LAN	Local Area Network
LTE-V2X	Long Term Evolution - Vehicle to Everything (also known as Cellular-V2X or C-V2X)
MAC	Medium Access Control
MIB	Management Information Base
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	On Board Unit
PDU	Protocol Data Unit

PER	Packed Encoding Rules
PSID	Provider Service Identifier
RSU	Roadside Unit
RTM	Requirements Traceability Matrix
RWIS	Road Weather Information System
SCMS	Security Credential Management System
SP	Special Publication
SSP	Service Specific Permissions
Std	Standard
TCIP	Transit Communications Interface Profiles
TCP	Transmission Control Protocol
TIM	Traveler Information Message
UDP	User Datagram Protocol
URI	Uniform Resource Identifier
URL	Uniform Resource Locator
USDOT	United States Department of Transportation
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle to everything
VRU	Vulnerable Road User
WAVE	Wireless Access in Vehicular Environments
WSM	WAVE Short Message
WSMP	WAVE Short Message Protocol
3GPP	3rd Generation Partnership Project

3. CONCEPT OF OPERATIONS

This section provides a high-level description of the CACC concept of operations and system description. This concept of operation can be applied to both single unit and articulated vehicles. Section 3.1 provides an overview of the system and 3.2 provides the system description for different CACC operation modes.

3.1 CACC System Overview

CACC is an extension of the ACC concept. In addition to determining the forward vehicle's speed and distance using ACC systems, CACC functionality facilitates obtaining additional information using wireless messages. This allows vehicles to "cooperate" by communicating with each other while in ACC mode as illustrated in Figure 1. The lead vehicle may or may not be equipped with ACC.

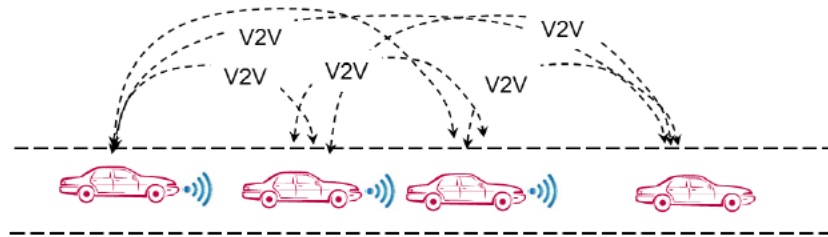


Figure 1 - CACC schematic overview

A CACC-equipped vehicle may receive wireless messages from multiple vehicles. This information would then be utilized to enhance the control of the subject vehicle brakes and accelerator in the presence of multiple preceding vehicles. This in turn helps mitigate string instability oscillation effects introduced by ACC systems and may potentially enhance safety. It should be noted that CACC is not considered as a safety system and has limitations in available acceleration and deceleration. In the event that limitations (e.g., supported time gaps, maximum deceleration) of the system are reached either the driver or the vehicle safety system are expected to take over. V2V communication provides the subject vehicle controller situational awareness to adapt to certain events ahead of the preceding vehicle. The controller can react to events beyond the sensor range.

From the vehicle driver's perspective CACC system will behave in a similar manner to the ACC system and the driver is expected to constantly monitor CACC operation and to take countermeasures in the case of system failure. Similar to existing ACC systems, the driver engages CACC upon deciding to follow a vehicle and selects the desired time gap. Once engaged, the CACC system takes over the engine and brake control of the vehicle and follows the preceding vehicle. In addition to the vehicle's own object detection system, the CACC vehicle receives wireless messages from other connected vehicles. The longitudinal controller uses information from both systems to maintain vehicle speed and gap as desired by the vehicle operator.

In CACC mode, there is no coordinated mechanism in place with other CACC vehicles to inform and detect string members for targeted (i.e., the same for all vehicles in the string) gap. Also, a vehicle can join or leave the string and no coordination is required. When a vehicle joins or leaves a string, the rest of the vehicles in the string will adjust their motions based on information received from other vehicles and on-board object detection systems.

Figure 2 illustrates the following subsystems within the system:

- OBE - The subsystems listed below collaboratively form the OBE. The OBE could feed the received over-the-air information to CACC module directly and/or through vehicle data bus.
- V2X Radio Subsystem - Transmits and receives wireless messages. In this standard the radio subsystem is assumed to be a single-channel-at-a-time device. The OBE can include one or more V2X radio subsystems and still comply with this standard.

- **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 1. Examples of these are speed data from the vehicle data, dead reckoning sensors, and optical/camera-based systems.
- **OBE Control Processor Electronic Control Unit (ECU)** - Executes software that generates wireless messages for transmission according to the requirements in this standard.
- **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 V2X antennas may be integrated (dual band).
- **CACC** - This subsystem is in charge of longitudinal controller command creation and providing the Brake/Accel actuators with the appropriate commands.

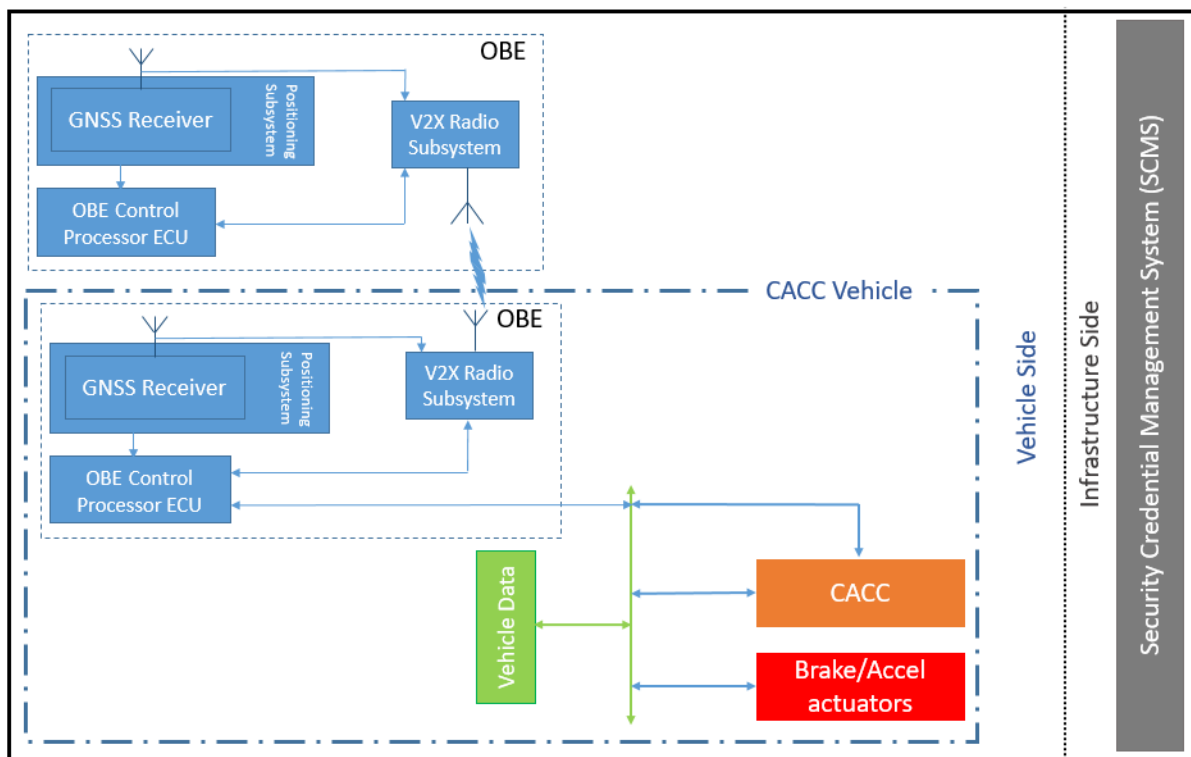


Figure 2 - Reference architecture - CACC system

The CACC system communicates with other connected vehicles using the V2X Radio Subsystem as an interface. The system (OBE) can interface to a CACC either directly or through vehicle data or both and provide the over-the-air received information for longitudinal controller decision making. The OBE and the CACC module can also interface with the vehicle data to obtain vehicle information required for the operation. The vehicle data and brake/accel actuators are outside the scope of this standard.

3.2 CACC Operating States

This section defines the logical behavior of the CACC system and includes four different operating states. The transition from one operating state to another will only occur when the system input and transition requirements are satisfied. The system required inputs are comprised of stimuli that can be originated from different sources. Stimuli can come from the external environment such as radio signals, from the subject vehicle such as machine vision subsystems, and from local processing environment, such as current state and supervisory inputs. The main system steady state operating modes include active and passive modes. CACC passive mode include manual driving state, while CACC active mode includes CC, ACC, and CACC states. Depending on the design, there might be temporary operating states such as ACC recovery and manual recovery which are outside the scope of this standard. These four operating states define a high-level behavior and serve as containers for sub-states that exist where necessary to define the internal behavior of each mode. For example, the CACC state is subject to transitions to and from other states at the same level but also could potentially support different sub-states of multi-vehicle look-ahead (where maneuvers by multiple vehicles ahead are taken into account in decision making) and one-vehicle look-ahead.

3.2.1 Manual

In manual state, the vehicle is fully controlled by the driver. The system is not controlling the vehicle at all, but it is monitoring the surroundings through forward ranging sensors and/or OBE. This is the initial state when the CACC system is initialized.

3.2.2 CC

In the Cruise Control (CC) state, the system controls the vehicle's acceleration and deceleration by maintaining the internal set speed of the system.

3.2.3 ACC

In the ACC state, the system controls the vehicle acceleration and deceleration by maintaining a fixed time gap to the preceding vehicle based on forward ranging sensor (e.g., radar) data.

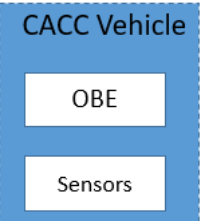
3.2.4 CACC

In the CACC state, the system controls the vehicle's acceleration and deceleration by maintaining a time gap to the preceding vehicle as well as other control strategies such as multi-vehicle look-ahead or single-vehicle look-ahead, which are considered sub-modes of the CACC mode.

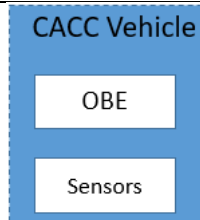
3.3 Operational Scenarios

The operational scenarios in this standard cover mixed traffic environment (V2X equipped and not equipped). The illustrations represent scenarios where the practical implementation involves multiple instances of architectural components in Figure 2. It should be noted that when CACC system is activated, the system could end up in any of the three states, CC, ACC, or CACC depending on what inputs the subject vehicle gets through its sensors and communication device.

3.3.1 Manual Driving/No CACC Activated

Operational Scenario Name	Manual Driving
Short Description	This is the initial state when the CACC system is engaged. In this state the vehicle is fully controlled by the driver but sensing mechanisms (e.g., radar, V2X) are used to monitor the surroundings even when the CACC is not activated by the driver.
Goal	Assess the situation to select the appropriate steady state mode.
Constraints	Sensor Blindness (e.g., damage, dirt, etc.).
Actors	Vehicles/devices Driver
Illustration	 The diagram shows a blue rectangular box labeled 'CACC Vehicle'. Inside this box, there are two smaller white rectangular boxes stacked vertically. The top box is labeled 'OBE' and the bottom box is labeled 'Sensors'.
Preconditions	None
Main Flow	• Driver is driving the vehicle manually. • Sensors are monitoring the surroundings to detect objects.
Information Requirements	NA

3.3.2 CC

Operational Scenario Name	Cruise Control
Short Description	CACC system is activated but there is no preceding vehicle detected or the preceding vehicle has a higher speed than set speed. The system maintains the internal set speed requested by the driver.
Goal	Maintaining the desired constant set speed.
Constraints	Preceding vehicle is not detected through vehicle sensing capabilities when its speed is equal or below the set speed.
Actors	Vehicle/CACC system Driver
Illustration	 The diagram shows a blue rectangular box labeled 'CACC Vehicle'. Inside this box, there are two smaller white rectangular boxes stacked vertically. The top box is labeled 'OBE' and the bottom box is labeled 'Sensors'.
Preconditions	System is engaged by driver and set speed is provided. No preceding vehicle is detected meeting either of the below criteria: • Speed lower than set speed. • Not far enough for system to maintain its set speed safely.
Main Flow	• Driver has engaged the CACC system. • Driver inputs the desired set speed and gap. • The CACC-equipped vehicle does not detect a preceding vehicle, or the preceding vehicle is too far away or going faster. • CACC system maintains the set speed until the preconditions change.
Information Requirements	• Driver desired set speed. • Desired time gap.