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Intelligent transport systems — Cooperative adaptive cruise control systems (CACC) — Performance requirements and test procedures

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 204, *Intelligent transport systems*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Cooperative Adaptive Cruise Control (CACC) system is an enhancement to the Adaptive Cruise Control (ACC) system by the addition of wireless communication with preceding vehicles and/or the infrastructure to augment the ACC active sensing capability. It uses active sensing data such as ranging to forward vehicle, subject vehicle data, over the air data from other surrounding vehicles and from infrastructure, and driver input to longitudinally control the vehicle via throttle and brake controls, and to convey the appropriate CACC status information to the driver (see Figure 1).

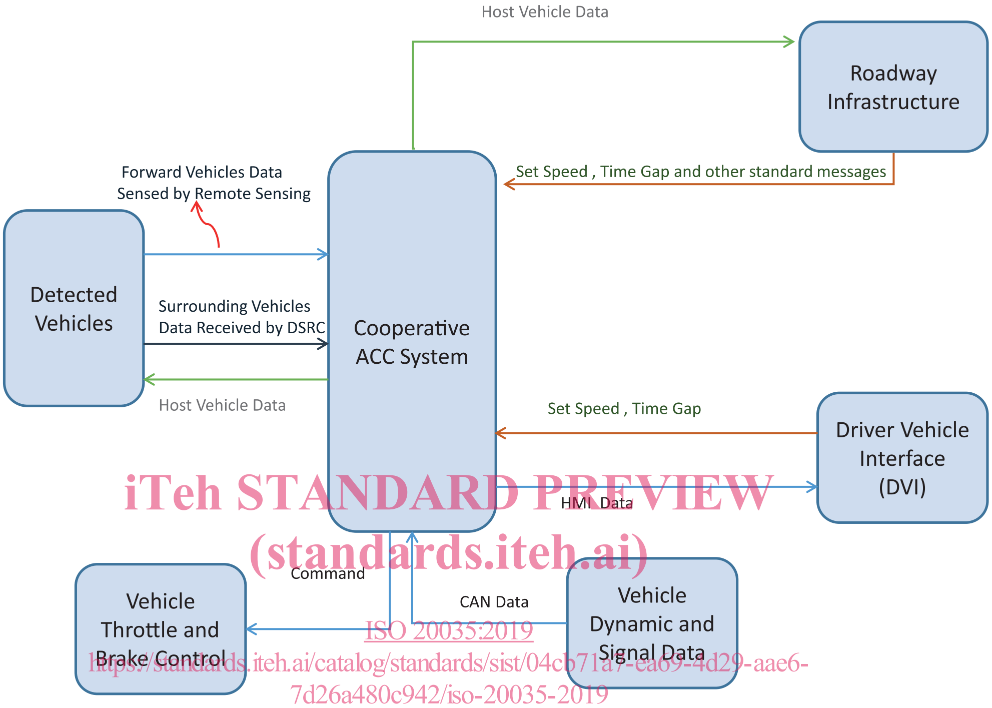

Figure 1 — Functional CACC elements

ACC systems can be made cooperative by adding vehicle-vehicle (V2V) and/or infrastructure-vehicle (I2V) communication capabilities and adjusting the performance of the system to make use of the information received via the communication system, e.g. Dedicated Short Range Communication System (DSRC) (see Figure 2).

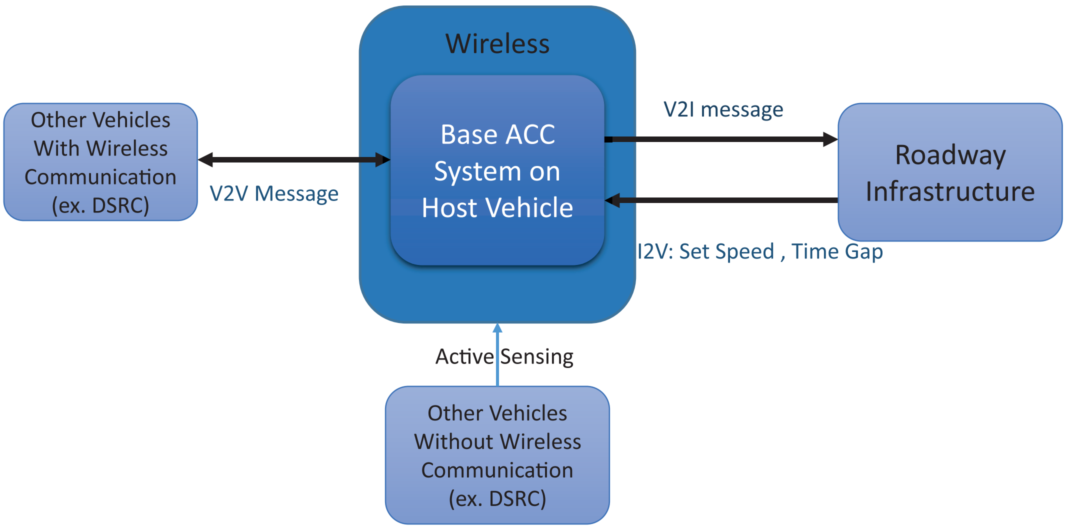

Figure 2 — CACC additions to ACC

The V2V communications can provide the ACC system with frequent updates about the speed, acceleration and commands (throttle and brake) of multiple vehicles driving in the surrounding area of the CACC-equipped vehicle. This enables the following performance improvements over ACC:

— higher-accuracy control of vehicle following gap, while maintaining smooth ride quality;

— significantly faster responses to speed changes by multiple forward vehicles, not only the vehicle immediately ahead of the subject vehicle;

— shorter vehicle-following gap settings, without compromising safety or driver confidence and comfort with the system.

These performance improvements produce the following benefits:

— increased driver confidence in the responsiveness of the system, leading to willingness to select shorter gap settings and use ACC under a wider range of traffic conditions;

— fewer cut-ins at the shorter gaps may make ACC acceptable to a wider range of drivers;

— significant damping of traffic flow disturbances, improving traffic flow dynamics and thereby reducing energy use and emissions;

— significant increase in the effective capacity (throughput) per lane of highway traffic.

The I2V communications can provide the ACC system with inputs from the local traffic management system, which determines the recommended values for set speed and vehicle-following gap. These can be used to enhance the effectiveness of traffic management strategies on limited access highways, where it is possible to determine the speed and gap settings that are likely to maximize the effective capacity of a bottleneck section. When the I2V CACC vehicles follow these recommended values, the overall traffic flow capacity can be optimized with a minimum of active intervention by the vehicle drivers (other than opting in to decide to follow the infrastructure-based guidance). This means that the driver of the subject vehicle gains a smoother trip, with less acceleration and braking and lower energy consumption, and the highway as a whole gains a higher effective capacity, reduced energy consumption and pollution, and reduced traffic delays.

Intelligent transport systems — Cooperative adaptive cruise control systems (CACC) — Performance requirements and test procedures

1 Scope

Cooperative Adaptive Cruise Control (CACC) system is an expansion to existing Adaptive Cruise Control (ACC) control strategy by using wireless communication with preceding vehicles (V2V) and/or the infrastructure (I2V). Both multi vehicle V2V data and I2V infrastructure data are within the scope of this document. When V2V data is used CACC can enable shorter time gaps and more accurate gap control, which can help increase traffic throughput and reduce fuel consumption. It can also receive data from the infrastructure, such as recommended speed and time gap setting, to improve traffic flow and safety.

This document addresses two types of Cooperative Adaptive Cruise Control (CACC): V2V, and I2V. Both types of CACC system require active sensing using for example radar, lidar, or camera systems. The combined V2V and I2V CACC is not addressed in this document. The following requirements are addressed in this document:

— classification of the types of CACC;

— definition of the performance requirements for each CACC type;

— CACC state transitions diagram;

— minimum set of wireless data requirements;

— test procedures.

CACC:

— does only longitudinal vehicle speed control;

— uses time gap control strategy similar to ACC;

— has similar engagement criteria as ACC.

Coordinated strategies to control groups of vehicles, such as platooning, in which vehicle controllers base their control actions on how they affect other vehicles, and may have a very short following clearance gap are not within the scope of this document. CACC system operates under driver responsibility and supervision.

This document is applicable to motor vehicles including light vehicles and heavy vehicles.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 15622, *Intelligent transport systems — Adaptive cruise control systems — Performance requirements and test procedures*

3 Terms and definitions

For the purpose of this document, the following definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at https://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
active brake control
function which causes application of the brake(s), controlled by the CACC system not by the driver

3.2
Adaptive Cruise Control
ACC
enhancement to conventional cruise control systems [see Conventional Cruise Control (3.7)], which allows the subject vehicle to follow a forward vehicle at an appropriate distance proportional to the time gap set by the driver by controlling the engine and/or power train and potentially the brake

3.3
brake
part in which the forces opposing the movement of the vehicle develop and which may be a friction brake (when the forces are generated by friction between two parts of the vehicle moving relatively to one another); an electrical brake (when the forces are generated by electro-magnetic action between two parts of the vehicle moving relatively but not in contact with one another); a fluid brake (when the forces are generated by the action of a fluid situated between two parts of the vehicle moving relatively to one another); or an engine brake (when the forces are derived from an artificial increase in the braking action, transmitted to the wheels, of the engine)

Note 1 to entry: For the purposes of this document, transmission control devices are not considered as brakes.

[SOURCE: UN ECE Regulation 13-H:1998, 2.6]

3.4
CACC system states
operation modes of the system presented in this document as three system states as shown in 6.1.4 and Figure 4

3.5
clearance
distance from the forward vehicle's trailing surface to the subject vehicle's leading surface

3.6
connected vehicle
any vehicle that has a V2X wireless communication system and broadcasts over the air standard message protocol

3.7
conventional cruise control
system capable of controlling the speed of a vehicle as set by the driver

3.8
forward vehicle
vehicle in front of and moving in the same direction and travelling on the same roadway as the subject vehicle

3.9
free-flowing traffic
smooth flowing and heavy traffic excluding stop and go and emergency braking situations

3.10
heavy vehicle category
single vehicle or combination of vehicles defined as Category 1-2 or Category 2 in the United Nations Economic and Social Council World Forum for Harmonization of Vehicle Regulations (WP.29) TRANS/WP.29/1045

Note 1 to entry: A truck is in the heavy vehicle category.

3.11
Potential Vehicle of Interest
PVOI
connected vehicle that exists in the V2V CACC region of interest, communicates with the subject vehicle, is of possible interest to the longitudinal control, and is not the target vehicle (TV)

3.12
region of interest
ROI
area where PVOI and TV may exist and affect CACC system control operations

3.13
set speed
desired travel speed, set by either the driver or by some control system that is external to the CACC system and which is the maximum desired speed of the vehicle while under CACC control

3.14
stationary object
object in front of the subject vehicle which is stationary

3.15
steady state
condition whereby the value of the described parameter does not change with respect to time, distance, etc.

3.16
subject vehicle
SV
vehicle equipped with the system in question and related to the topic of discussion

3.17
target vehicle
TV
vehicle that the subject vehicle follows which may or may not be equipped with a connected vehicle device

3.18
time gap
τ
value calculated from vehicle speed v and clearance c by $\tau = c/v$

Note 1 to entry: to entry: v is the subject vehicle speed and c the distance between the subject vehicle and the forward vehicle.

4 Symbols and abbreviated terms

A	utilised area, general for area
A_{t}	illuminated surface
$a_{\mathrm{lateral\_max}}$	maximum allowed lateral acceleration in curves

a_{min} minimum allowed longitudinal acceleration = Maximum allowed longitudinal deceleration

a_{max} maximum allowed longitudinal acceleration

a_{test} maximum allowed acceleration during curve test

$a_{vehicle\_max}$ maximum possible deceleration capability during manual driving

CTT coefficient for Test Target for infrared reflectors

c clearance, inter vehicle distance

PVOI Potential Vehicle of Interest

ROI region of interest

TV target vehicle

V2V vehicle to vehicle

v the true subject vehicle speed over ground

τ gap, time gap between vehicles

5 Classification

5.1 Type of CACC systems

Types of CACC are based on the type of the over the air data that may affect the longitudinal control of the vehicle. Two types of CACC systems are addressed in this document: V2V and I2V.

Table 1 — CACC system types

CACC type	Active sensing required	Wireless communication requirement (for example: DSRC is low latency, and 4G is higher latency)	Type of data affecting the longitudinal control
V2V	Yes	Low latency is minimum requirement	V2V over the air data
I2V	Yes	Some data can be broadcast using higher latency as appropriate to message urgency.	I2V over the air data

5.2 Curve capabilities

This document is applicable to CACC systems of different curve capabilities as specified in ISO 15622.

5.3 Classes of on-board V2X devices

Type A: OEM device that receives and processes vehicle CAN data.

Type B: OEM device that does not receive or process CAN data.

Type C: Non-OEM device that receives and processes CAN data.

Type D: Non OEM device that does not receive or process CAN data.

6 Requirements

6.1 V2V CACC

6.1.1 V2V CACC response

V2V CACC system reacts to V2V over the air data in addition to the active sensing data originated from sensors such as radar or camera.

6.1.2 Region of interest

Region of interest (ROI) is defined for a straight road as in Figure 3. This ROI is 32 m wide and extends from the driver position in the subject vehicle up to 250 m ahead of the subject vehicle and 100 m behind the subject vehicle. The ROI in Figure 3 is illustrated for a straight road. For a curved road, the ROI is to bend itself to follow the curvature of the road.

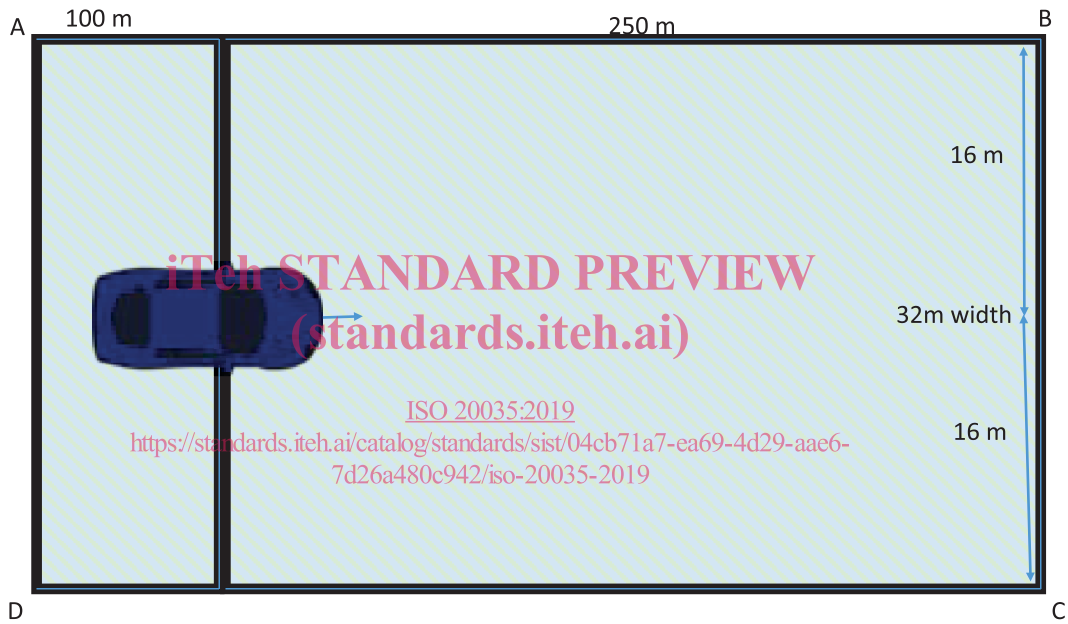

Figure 3 — V2V CACC region of interest

6.1.3 Potential Vehicle of Interest (PVOI)

PVOI is any connected vehicle that exists in the V2V CACC ROI, communicates with the subject vehicle, is of possible interest to the longitudinal control, and is not the target vehicle (TV), e.g. a vehicle that is predicted to merge into the subject vehicle's lane (for illustration please refer to Figure 7). Another example: a vehicle that is braking hard ahead of and in the same lane as the target vehicle (for illustration, please refer to Figure 8). PVOI may have the potential to become a TV.