



SURFACE VEHICLE INFORMATION REPORT

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Taxonomy and Definitions for Terms Related to Cooperative Driving Automation for On-Road Motor Vehicles

RATIONALE

Update is limited to graphics that improve readability.

1. SCOPE

This document describes machine-to-machine (M2M) communication to enable cooperation between two or more participating entities or communication devices possessed or controlled by those entities. The cooperation supports or enables performance of the dynamic driving task (DDT) for a subject vehicle with driving automation feature(s) engaged. Other participants may include other vehicles with driving automation feature(s) engaged, shared road users (e.g., drivers of manually operated vehicles or pedestrians or cyclists carrying personal devices), or road operators (e.g., those who maintain or operate traffic signals or workzones).

Cooperative driving automation (CDA) aims to improve the safety and flow of traffic and/or facilitate road operations by supporting the movement of multiple vehicles in proximity to one another. This is accomplished, for example, by sharing information that can be used to influence (directly or indirectly) DDT performance by one or more nearby road users. Vehicles and infrastructure elements engaged in cooperative automation may share information, such as state (e.g., vehicle position, signal phase), intent (e.g., planned vehicle trajectory, signal timing), or seek agreement on a plan (e.g., coordinated merge). Cooperation among multiple participants and perspectives in traffic can improve safety, mobility, situational awareness, and operations. However, nothing in this document is intended to suggest that driving automation requires such cooperation in order to be performed safely.

Cooperative strategies may be enabled by the sharing of information in a way that meets the needs of a given application. The needs may be expressed in terms of performance characteristics, such as latency, transmission mode (e.g., one-way, two-way), range, privacy and security, and information content and quality. There are several potential technologies for communicating information between the subject vehicle and other participants.

This document focuses on application-oriented functionality and does not imply the need for or require any specific functionality associated with communications protocols or the open systems interconnection model layers in a protocol stack. This document addresses the operational and tactical timescales of dynamic driving on ADS-operated vehicles, and excludes strategic functions such as trip scheduling and selection of destinations and waypoints. This information report is intended to facilitate communication and awareness for the design and anticipated development and validation of cooperative driving automation.

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Documents

Document Sharing Hub

2. REFERENCES

2.1 Applicable Documents

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

2.1.1 SAE Publications

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

- SAE J2735 Dedicated Short Range Communications (DSRC) Message Set Dictionary
- SAE J2945 Dedicated Short Range Communication (DSRC) Systems Engineering Process Guidance for SAE J2945/X Documents and Common Design Concepts™
- SAE J2945/1 On-Board System Requirements for V2V Safety Communications
- SAE J2945/3 Requirements for Road Weather Applications
- 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 J3063 Active Safety Systems Terms and Definitions

2.1.2 Other Publications

5G-PPP, "5GCAR Scenarios, Use Cases, Requirements and KPIs," 5GCAR project deliverable D2.1, Tech. Rep., 2017.

Albus et. al., "A Reference Model Architecture for Intelligent Unmanned Vehicle Systems, Version 2.0," Prepared for the Army Research Laboratory Demo III Program, (2002).

"Automotive Vertical Sector," 5G-PPP, White Paper, 2015.

Barickman, F., "Automated Vehicle Research," National Highway Traffic Safety Administration, (2016).
https://system-safety.org/issc2016/P04a_Vernacchia_Automation.pdf.

Kosseff, J., "Defining Cybersecurity Law," 103 Iowa Law Review 985 (2018).

Lochrane, Taylor. "Transforming the Transportation Industry with Cooperative Automation Research Mobility Applications (CARMA)," Dec. 2018.
https://transops.s3.amazonaws.com/uploaded_files/NOCoe%20CARMA%20Webinar%20Slides.pdf.

OECD Handbook for Internationally Comparative Education Statistics, 2017, Chapter 6.

Office of the Victorian Information Commission, <https://ovic.vic.gov.au/privacy/what-is-privacy/>.

U.S. DOT, "DSRC Report to Congress," 2015, Chapter 2.

U.S. DOT, "Preparing for the Future of Transportation: Automated Vehicle 3.0 (AV 3.0)," 2018, Appendix C.
<https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/320711/preparing-future-transportation-automated-vehicle-30.pdf>.

U.S. DOT, "Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0 (AV 4.0)," 2020.
<https://www.transportation.gov/sites/dot.gov/files/2020-02/EnsuringAmericanLeadershipAVTech4.pdf>.

3. ABBREVIATIONS AND ACRONYMS

The terms, abbreviations, and acronyms cited below shall be a part of the terms of this information report unless specifically cited otherwise.

ADS	Automated Driving System
ADS-DV	ADS-Dedicated Vehicle
C-ADS	Cooperative-Automated Driving System
CACC	Cooperative Adaptive Cruise Control
CARMA	Cooperative Automation Research Mobility Applications
CDA	Cooperative Driving Automation
CSP	Communication Service Provider
DDT	Dynamic Driving Task
ITS	Intelligent Transportation System
M2M	Machine-to-Machine
ODD	Operational Design Domain
RSE	Roadside Equipment
SPaT	Signal Phase and Timing
TSMO	Transportation Systems Management and Operations

4. DEFINITIONS

4.1 AUTOMATED DRIVING SYSTEM (ADS)

The hardware and software that are collectively capable of performing the entire DDT on a sustained basis, regardless of whether it is limited to a specific operational design domain (ODD); this term is used specifically to describe a Level 3, 4, or 5 driving automation system. (For up-to-date definitions, notes, and examples, refer to the latest version of SAE J3016.)

4.2 ADS-DEDICATED VEHICLE (ADS-DV)

A vehicle designed to be operated exclusively by a Level 4 or 5 ADS for all trips within its given ODD limitations (if any). (For up-to-date definitions, notes, and examples, refer to the latest version of SAE J3016.)

4.3 COOPERATIVE DRIVING AUTOMATION (CDA)

Automation that uses M2M communication to enable cooperation among two or more entities with capable communications technology and is intended to facilitate the safer, more efficient movement of road users, including enhancing performance of the DDT for a vehicle with driving automation feature(s) engaged.

NOTE 1: For C-ADS-equipped vehicles (see [4.3.1](#)) engaged in cooperative automation, the M2M communications may enhance the performance of the DDT for the subject vehicle (e.g., object and event detection (OEDR) and response, operational, and tactical maneuvers).

NOTE 2: For road operators engaged in cooperative automation, the M2M communications may provide situational awareness and influence performance of traffic management (e.g., signal phase and timing (SPaT), speed limits, and emergency response).

4.3.1 COOPERATIVE AUTOMATED DRIVING SYSTEM (C-ADS)

An ADS capable of utilizing CDA.

4.3.1.1 COOPERATIVE AUTOMATED DRIVING SYSTEM (C-ADS)-EQUIPPED VEHICLE

A vehicle equipped with Level 3, 4, or 5 driving automation and capable of utilizing CDA. Note that Level 3 systems require human driver intervention upon ADS request. (Refer to SAE J3016 for additional information about driving automation systems.)

4.3.2 CDA DRIVER SUPPORT FEATURE

A Level 1 or 2 driving automation system capable of utilizing CDA. (Refer to SAE J3016 for additional information about driving automation systems.)

4.4 CDA COOPERATION CLASSES

Classes of cooperation facilitated by M2M communications among CDA devices that may influence DDT performance and traffic operations, defined as Classes A through D based on the increasing amount of cooperation entailed in each successive class.

NOTE: The use of CDA information to influence DDT performance by one or more C-ADS-equipped vehicle in any given situation depends upon the type of message provided (see [4.4.1](#) through [4.4.4](#)), as well as other information used by the C-ADS-equipped vehicle(s).

4.4.1 STATUS-SHARING COOPERATION (CLASS A)

Perception information about the traffic environment and information about the sending entity provided by the sending entity for potential utilization by receiving entities. ("Here I am, and here is what I see.")

NOTE 1: Status-sharing cooperation does not require the ability or consent of transmitting entities to employ the information provided via M2M communication, which may originate from any nearby traffic participant.

NOTE 2: Status-sharing cooperation may be used to enhance an entity's situational awareness.

NOTE 3: CDA devices that do not have direct control over the actions of the CDA device agent, e.g., pedestrians or conventional vehicles in which a human directly controls actions, may engage in status-sharing cooperation.

EXAMPLE 1: A C-ADS-equipped vehicle shares its current velocity and the velocity of the vehicle immediately in front with nearby vehicles. A C-ADS-equipped vehicle behind the status-sharing vehicle adjusts its speed to improve traffic flow and safety.

EXAMPLE 2: Cooperative situational awareness whereby a roadside equipment CDA device at a crosswalk communicates to nearby vehicles information that a pedestrian is approaching the crosswalk. A nearby C-ADS-equipped vehicle receives the information, which it may use along with information provided by the ADS's sensors to plan the DDT performance near the crosswalk.

4.4.2 INTENT-SHARING COOPERATION (CLASS B)

Information about planned future actions of the sending entity provided by that entity for potential utilization by receiving entities. ("This is what I plan to do.")

NOTE 1: Intent-sharing cooperation does not require the ability or consent of receiving entities to employ the information provided via M2M communication, which may originate from any nearby traffic participant. Receiving entities do not necessarily need to act on the shared intent, and all entities are expected to conduct competent operations regardless of others' actions.

NOTE 2: Intent-sharing cooperation may be used to augment prediction of future states to enhance models of the planned future actions of the sending entity.

NOTE 3: Intent-sharing cooperation may augment status-sharing cooperation by providing information that relates to a future state (rather than just the current state) of a sending entity.

NOTE 4: In some cases, intent information may be shared without M2M communication (e.g., turn signals), but in many cases (e.g., occlusion of tail lights), this information could not otherwise be determined at all or as soon by a receiving entity that is not participating in CDA. These non-CDA forms of intent sharing (e.g., turn signals, human gestures, etc.) are beyond the scope of this document.

NOTE 5: CDA devices that do not have direct control over the actions of the CDA device agent, e.g., pedestrians or conventional vehicles in which a human directly controls actions, may engage in intent-sharing communication.

EXAMPLE 1: A C-ADS-equipped vehicle using a Level 3 automation highway feature acts as the sending entity to share a planned lane change with proximal traffic participants to facilitate safer and more efficient traffic flow in the immediate vicinity. A proximal vehicle with a Level 4 automation highway feature acts as the receiving entity and slows down to maintain a desired longitudinal distance when the Level 3 C-ADS-equipped vehicle merges into the lane ahead.

EXAMPLE 2: Roadside equipment (RSE) at a traffic signal acting as the sending entity shares a planned signal phase change with proximal traffic participants to facilitate eco-drive functionality. A C-ADS-equipped vehicle using a Level 3 feature approaching the signal acts as the receiving entity, and uses the signal timing to adjust longitudinal vehicle motion control for enhanced safety and efficiency by avoiding sudden emergency maneuvers.

4.4.3 AGREEMENT-SEEKING COOPERATION [AMONG CDA DEVICE AGENTS] (CLASS C)

A sequence of collaborative messages among specific CDA devices intended to influence local planning of specific DDT-related actions. ("Let's do this together.")

NOTE 1: Agreement-seeking cooperation requires the ability and authority of the CDA device agents involved to cooperate and agree on plan(s) based on the information provided via M2M communication, which may originate from any nearby traffic participant.

NOTE 2: Agreement-seeking cooperation includes an interactive exchange of messages that may include plans, acceptance or rejection of plans, or considerations for arriving at consensus on a proposed plan. Depending on circumstances, CDA device agents may not follow a planned future action, and all entities must conduct competent operations regardless of others' actions.

NOTE 3: Agreement-seeking cooperation may utilize status-sharing and intent sharing cooperation.

NOTE 4: This document does not consider planning for CDA devices that do not have direct control over the actions of the CDA device agent, e.g., pedestrians or conventional vehicles and driver support features in which a human directly controls actions, instead focusing on planning for systems with driving automation.

NOTE 5: Agreement-seeking cooperation includes proposing plans for other traffic participants (i.e., "What I want you to do"). In contrast, intent-sharing includes only sharing a plan for the sending entity (i.e., "What I plan to do").

EXAMPLE 1: Cooperative merging (see [Figure 1](#)) of Vehicle 1 between Vehicles 2 and 3 that currently occupy an adjacent lane (all vehicles are C-ADS-equipped), may be conducted in the following steps: (1) Vehicle 1 indicates a plan to merge via intent-sharing cooperation with Vehicles 2 and 3; (2) Vehicle 1 shares a proposed action that would enable a merging maneuver, e.g., specified longitudinal spacing between Vehicles 2 and 3 so that Vehicle 1 may change lanes; (3) Vehicles 2 and 3 indicate willingness to engage in agreement-seeking cooperation. This may result in multiple outcomes:

Scenario A: Vehicles 2 and 3 acknowledge consent to allow the proposed action, and all entities conduct competent operations while executing the intended maneuvers (i.e., Vehicle 3 slows down, and/or Vehicle 2 speeds up, and Vehicle 1 changes lanes).

Scenario B: Vehicle 2 and/or Vehicle 3 share intent not to allow the proposed action or goal, and Vehicle 1 does not execute the intended maneuver.

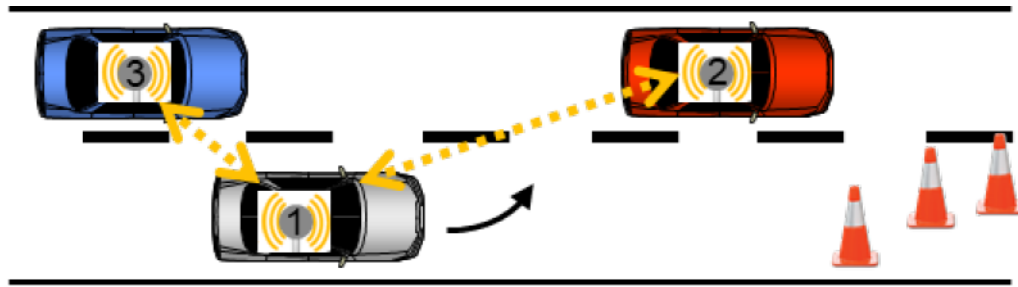


Figure 1 - Cooperative merging example

EXAMPLE 2: Cooperative intersection departure whereby: (1) a CDA device representing the traffic management authority provides SPaT information to nearby road users; (2) C-ADS-equipped vehicles stopped at the intersection receive the SPaT information, and the second-in-line vehicle requests to engage in agreement-seeking cooperation with the first-in-line vehicle; (3) the first-in-line vehicle is a C-ADS-equipped and agrees to engage in agreement-seeking cooperation; (4) the second-in-line vehicle proposes an acceleration and final velocity for departing the intersection based on SPaT information; (5) the first-in-line vehicle agrees to the proposed acceleration and final velocity; (6) both vehicles conduct competent operations while following the agreed-upon acceleration and final velocity resulting in a safer and more efficient intersection navigation and more efficient departure and navigation of the intersection.

EXAMPLE 3: Cooperative stop sign intersection management for two C-ADS-equipped vehicles arriving coincidentally from opposing directions may be conducted in the following steps: (1) Vehicle 1 indicates intent to engage in agreement-seeking cooperation; (2) Vehicle 2 agrees to engage in agreement-seeking cooperation; (3) Vehicle 1 shares intent to perform a left-hand turn maneuver and Vehicle 2 shares intent to perform a straight forward maneuver; (4) Vehicle 1 provides a plan that Vehicle 1 goes first and Vehicle 2 goes second; (5) Vehicle 2 agrees to the plan; and (6) both vehicles conduct competent operations while executing the plan (i.e., Vehicle 1 makes the left-hand turn and then Vehicle 2 drives straight). This coordination results in a shorter overall time for both vehicles to navigate the intersection and avoids potential conflicts.

4.4.4 PRESCRIPTIVE COOPERATION (CLASS D)

The direction of specific action(s) to specific traffic participants for imminent performance of the DDT or performance of a particular task by a road operator (e.g., changing traffic signal phase), provided by a prescribing CDA device agent(s) and adhered to by a receiving CDA device agent(s). ("I will do as directed.")

NOTE 1: CDA devices that do not have control over the actions of their corresponding CDA Agents, e.g., pedestrians or conventional vehicles and driver support features in which a human directly controls actions, cannot participate in prescriptive cooperation-based CDA features.

NOTE 2: Prescriptive cooperation does not require the willingness of the affected entities to cooperate. It relies on a pre-existing understanding between parties to adhere to commands, such as a specific aspect of DDT performance, under particular circumstances.

NOTE 3: Prescriptive cooperation may be performed by transportation authorities and/or fleet operations centers communicating with fleet vehicles under their control.

NOTE 4: Transportation authorities may have the ability to direct prescriptive cooperation to any relevant traffic participants.

NOTE 5: Prescriptive cooperation may utilize status-sharing, intent-sharing, and agreement-seeking cooperation to provide context for the understanding to cede control over actions that relate to the DDT performance.

EXAMPLE 1: Cooperative incident scene management whereby a CDA device associated with incident response communicates a geofenced area that is temporarily closed to traffic and a reduced speed limit that is not to be exceeded. Surrounding C-ADS-equipped vehicles with CDA devices use this information to perform the DDT in accordance with the reduced speed limit within that geo-fenced area.