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SURFACE VEHICLE RECOMMENDED PRACTICE	J3016™	APR2021
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(R) Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles

RATIONALE

This revision of SAE J3016 was undertaken in close cooperation between the SAE On-Road Automated Driving (ORAD) Committee and ISO TC204/WG14 through a Joint Working Group formed in 2018. This collaboration brought to bear the knowledge and expertise of global experts in *driving automation* technology and safety. Several new terms and definitions have been added and multiple corrections and clarifications have been made to address frequently misunderstood concepts and improve the utility of the document, especially for non-native English speakers. As in the previous version, it provides a taxonomy describing the full range of levels of *driving automation* in on-road motor *vehicles* and includes functional definitions for advanced levels of *driving automation* and related terms and definitions. This document does not provide specifications, or otherwise impose requirements on, *driving automation system*s (for further elaboration, see 8.1). Standardizing levels of *driving automation* and supporting terms serves several purposes, including:

1. Clarifying the role of the (human) *driver*, if any, during *driving automation system* engagement.

2. Answering questions of scope when it comes to developing laws, policies, regulations, and standards.

3. Providing a useful framework for *driving automation* specifications and technical requirements.

4. Providing clarity and stability in communications on the topic of *driving automation*, as well as a useful short-hand that saves considerable time and effort.

This document has been developed according to the following guiding principles; namely, it should:

1. Be descriptive and informative rather than normative.

2. Provide functional definitions.

3. Be consistent with current industry practice.

4. Be consistent with prior art to the extent practicable.

5. Be useful across disciplines, including engineering, law, media, and public discourse.

6. Be clear and cogent and, as such, it should avoid or define ambiguous terms.

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The document reflects lessons learned from various stakeholder discussions, as well as from research projects conducted in Europe and the United States by the AdaptIVe Project and by the Crash Avoidance Metrics Partnership (CAMP) Automated Vehicle Research (AVR) Consortium, respectively.

Italicized terms used in this document are also defined herein. Bracketed text within a term name indicates optional inclusion when using the term (i.e., bracketed text may be unnecessary, given the usage context).

FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

SAE International is a global association of more than 128000 engineers and related technical experts in the aerospace, automotive, and commercial-vehicle industries. Standards from SAE International are used to advance mobility engineering throughout the world. The SAE Technical Standards Development Program is among the organization's primary provisions to those mobility industries it serves aerospace, automotive, and commercial vehicle. These works are authorized, revised, and maintained by the volunteer efforts of more than 9000 engineers, and other qualified professionals from around the world. SAE subject matter experts act as individuals in the standards process, not as representatives of their organizations. Thus, SAE standards represent optimal technical content developed in a transparent, open, and collaborative process.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1 and the SAE Technical Standards Board Policy. 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 (refer to www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and SAE International shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (refer to www.iso.org/patents).

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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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), refer to www.iso.org/iso/foreword.html.

This document was jointly prepared in the ISO/SAE Definitions Joint Working Group, with experts from ISO Technical Committee 204 Intelligent Transport Systems, Working Group 14 Vehicle/roadway warning and control systems and SAE On Road Automated Driving Committee, Definitions Task Force.

This standard and its counterpart document published by ISO (PAS 22736) are technically equivalent. The only difference between the documents is the standard number and name and minor editorial elements.

This edition cancels and supersedes the SAE J3016_201806.

TABLE OF CONTENTS

1. SCOPE

This document describes [motor] *vehicle driving automation system*s that perform part or all of the *dynamic driving task* (*DDT*) on a *sustained* basis. It provides a taxonomy with detailed definitions for six levels of *driving automation*, ranging from no *driving automation* (Level 0) to full *driving automation* (Level 5), in the context of [motor] *vehicles* (hereafter also referred to as "*vehicle*" or "*vehicles*") and their *operation* on roadways:

Level 0: No Driving Automation

Level 1: Driver Assistance

Level 2: Partial Driving Automation

Level 3: Conditional Driving Automation

Level 4: High Driving Automation

Level 5: Full Driving Automation

These level definitions, along with additional supporting terms and definitions provided herein, can be used to describe the full range of *driving automation features* equipped on [motor] *vehicles* in a functionally consistent and coherent manner. "On-road" refers to publicly accessible roadways (including parking areas and private campuses that permit public access) that collectively serve all road *users*, including cyclists, pedestrians, and *users* of *vehicles* with and without *driving automation features*.

The levels apply to the *driving automation feature*(s) that are engaged in any given instance of on-road *operation* of an equipped *vehicle*. As such, although a given *vehicle* may be equipped with a *driving automation system* that is capable of delivering multiple *driving automation features* that perform at different levels, the level of *driving automation* exhibited in any given instance is determined by the *feature*(s) that are engaged.

This document also refers to three primary actors in driving: the (human) *user*, the *driving automation system*, and other *vehicle* systems and components. These other *vehicle* systems and components (or the *vehicle* in general terms) do not include the *driving automation system* in this model, even though as a practical matter a *driving automation system* may actually share hardware and software components with other *vehicle* systems, such as a processing module(s) or *operating* code.

The levels of *driving automation* are defined by reference to the specific role played by each of the three primary actors in performance of the *DDT* and/or *DDT fallback*. "Role" in this context refers to the expected role of a given primary actor, based on the design of the *driving automation system* in question and not necessarily to the actual performance of a given primary actor. For example, a *driver* who fails to monitor the roadway during engagement of a Level 1 adaptive cruise control (ACC) system still has the role of *driver*, even while s/he is neglecting it.

Active safety systems, such as electronic stability control (ESC) and automatic emergency braking (AEB), and certain types of *driver* assistance systems, such as lane keeping assistance (LKA), are excluded from the scope of this *driving automation* taxonomy because they do not perform part or all of the *DDT* on a *sustained* basis, but rather provide momentary intervention during potentially hazardous situations. Due to the momentary nature of the actions of *active safety systems*, their intervention does not change or eliminate the role of the *driver* in performing part or all of the *DDT*, and thus are not considered to be *driving automation*, even though they perform automated functions. In addition, systems that inform, alert, or warn the *driver* about hazards in the driving environment are also outside the scope of this *driving automation* taxonomy, as they neither automate part or all of the *DDT*, nor change the *driver*'s role in performance of the *DDT* (see 8.13).

It should be noted, however, that crash avoidance *features*, including intervention-type *active safety systems*, may be included in *vehicles* equipped with *driving automation system*s at any level. For *automated driving system* (*ADS*) *features* (i.e., Levels 3 to 5) that perform the complete *DDT*, crash mitigation and avoidance capability is part of *ADS* functionality (see also 8.13).

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 J670 *Vehicle* Dynamics Terminology

SAE J3063 Active Safety Systems Terms and Definitions

Shi, E., Gasser, T., Seeck, A., and Auerswald, R., "The Principles of Operation Framework: A Comprehensive Classification Concept for Automated Driving Functions," SAE Intl. J CAV 3(1):27-37, 2020, https://doi.org/10.4271/12-03-01-0003.

2.1.2 ANSI Accredited Publications

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

ANSI D16.1-2007 Manual on Classification of Motor *Vehicle* Traffic Accidents

2.1.3 Other Publications

49 U.S.C. § 30102(a)(6) (definition of [motor] *vehicle*)

Crash Avoidance Metrics Partnership - Automated Vehicle Research Consortium, "Automated Vehicle Research for Enhanced Safety - Final Report," available at https://www.regulations.gov/document?D=NHTSA-2014-0070-0003.

Gasser, T. et al., "Legal Consequences of an Increase in Vehicle Automation," July 23, 2013, available at http://bast.opus.hbz-nrw.de/volltexte/2013/723/pdf/Legal_consequences_of_an_increase_in_*vehicle*_automation.pdf.

Michon, J.A., 1985, "A Critical View of Driver Behavior Models: What Do We Know, What Should We Do?" In Evans, L. and Schwing, R.C. (Eds.). Human behavior and traffic safety (pp. 485-520). New York: Plenum Press, 1985.

Smith, B.W., "Engineers and Lawyers Should Speak the Same Robot Language," in ROBOT LAW (2015), available at https://newlypossible.org.

2.2 List of Abbreviations

ACC	Adaptive cruise control
ADAS	Advanced driver assistance system
ADS	Automated driving system
ADS-DV	Automated driving system-dedicated vehicle
AEB	Automatic emergency braking
DDT	Dynamic driving task
DSRC	Dedicated short range communications

ESC Electronic stability control

LKA Lane keeping assistance

ODD Operational design domain

OEDR Object and event detection and response

3. DEFINITIONS

3.1 ACTIVE SAFETY SYSTEM (SAE J3063)

Active safety systems are *vehicle* systems that sense and monitor conditions inside and outside the *vehicle* for the purpose of identifying perceived present and potential dangers to the *vehicle*, occupants, and/or other road *users*, and automatically intervene to help avoid or mitigate potential collisions via various methods, including alerts to the *driver*, *vehicle* system adjustments, and/or active control of the *vehicle* subsystems (brakes, throttle, suspension, etc.).

NOTE: For purposes of this report, systems that meet the definition of *active safety systems* are considered to have a design purpose that is primarily focused on improving safety rather than comfort, convenience, or general *driver* assistance. *Active safety systems* warn or intervene during a high-risk event or maneuver.

3.2 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*.

NOTE: In contrast to *ADS*, the generic term "*driving automation system*" (see 3.6) refers to any Level 1 to 5 system or *feature* that performs part or all of the *DDT* on a *sustained* basis. Given the similarity between the generic term, "*driving automation system*," and the Level 3 to 5 specific term, "*automated driving system*," the latter term should be capitalized when spelled out and reduced to its abbreviation, *ADS*, as much as possible, while the former term should not be.

3.3 [DRIVERLESS OPERATION] DISPATCHING ENTITY

An entity that *dispatch*es an *ADS*-equipped *vehicle*(s) in *driverless operation*.

NOTE: The functions carried out by a *dispatching entity* may be divided among one or several agents, depending on the *usage specification* for the *ADS*-equipped *vehicle*(s) in question.

EXAMPLE: A fleet of Level 4 closed campus *ADS-dedicated vehicles* is placed into service by a *driverless operation dispatching entity*, which engages the *ADS* for each *vehicle* after verifying its *operational* readiness and disengages the *ADS* when each *vehicle* is taken out of service.

3.4 DISPATCH [IN DRIVERLESS OPERATION]

To place an *ADS*-equipped *vehicle* into service in *driverless operation* by engaging the *ADS*.

NOTE 1: The term "*dispatch*," as used outside of the context of *ADS*-equipped *vehicles*, is generally understood to mean sending a particular *vehicle* to a particular pick-up or drop-off location for purposes of providing a transportation service. In the context of *ADS*-equipped *vehicles*, and as used herein, this term includes software-enabled *dispatch* of multiple *ADS*-equipped *vehicles* in *driverless operation* that may complete multiple *trip*s involving pick-up and drop-off of *passengers* or goods throughout a day or other pre-defined period of service, and which may involve multiple agents performing various tasks related to the *dispatch* function. In order to highlight this specialized use of the term *dispatch*, the term is modified and conditioned by the stipulation that it refers exclusively to *dispatching vehicles* in *driverless operation*.

NOTE 2: Only *ADS*-equipped *vehicles* capable of *driverless operation* (namely, an *ADS-DV* or a *dual-mode vehicle*) are potentially subject to being *dispatched*.

3.5 DRIVING AUTOMATION

The performance by hardware/software systems of part or all of the *DDT* on a *sustained* basis.

3.6 DRIVING AUTOMATION SYSTEM OR TECHNOLOGY

The hardware and software that are collectively capable of performing part or all of the *DDT* on a *sustained* basis; this term is used generically to describe any system capable of Level 1 to 5 *driving automation*.

NOTE: In contrast to this generic term for any Level 1 to 5 system, the specific term for a Level 3 to 5 system is "*automated driving system* (*ADS*)." Given the similarity between the generic term, "*driving automation system*," and the Level 3 to 5 specific term, "*Automated Driving System*," the latter term should be capitalized when spelled out and reduced to its abbreviation, *ADS*, as much as possible, while the former term should not be (see 3.2).

3.7 [DRIVING AUTOMATION SYSTEM] FEATURE

A Level 1-5 *driving automation system's* design-specific functionality at a given level of *driving automation* within a particular *ODD*, if applicable.

NOTE 1: Because the term "*driving automation system*" subsumes both *driver support features* and *ADS features*, it is also acceptable to refer to them as such.

NOTE 2: A given *driving automation system* may have multiple *features*, each associated with a particular level of *driving automation* and *ODD*.

NOTE 3: Each *feature* satisfies a *usage specification*.

NOTE 4: *Features* may be referred to by generic names (e.g., automated parking) or by proprietary names.

EXAMPLE 1: A Level 3 *ADS feature* that performs the *DDT*, excluding *DDT fallback*, in high-volume traffic on fully access-controlled freeways.

EXAMPLE 2: A Level 4 *ADS feature* that performs the *DDT*, including *DDT fallback*, in a specified geo-fenced urban center.

3.7.1 MANEUVER-BASED FEATURE

A *driving automation system feature* equipped on a *conventional vehicle* that either:

1. Supports the *driver* by executing a limited set of lateral and/or longitudinal *vehicle* motion control actions sufficient to fulfil a specific, narrowly defined use case (e.g., parking maneuver), while the *driver* performs the rest of the *DDT* and supervises the Level 1 or Level 2 *feature's* performance (i.e., Level 1 or Level 2 *driver support features*);

   or

2. Executes a limited set of lateral and longitudinal *vehicle* motion control actions, as well as associated *object and event detection and response* (*OEDR*) and all other elements of the complete *DDT* in order to fulfil a specific, narrowly defined use case without human supervision (Level 3 or 4 *ADS features*).

EXAMPLE 1: A Level 1 parking assistance *feature* automatically performs the lateral *vehicle* motion control actions necessary to parallel park a *vehicle*, while the *driver* performs the longitudinal *vehicle* motion control actions and supervises the *feature*.

EXAMPLE 2: A Level 2 parking assistance *feature* automatically performs the lateral and longitudinal *vehicle* motion control actions necessary to parallel park a *vehicle* under the *supervision* of the *driver*.

EXAMPLE 3: A Level 3 highway overtaking assistance *feature* automatically performs the lateral and longitudinal *vehicle* motion control actions, as well as associated *OEDR*, necessary to pass a slower-moving *vehicle* on a multi-lane highway when activated by the *driver* or *fallback-ready user*.

3.7.2 SUB-TRIP FEATURE

A *driving automation system feature* equipped on a *conventional vehicle* that requires a human *driver* to perform the complete *DDT* for at least part of every *trip*.

NOTE: *Sub-trip features* require a human *driver* to *operate* the *vehicle* between the point-of-origin and the boundary of the feature's *ODD* and/or after leaving the *feature's ODD* until the destination is reached (i.e., *trip* completion).

EXAMPLE 1: A Level 1 adaptive cruise control (ACC) *feature* performs longitudinal *vehicle* motion control functions to support the *driver* in maintaining consistent headway to a lead *vehicle* in its lane when travelling at higher speeds.

EXAMPLE 2: A Level 2 highway *feature* performs lateral and longitudinal *vehicle* motion control functions to support the *driver* in maintaining position within its lane of travel, as well as consistent headway to a lead *vehicle* in its lane when travelling at higher speeds.

EXAMPLE 3: A Level 3 traffic jam *feature* performs the complete *DDT* on a fully access-controlled freeway in dense traffic, but requires a human *driver* to *operate* the *vehicle* upon *ODD* exit (e.g., when traffic clears, as well as before entering the congested freeway, and again upon exiting it).

EXAMPLE 4: During a given *vehicle trip*, a *user* with a Level 4 automated parking *feature dispatches* the *vehicle* in *driverless operation* for the purpose of finding a parking space in a nearby designated parking facility. Following a period of shopping, the *user* retrieves the *vehicle* via *dispatch* in order to begin his/her *trip* home.

3.7.3 FULL-TRIP FEATURE

ADS features that *operate* a *vehicle* throughout complete *trips*.

EXAMPLE 1: A Level 4 *ADS-DV* is *dispatched* in *driverless operation* for purposes of providing ride-hailing services to customers located within its geo-fenced area of *operation*.

EXAMPLE 2: A Level 5 *dual-mode vehicle* is *dispatched* in *driverless operation* by its owner to go to a designated airport, pick up several family members, and bring them home. All *vehicle* occupants remain *passengers* throughout the return *trip*.

Figure 1 illustrates how a *trip* could be completed by use of various combinations of *driving automation features* engaged at different levels of *driving automation*.

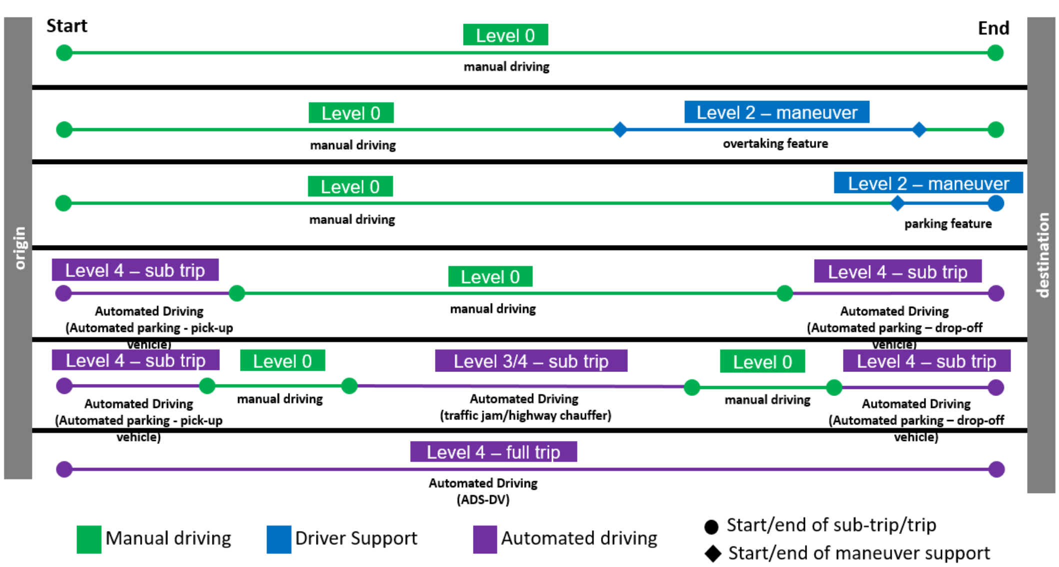


Figure 1 - Examples of driving automation system features/types that could be available during a given trip

3.8 DRIVER SUPPORT [DRIVING AUTOMATION SYSTEM] FEATURE

A general term for Level 1 and Level 2 *driving automation system features*.

NOTE: Level 1 (*driver* assistance) and Level 2 (partial automation) *features* are capable of performing only part of the *DDT*, and thus require a *driver* to perform the remainder of the *DDT*, as well as to supervise the *feature's* performance while engaged. As such, these *features*, when engaged, support—but do not replace—a *driver* in performing the *DDT*.

3.9 DRIVERLESS OPERATION [OF AN ADS-EQUIPPED VEHICLE]

On-road *operation* of an *ADS*-equipped *vehicle* that is unoccupied, or in which on-board *users* are not *drivers* or *in-vehicle fallback-ready users*.

NOTE 1: *ADS-DVs* are always *dispatched* in *driverless operation* (subject to NOTE 3 in 3.33.3).

NOTE 2: *ADS*-equipped *dual-mode vehicles* may be *dispatched* in *driverless operation*.

NOTE 3: On-board *passengers* are neither *drivers* nor *fallback-ready users*.

EXAMPLE: A Level 4 *ADS-DV* is *dispatched* in *driverless operation* for purposes of providing transportation service.

3.10 DYNAMIC DRIVING TASK (DDT)

All of the real-time *operational* and tactical functions required to *operate* a *vehicle* in on-road traffic, excluding the strategic functions such as *trip* scheduling and selection of destinations and waypoints, and including, without limitation, the following subtasks:

1. Lateral *vehicle* motion control via steering (*operational*).

2. Longitudinal *vehicle* motion control via acceleration and deceleration (*operational*).

3. Monitoring the driving environment via object and event detection, recognition, classification, and response preparation (*operational* and tactical).

4. Object and event response execution (*operational* and tactical).

5. Maneuver planning (tactical).

6. Enhancing conspicuity via lighting, sounding the horn, signaling, gesturing, etc. (tactical).

NOTE 1: Some *driving automation system*s (or the *vehicles* equipped with them) may have a means to change longitudinal *vehicle* motion control between forward and reverse.

NOTE 2: For simplification and to provide a useful shorthand term, subtasks (3) and (4) are referred to collectively as *object and event detection and response* (*OEDR*) (see 3.19).

NOTE 3: In this document, reference is made to "complete(ing) the *DDT*." This means fully performing all of the subtasks of the *DDT*, whether that role is fulfilled by the (human) *driver*, by the *driving automation system*, or by a combination of both.

NOTE 4: Figure 2 displays a schematic view of the driving task. For more information on the differences between *operational*, tactical, and strategic functions of driving, see 8.11.

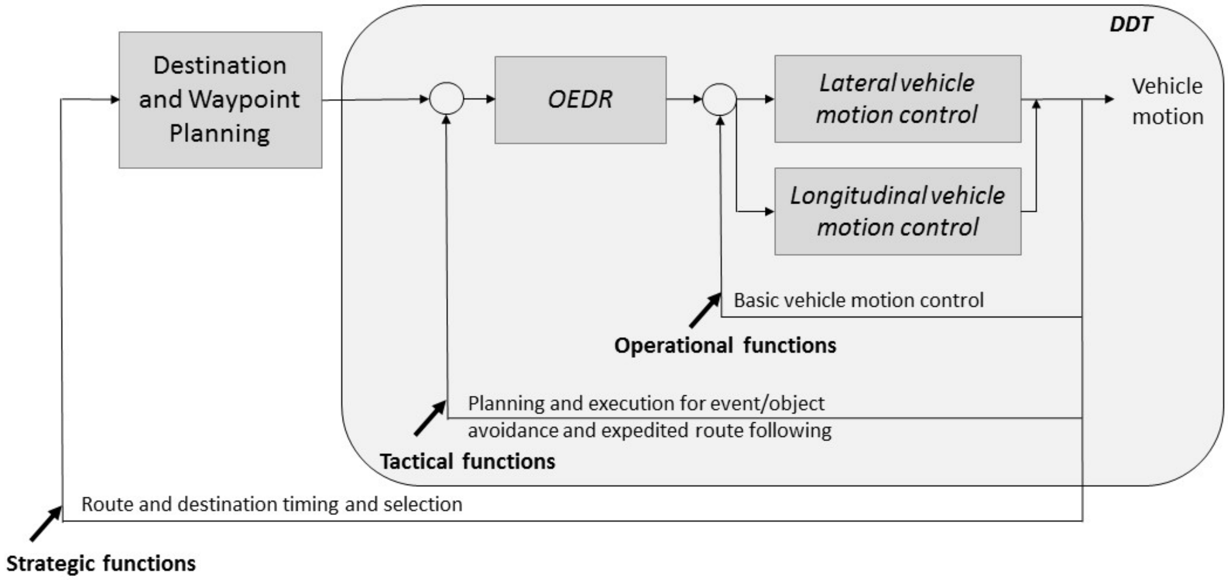


Figure 2 - Schematic (not a control diagram) view of driving task showing DDT portion

For purposes of *DDT* performance, Level 1 *driving automation* encompasses automation of part of the innermost loop (i.e., either lateral *vehicle* motion control functionality or longitudinal *vehicle* motion control functionality and limited *OEDR* associated with the given axis of *vehicle* motion control); Level 2 *driving automation* encompasses automation of the innermost loop (lateral and longitudinal *vehicle* motion control and limited *OEDR* associated with *vehicle* motion control), and Level 3 to 5 *driving automation* encompasses automation of both inner loops (lateral and longitudinal *vehicle* motion control and complete *OEDR*). Note that *DDT* performance does not include strategic aspects of driving (e.g., determining whether, when, and where to travel).

3.11 FAILURE MITIGATION STRATEGY

A *vehicle* function (not an *ADS* function) designed to automatically bring an *ADS*-equipped *vehicle* to a controlled stop in path following either: (1) prolonged failure of the *fallback-ready user* of a Level 3 *ADS feature* to perform the *fallback* after the *ADS* has issued a *request to intervene*, or (2) occurrence of a *system failure* or external event so catastrophic that it incapacitates the *ADS*, which can no longer perform *vehicle* motion control in order to perform the *fallback* and achieve a *minimal risk condition*. (See 8.6.)

NOTE: Some *vehicles* equipped with Level 2 *driver support features* may be designed to brake a *vehicle* to a full stop if the *driver* fails to indicate his/her continued *supervision* of *feature* performance during engagement. Although that is similar in function to a *failure mitigation strategy* as defined above, the term "*failure mitigation strategy*" is reserved for *ADS features* that do not require *driver supervision*.

3.12 [DYNAMIC DRIVING TASK (DDT)] FALLBACK

The response by the *user* to either perform the *DDT* or achieve a *minimal risk condition* (1) after occurrence of a *DDT* performance-relevant *system failure*(s), or (2) upon *operational design domain* (*ODD*) exit, or the response by an *ADS* to achieve *minimal risk condition*, given the same circumstances.

NOTE 1: The *DDT* and the *DDT fallback* are distinct functions, and the capability to perform one does not necessarily entail the ability to perform the other. Thus, a Level 3 *ADS*, which is capable of performing the entire *DDT* within its *ODD*, may not be capable of performing the *DDT fallback* in all situations that require it and thus will issue a *request to intervene* to the *DDT fallback-ready user* when necessary (see Figures 3 to 6).

NOTE 2: Some Level 3 *features* may be designed to automatically perform the *fallback* and achieve a *minimal risk condition* in some circumstances, such as when an obstacle-free, adjacent shoulder is present, but not in others, such as when no such road shoulder is available. The assignment of Level 3 therefore does not restrict the *ADS* from automatically achieving the *minimal risk condition*, but it cannot guarantee automated achievement of *minimal risk condition* in all cases within its *ODD*. Moreover, automated *minimal risk condition* achievement in some, but not all, circumstances that demand it does not constitute Level 4 functionality.

NOTE 3: At Level 3, an *ADS* is capable of continuing to perform the *DDT* for at least several seconds after providing the *fallback-ready user* with a *request to intervene*. The *DDT fallback-ready user* is then expected to resume manual *vehicle operation*, or to achieve a *minimal risk condition* if s/he determines it to be necessary.

NOTE 4: At Levels 4 and 5, the *ADS* must be capable of performing the *DDT fallback* and achieving a *minimal risk condition*. Level 4 and 5 *ADS*-equipped *vehicles* that are designed to also accommodate *operation* by a *driver* (whether in-*vehicle* or remote) may allow a *user* to perform the *DDT fallback*, when circumstances allow this to be done safely, if s/he chooses to do so (see Figures 7 and 8). However, a Level 4 or 5 *ADS* need not be designed to allow a *user* to perform *DDT fallback* and, indeed, may be designed to disallow it in order to reduce crash risk (see 8.9).

NOTE 5: While a Level 4 or 5 *ADS* is performing the *DDT fallback*, it may be limited by design in speed and/or range of lateral and/or longitudinal *vehicle* motion control (i.e., it may enter so-called “limp-home mode”).

NOTE 6: While performing *DDT fallback*, an *ADS* may *operate* temporarily outside of its *ODD* (see 3.21 NOTE 1).

EXAMPLE 1: A Level 1 adaptive cruise control (ACC) *feature* experiences a *system failure* that causes the *feature* to stop performing its intended function. The human *driver* performs the *DDT fallback* by resuming performance of the complete *DDT*.

EXAMPLE 2: A Level 3 *ADS feature* that performs the entire *DDT* during traffic jams on freeways is not able to do so when it encounters a crash scene and therefore issues a *request to intervene* to the *DDT fallback-ready user*. S/he responds by taking over performance of the entire *DDT* in order to maneuver around the crash scene (see Figure 4). (Note that in this example, a *minimal risk condition* is not needed or achieved.)

EXAMPLE 3: A Level 4 *ADS-dedicated vehicle* (*ADS-DV*) that performs the entire *DDT* within a geo-fenced city center experiences a *DDT* performance-relevant *system failure*. In response, the *ADS-DV* performs the *DDT fallback* by turning on the hazard flashers, maneuvering the *vehicle* to the road shoulder and parking it, before automatically summoning emergency assistance (see Figure 7). (Note that in this example, the *ADS-DV* automatically achieves a *minimal risk condition*.)

The following Figures 3 through 8 illustrate *DDT fallback* at various levels of *driving automation*.

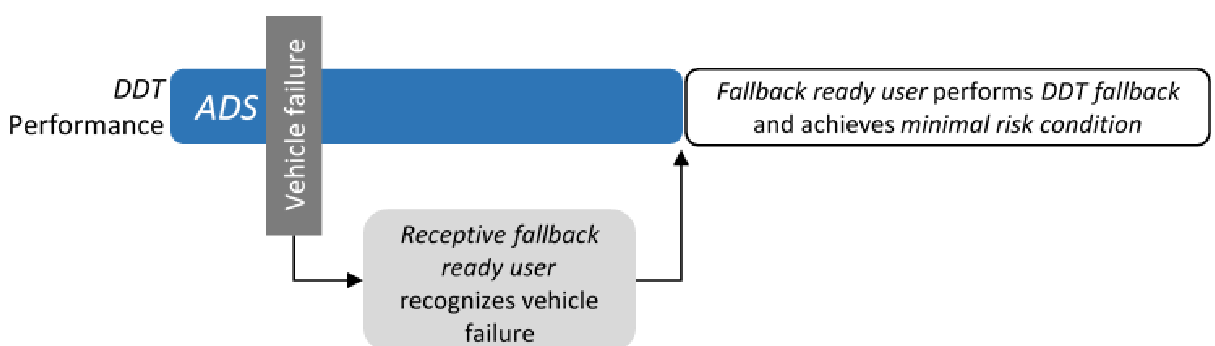


Figure 3

Sample use case sequence at Level 3 showing *ADS* engaged and occurrence of a *vehicle system failure* that prevents continued *DDT* performance. *User* performs *fallback* and achieves a *minimal risk condition*.

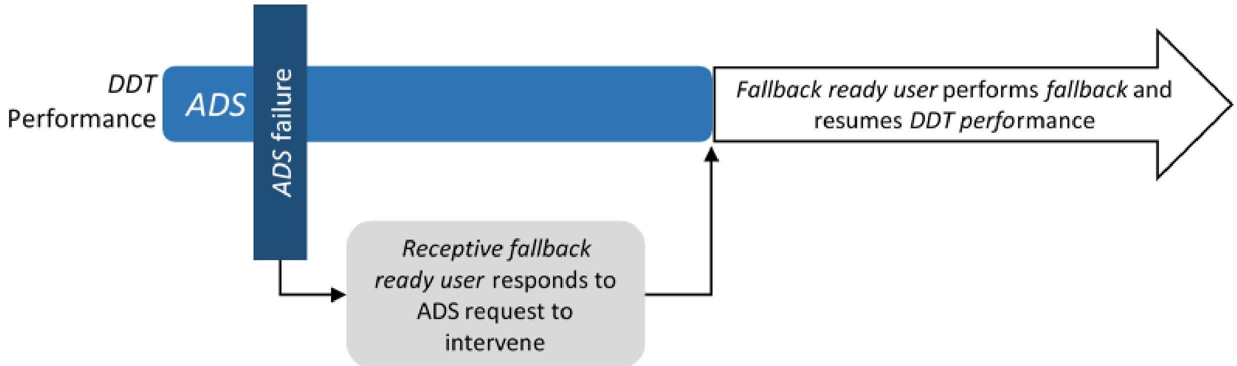


Figure 4

Sample use case sequence at Level 3 showing *ADS* engaged and occurrence of an *ADS system failure* that does not prevent continued *DDT* performance. *User* performs the *fallback* and resumes *DDT* performance.

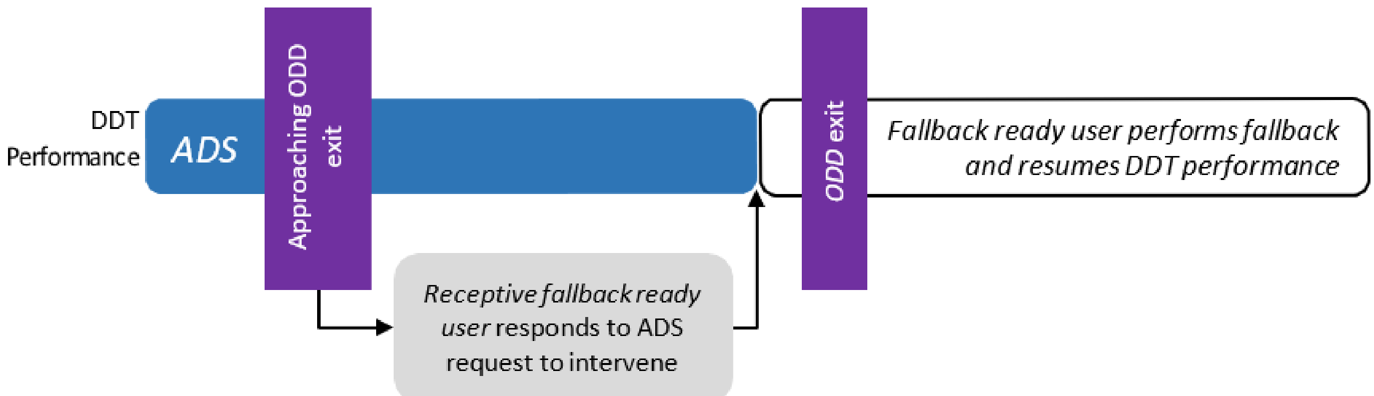


Figure 5

Sample use case sequence at Level 3 showing *ADS* engaged and occurrence of exiting the *ODD* that does not prevent continued *DDT* performance. *User* performs the *fallback* and resumes *DDT* performance.

Figure 6

Sample use case sequence at Level 4 showing *ADS* engaged and occurrence of a *vehicle system failure* that prevents continued *DDT* performance. *ADS* performs the *fallback* and achieves a *minimal risk condition*.

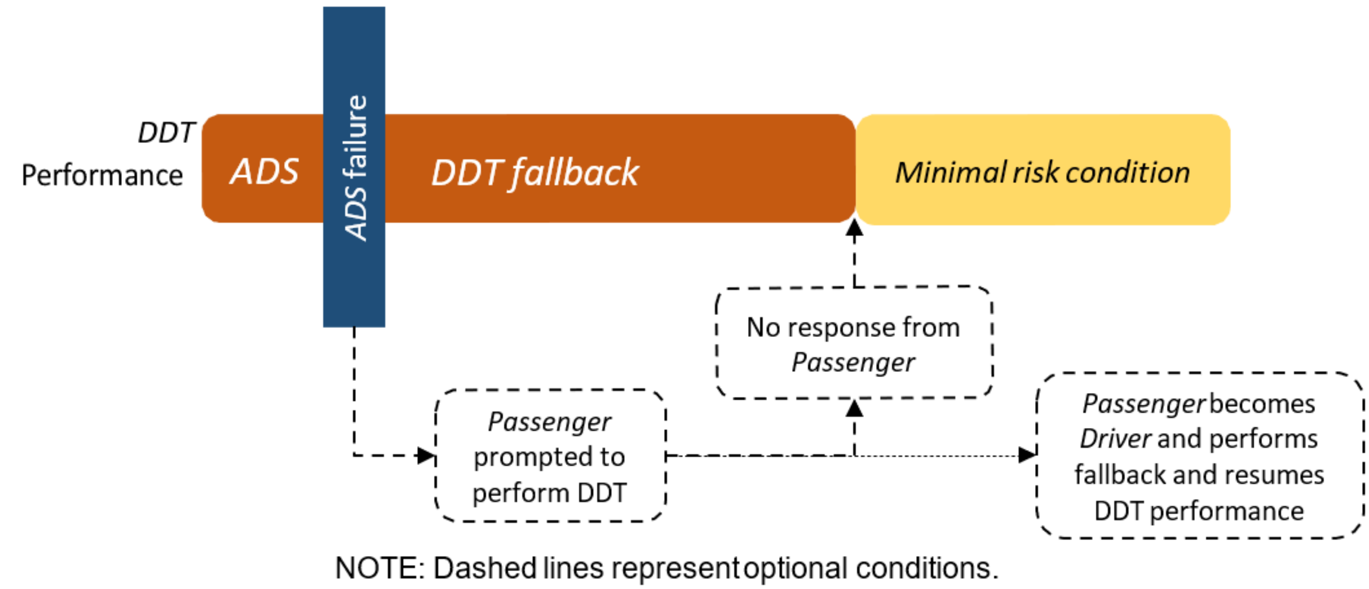


Figure 7

Sample use case sequence at Level 4 showing *ADS* engaged and occurrence of an *ADS* failure that does not prevent continued *DDT* performance by an available human *user*. The *ADS feature* may prompt a *passenger* seated in the *driver*'s seat (if available) to resume *DDT* performance; if no *driver*'s seat with receptive *passenger*, the *ADS* automatically achieves a *minimal risk condition*.

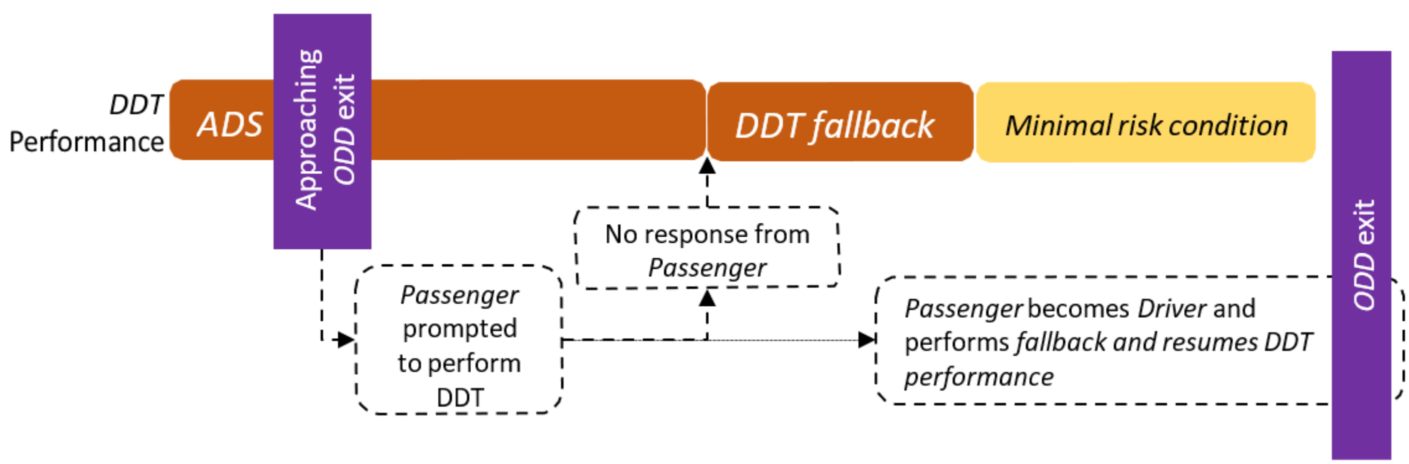


Figure 8

Use case sequence at Level 4 showing *ADS* engaged with *ODD* exit, which does not prevent continued *DDT* performance by an available human *user*. The *ADS feature* may prompt a *passenger* seated in the *driver*'s seat (if available) to resume *DDT* performance; if no *driver*'s seat with receptive *passenger*, the *ADS* automatically achieves a *minimal risk condition*.

3.13 FLEET OPERATIONS [FUNCTIONS]

The activities that support the management of a fleet of *ADS*-equipped *vehicles* in *driverless operation*, which may include, without limitation:

- Ensuring *operational* readiness.
- *Dispatch*ing *ADS*-equipped *vehicles* in *driverless operation* (i.e., engaging the *ADS*s prior to placing the *vehicles* in service on public roads).
- Authorizing each *trip* (e.g., payment, *trip* route selection).
- Providing fleet asset management services to *vehicles* while in-use (e.g., managing emergencies, summoning or providing *remote assistance* as needed, responding to customer requests and break-downs).
- Serving as the responsible agent vis-a-vis law enforcement, emergency responders and other authorities for *vehicles* while in use.
- Disengaging the *ADS* at the end of service.
- Performing *vehicle* repair and maintenance as needed.

3.14 LATERAL VEHICLE MOTION CONTROL

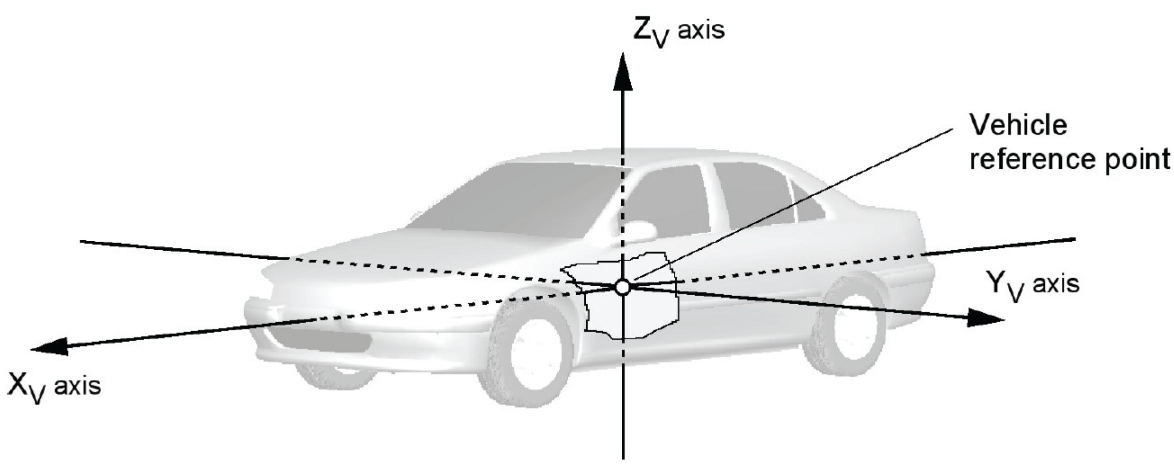
The *DDT* subtask comprising the activities necessary for the real-time, *sustained* regulation of the y-axis component of *vehicle* motion (see Figure 9).

NOTE: Lateral *vehicle* motion control includes the detection of the *vehicle* positioning relative to lane boundaries and application of steering and/or differential braking inputs to maintain appropriate lateral positioning.

3.15 LONGITUDINAL VEHICLE MOTION CONTROL

The *DDT* subtask comprising the activities necessary for the real-time, *sustained* regulation of the x-axis component of *vehicle* motion (see Figure 9).

NOTE: Longitudinal *vehicle* motion control may include forward and reverse directionality depending on the *usage specification*.



A. VEHICLE AXIS SYSTEM – Z-UP

Figure 9 - Diagram showing vehicle axes of motion (SAE J670)

3.16 MINIMAL RISK CONDITION

A stable, stopped condition to which a *user* or an *ADS* may bring a *vehicle* after performing the *DDT fallback* in order to reduce the risk of a crash when a given *trip* cannot or should not be continued.

NOTE 1: At Levels 1 and 2, the *in-vehicle driver* is expected to achieve a *minimal risk condition* as needed.

NOTE 2: At Level 3, given a *DDT* performance-relevant *system failure* in the *ADS* or *vehicle*, the *DDT fallback-ready user* is expected to achieve a *minimal risk condition* when s/he determines that it is necessary, or to otherwise perform the *DDT* if the *vehicle* is operable.

NOTE 3: At Levels 4 and 5, the *ADS* is capable of automatically achieving a *minimal risk condition* when necessary (i.e., due to *ODD* exit, if applicable, or due to a *DDT* performance-relevant *system failure* in the *ADS* or *vehicle*). The characteristics of automated achievement of a *minimal risk condition* at Levels 4 and 5 will vary according to the type and extent of the *system failure*, the *ODD* (if any) for the *ADS feature* in question, and the particular *operating* conditions when the *system failure* or *ODD* exit occurs. It may entail automatically bringing the *vehicle* to a stop within its current travel path, or it may entail a more extensive maneuver designed to remove the *vehicle* from an active lane of traffic and/or to automatically return the *vehicle* to a *dispatching* facility.

EXAMPLE 1: A Level 4 *ADS feature* designed to *operate* a *vehicle* at high speeds on freeways experiences a *DDT* performance-relevant *system failure* and automatically removes the *vehicle* from active lanes of traffic before coming to a stop.

EXAMPLE 2: A *vehicle* in which a Level 4 *ADS* is installed experiences a *DDT* performance-relevant *system failure* in its primary electrical power system. The *ADS* utilizes a backup power source in order to achieve a *minimal risk condition*.

3.17 [DDT PERFORMANCE-RELEVANT] SYSTEM FAILURE

A malfunction in a *driving automation system* and/or other *vehicle* system that prevents the *driving automation system* from reliably performing its portion of the *DDT* on a *sustained* basis, including the complete *DDT*, that it would otherwise perform.

NOTE 1: This definition applies to *vehicle* fault conditions and *driving automation system failures* that prevent a *driving automation system* from performing at full capability according to design intention.

NOTE 2: This term does not apply to transient lapses in performance by a Level 1 or 2 *driver support feature* that are due to inherent design limitations and that do not otherwise prevent the system from performing its part of the *DDT* on a *sustained* basis.

EXAMPLE 1: A Level 1 *driver support feature* that performs the lateral *vehicle* motion control subtask of the *DDT* experiences a *DDT* performance-relevant *system failure* in one of its cameras, which prevents it from reliably detecting lane markings. The *feature* causes a malfunction indication message to be displayed in the center console at the same time that the *feature* automatically disengages, requiring the *driver* to immediately resume performing the lateral *vehicle* motion control subtask of the *DDT*.

EXAMPLE 2: A Level 3 *ADS* experiences a *DDT* performance-relevant *system failure* in one of its radar sensors, which prevents it from reliably detecting objects in the *vehicle*'s pathway. The *ADS* responds by issuing a *request to intervene* to the *DDT fallback-ready user*. The *ADS* continues to perform the *DDT*, while reducing *vehicle* speed, for several seconds to allow time for the *DDT fallback-ready user* to resume *operation* of the *vehicle* in an orderly manner.

EXAMPLE 3: A *vehicle* with an engaged Level 3 *ADS* experiences a sudden tire blow-out, which causes the *vehicle* to handle very poorly, giving the *fallback-ready user* ample kinesthetic feedback indicating a *vehicle* malfunction necessitating intervention. The *fallback-ready user* responds by resuming the *DDT*, turning on the hazard lamps, and pulling the *vehicle* onto the closest road shoulder, thereby achieving a *minimal risk condition*.

EXAMPLE 4: A Level 4 *ADS* experiences a *DDT* performance-relevant *system failure* in one of its computing modules. The *ADS* transitions to *DDT fallback* by engaging a redundant computing module(s) to achieve a *minimal risk condition*.

3.18 MONITOR

A general term describing a range of functions involving real-time human or machine sensing and processing of data used to *operate* a *vehicle*, or to support its *operation*.

NOTE 1: The terms below describing types of monitoring should be used when the general term "monitor" and its derivatives are insufficiently precise.

NOTE 2: The following four terms (1 - *monitor the user*, 2 - *monitor the driving environment*, 3 - *monitor vehicle performance*, and 4 - *monitor driving automation system performance*) describe categories of monitoring (see scope regarding primary actors).

NOTE 3: The *driver* state or condition of being receptive to alerts or other indicators of a *DDT* performance-relevant *system failure*, as assumed in Level 3, is not a form of monitoring. The difference between *receptivity* and monitoring is best illustrated by example: A person who becomes aware of a fire alarm or a telephone ringing may not necessarily have been monitoring the fire alarm or the telephone. Likewise, a *user* who becomes aware of a trailer hitch falling off may not necessarily have been monitoring the trailer hitch. By contrast, a *driver* in a *vehicle* with an active Level 1 adaptive cruise control (ACC) system is expected to monitor both the driving environment and the ACC performance and otherwise not to wait for an alert to draw his/her attention to a situation requiring a response (see 3.22).

3.18.1 MONITOR THE USER

The activities and/or automated routines designed to assess whether and to what degree the *user* is performing the role specified for him/her.

NOTE 1: *User* monitoring in the context of *driving automation* is most likely to be deployed as a countermeasure for misuse or abuse (including over-reliance due to complacency) of a *driving automation system*, but may also be used for other purposes.

NOTE 2: *User* monitoring is primarily useful for Levels 2 and 3, as evidence from the field on the use of Level 1 *features* has not identified significant incidence of misuse or abuse of *driving automation* technology, and above these levels, the *ADS* is by definition capable of achieving a *minimal risk condition* automatically.

3.18.2 MONITOR THE DRIVING ENVIRONMENT

The activities and/or automated routines that accomplish real-time roadway environmental object and event detection, recognition, classification, and response preparation (excluding actual response), as needed to *operate* a *vehicle*.

NOTE: When *operating conventional vehicles* that are not equipped with an engaged *ADS*, *drivers* visually sample the road scene sufficiently to competently perform the *DDT* while also performing secondary tasks that require short periods of eyes-off-road time (e.g., adjusting cabin comfort settings, scanning road signs, tuning a radio, etc.). Thus, monitoring the driving environment does not necessarily entail continuous eyes-on-road time by the *driver*.

3.18.3 MONITOR VEHICLE PERFORMANCE [FOR DDT PERFORMANCE-RELEVANT SYSTEM FAILURES]

The activities and/or automated routines that accomplish real-time evaluation of the *vehicle* performance, and response preparation, as needed to *operate* a *vehicle*.

NOTE: While performing the *DDT*, Level 4 and 5 *ADS*s *monitor vehicle performance*. However, for Level 3 *ADS*s, as well as for Level 1 and 2 *driving automation system*s, the human *driver* is assumed to be receptive to *vehicle* conditions that adversely affect performance of the *DDT* (see 3.22).

EXAMPLE 1: While a Level 2 *driver support feature* is engaged in stop-and-go traffic, a malfunctioning brake caliper causes the *vehicle* to pull slightly to the left when the brakes are applied. The human *driver* observes that the *vehicle* is deviating from its lane and either corrects the *vehicle*'s lateral position or disengages the *feature* entirely.

EXAMPLE 2: While a Level 4 *ADS* is engaged in stop-and-go traffic, a malfunctioning brake caliper causes the *vehicle* to pull to the left when the brakes are applied. The *ADS* recognizes this deviation, corrects the *vehicle*'s lateral position and transitions to a limp-home mode until it achieves a *minimal risk condition*.

3.18.4 MONITOR DRIVING AUTOMATION SYSTEM PERFORMANCE

The activities and/or automated routines for evaluating whether the *driving automation system* is performing part or all of the *DDT* appropriately.

NOTE 1: The term *monitor driving automation system performance* should not be used in lieu of supervise, which includes both monitoring and responding as needed to perform the *DDT* and is therefore more comprehensive.

NOTE 2: Recognizing requests to intervene issued by a *driving automation system* is not a form of monitoring *driving automation system* performance, but rather a form of *receptivity*.

NOTE 3: At Levels 1 and 2, the *driver* monitors the *driver support feature*'s performance as part of supervising.

NOTE 4: At higher levels of *driving automation* (Levels 3 to 5), the *ADS* monitors its own performance of the complete *DDT*.

EXAMPLE 1: An *in-vehicle driver* monitors an engaged ACC *feature* to verify that it is maintaining an appropriate gap while following a preceding *vehicle* in a curve.

EXAMPLE 2: A *remote driver* engaging a Level 2 automated parking *feature* monitors the pathway of the *vehicle* to verify that the *feature* is responsive to pedestrians and obstacles.

3.19 OBJECT AND *EVENT* DETECTION AND RESPONSE (OEDR)

The subtasks of the *DDT* that include monitoring the driving environment (detecting, recognizing, and classifying objects and events and preparing to respond as needed) and executing an appropriate response to such objects and events (i.e., as needed to complete the *DDT* and/or *DDT fallback*).

3.20 OPERATE [A MOTOR VEHICLE]

Collectively, the activities performed by a (human) *driver* (with or without support from one or more Level 1 or 2 *driving automation features*) or by an *ADS* (Level 3 to 5) to perform the entire *DDT* for a given *vehicle*.

NOTE 1: The term "drive" is not used in this document, however, in many cases it could be used correctly in lieu of "*operate*."

NOTE 2: Although use of the term *operate*/*operating*/*operation* implies the existence of a *vehicle* "operator," this term is not defined or used in this document, which otherwise provides very specific terms and definitions for the various types of *ADS*-equipped *vehicle users* (see 3.32).

NOTE 3: Terms such as "drive," "*operate*," "*driver*," and "operator" may have legal meanings that are different from their technical meanings, as contained in this document.

3.21 OPERATIONAL DESIGN DOMAIN (ODD)

Operating conditions under which a given *driving automation system* or *feature* thereof is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics.

NOTE 1: While Level 3 and 4 *ADS features*/*vehicles* are designed to *operate* exclusively within their respective *ODD*s, some *ODD* conditions are subject to rapid change during on-road *operation* (e.g., inclement weather, obscured lane lines). Such transient changes in the *operating* environment do not necessarily represent an "*ODD* exit," as the *ADS* determines when such a change in conditions requires *fallback* performance (whether by the *fallback-ready user* or *ADS*).

NOTE 2: Section 6 discusses the significance of *ODD*s in the context of the levels of *driving automation*.

EXAMPLE 1: A Level 1 ACC *driver support feature* is designed to provide longitudinal *vehicle* motion control support to the *driver* on fully access-controlled freeways under fair weather conditions.

EXAMPLE 2: An *ADS feature* is designed to *operate* a *vehicle* only on fully access-controlled freeways in low-speed traffic, under fair weather conditions and optimal road maintenance conditions (e.g., good lane markings and not under construction).

EXAMPLE 3: An *ADS-dedicated vehicle* is designed to *operate* only within a geographically defined military base, and only during daylight at speeds not to exceed 25 mph.

EXAMPLE 4: An *ADS*-dedicated commercial truck is designed to pick up parts from a geo-fenced sea port and deliver them via a specific route to a distribution center located 30 miles away. The *vehicle*'s *ODD* is limited to day- time *operation* within the specified sea port and the specific roads that constitute the prescribed route between the sea port and the distribution center.

EXAMPLE 5: A level 3 *ADS* highway *feature* with an *ODD* requirement of clearly visible lane lines encounters a short stretch of roadway with obscured lane lines. The *ADS feature* is able to compensate for brief periods of faded or missing lane markings through other means (e.g., sensor fusion, digital map, lead *vehicle* following) and continues to *operate* the *vehicle* for a brief period before the lane lines again become clearly visible. A short while later, the lane lines again become obscured and remain so for longer duration, causing the *ADS feature* to issue a *request to intervene* to the *fallback-ready user*.

3.22 RECEPTIVITY [OF THE USER]

An aspect of consciousness characterized by a person's ability to reliably and appropriately focus his/her attention in response to a stimulus.

NOTE 1: In Level 0 to 2 *driving automation*, the *driver* is expected to be receptive to evident *vehicle system failures*, such as a broken tie rod.

NOTE 2: In Level 3 *driving automation*, a *DDT fallback-ready user* is considered to be receptive to a *request to intervene* and/or to an evident *vehicle system failure*, whether or not the *ADS* issues a *request to intervene* as a result of such a *vehicle system failure*.

EXAMPLE 1: While a Level 3 *ADS* is performing the *DDT* in stop-and-go traffic, the left-front tire experiences a sudden blow-out. The *DDT fallback-ready user* is receptive to the kinesthetic cue of the *vehicle* pulling significantly to the left and intervenes in order to move the *vehicle* onto the road shoulder.

EXAMPLE 2: While a Level 3 *ADS* is performing the *DDT* on a free-flowing highway, the left side mirror glass falls out of the housing. The *DDT fallback-ready user*, while receptive, does not and is not expected to notice this failure, because it is not apparent, and does not adversely affect *DDT* performance by the *ADS*.

3.23 REMOTE ASSISTANCE

Event-driven provision, by a remotely located human (see 3.31.5), of information or advice to an *ADS*-equipped *vehicle* in *driverless operation* in order to facilitate *trip* continuation when the *ADS* encounters a situation it cannot manage.

NOTE 1: *Remote assistance* does not include real-time *DDT* or *fallback* performance by a *remote driver*. Rather, the *ADS* performs the complete *DDT* and/or *fallback*, even when assisted by a remotely located human.

NOTE 2: *Remote assistance* may include providing an *ADS* with revised goals and/or tasks.

NOTE 3: The *remote assistance* function does not include providing strategic instruction regarding selection of destinations or *trip* initiation timing (i.e., *dispatch* functions), even if the same person performs both *remote assistance* and *dispatching* functions.

EXAMPLE 1: A Level 4 *ADS-DV* encounters an unannounced area of road construction within its *ODD*. The *ADS-DV* communicates to a remotely located human that it is unable to proceed around the construction. The remotely located human provides a new pathway for the *vehicle* to follow around the construction zone that allows the *ADS-DV* to automatically proceed and complete its *trip*.

EXAMPLE 2: A Level 4 *ADS-DV* detects an object in its lane that appears to be too large to drive over and stops. A *remote assistant* uses the *vehicle*'s cameras to identify that the object is an empty bag that can be safely driven through/over, and provides the instruction to the *ADS-DV* to proceed.

3.24 REMOTE DRIVING

Real-time performance of part or all of the *DDT* and/or *DDT fallback* (including, real-time braking, steering, acceleration, and transmission shifting), by a *remote driver*.

NOTE 1: A receptive *remote fallback-ready user* becomes a *remote driver* when s/he performs the *fallback*.

NOTE 2: The *remote driver* performs or completes the *OEDR* and has the authority to overrule the *ADS* for purposes of lateral and longitudinal *vehicle* motion control.

NOTE 3: Remote driving is not *driving automation*.

NOTE 4: Remote driving of a *vehicle* by a human is sometimes referred to as "teleoperation." However, "teleoperation" is not defined consistently in the literature, and thus, to avoid confusion, is not used herein.

3.25 REQUEST TO INTERVENE

An alert provided by a Level 3 *ADS* to a *fallback-ready user* indicating that s/he should promptly perform the *DDT fallback*, which may entail resuming manual *operation* of the *vehicle* (i.e., becoming a *driver* again), or achieving a *minimal risk condition* if the *vehicle* is not operable.

NOTE: As previously noted in this document, it may be possible for a *passenger* in a Level 4 or 5 *ADS-operated vehicle* to also resume manual *operation* of the *vehicle* under certain conditions, provided that the *vehicle* and *feature* are designed for this (e.g., a *dual-mode vehicle* or a *conventional vehicle* with a Level 4 *sub-trip feature*). However, even when alerted by the *ADS* to take over *vehicle operation*, a *passenger* of such a *vehicle* is not required to do so to ensure competent *operation*, as Level 4 and 5 *ADS features*/*vehicles* are capable of automatically achieving a *minimal risk condition* when necessary. Thus, such an alert to a *passenger* of a Level 4 or 5 *ADS-operated vehicle* is not a "request to intervene" as defined herein for Level 3 *ADS*-equipped *vehicles*.

3.26 ROUTINE/NORMAL [ADS] OPERATION

Operation of a *vehicle* by an *ADS* within its prescribed *ODD*, if any, while no *DDT* performance-relevant *system failure* is occurring.

NOTE: Routine/normal *ADS operation* includes *vehicle* responses to objects and events that are safety- and time-critical, as well as *vehicle* responses to the same that are not safety- and time-critical.

3.27 SUPERVISE [DRIVING AUTOMATION SYSTEM PERFORMANCE]

The *driver* activities, performed while *operating* a *vehicle* with an engaged Level 1 or 2 *driver support feature*, to monitor that *feature's* performance, respond to inappropriate actions taken by the *feature*, and to otherwise complete the *DDT*.

EXAMPLE: A *driver* notices that an engaged adaptive cruise control (ACC) *feature* is not maintaining headway to a preceding *vehicle* in a curve and brakes accordingly.

3.28 SUSTAINED [OPERATION OF A VEHICLE]

Performance of part or all of the *DDT* both between and across external events, including responding to external events and continuing performance of part or all of the *DDT* in the absence of external events.

NOTE 1: External events are situations in the driving environment that necessitate a response by a *driver* or *driving automation system* (e.g., other *vehicles*, lane markings, traffic signs).

NOTE 2: *Sustained* performance of part or all of the *DDT* by a *driving automation system* changes the *user*'s role. (See scope for discussion of roles.) By contrast, an automated intervention that is not *sustained* according to this definition does not qualify as *driving automation*. Hence, systems that provide momentary intervention in lateral and/or longitudinal *vehicle* motion control but do not perform any part of the *DDT* on a *sustained* basis (e.g., anti-lock brake systems, electronic stability control, automatic emergency braking) are not classifiable (other than at Level 0) under the taxonomy.

NOTE 3: Conventional cruise control does not provide *sustained operation* because it does not respond to external events. It is therefore also not classifiable (other than at Level 0) under the taxonomy.

3.29 TRIP

The traversal of an entire travel pathway by a *vehicle* from the point of origin to a destination.

NOTE: Performance of the *DDT* during a given *trip* may be accomplished in whole or in part by a *driver*, *driving automation system*, or both.

3.30 USAGE SPECIFICATION

A particular level of *driving automation* within a particular *ODD*.

NOTE: Each *feature* satisfies a *usage specification*.

EXAMPLE 1: A Level 2 *feature* provides lateral and longitudinal *vehicle* motion control support to the *driver* on fully access-controlled freeways.

EXAMPLE 2: A Level 3 *feature operates* the *vehicle* in high-volume traffic on designated fully access-controlled freeways.

EXAMPLE 3: A Level 4 *ADS-DV operates* at low speeds in designated urban centers.

3.31 [HUMAN] USER

A general term referencing the human role in *driving automation*.

NOTE 1: The following five terms (1 - *driver*, 2 - *passenger*, 3 - *DDT fallback-ready user*, 4 - *driverless operation dispatcher*, and 5 - *remote assistant*) describe categories of (human) *users*.

NOTE 2: These human categories define roles that do not overlap and may be performed in varying sequences during a given *trip*.

3.31.1 [HUMAN] DRIVER

A *user* who performs in real time part or all of the *DDT* and/or *DDT fallback* for a particular *vehicle*.

NOTE: This definition of "*driver*" does not include a robotic test device designed to exercise steering, braking, and acceleration during certain dynamic test maneuvers.

3.31.1.1 IN-VEHICLE DRIVER

A *driver* who manually exercises in-vehicle braking, accelerating, steering, and transmission gear selection input devices in order to *operate* a *vehicle*.

NOTE 1: An *in-vehicle driver* is seated in what is normally referred to as "the *driver*'s seat" in automotive contexts, which is a unique seating position that makes in-vehicle input devices (steering wheel, brake and accelerator pedals, gear shift) accessible to a (human) *driver*.

NOTE 2: "Conventional *driver*" is an acceptable synonym for *in-vehicle driver*.

NOTE 3: In a conventional or *dual-mode vehicle* equipped with a *driving automation system*, an *in-vehicle driver*, who may be a *passenger* or a *fallback-ready user* during *ADS* engagement, may assume or resume performance of part or all of the *DDT* from the *driving automation system* during a given *trip*.

3.31.1.2 REMOTE DRIVER

A *driver* who is not seated in a position to manually exercise in-vehicle braking, accelerating, steering, and transmission gear selection input devices (if any), but is able to *operate* the *vehicle*.

NOTE 1: A *remote driver* may include a *user* who is within the *vehicle*, within line-of-sight of the *vehicle*, or beyond line-of-sight of the *vehicle*.

NOTE 2: A *remote driver* is not the same as a *driverless operation dispatcher* (see 3.32.4), although a *driverless operation dispatcher* may become a *remote driver* if s/he has the means to *operate* the *vehicle* remotely.

NOTE 3: A *remote driver* does not include a person who merely creates driving-relevant conditions that are sensed by, or communicated to, the *ADS* (e.g., a police officer who announces over a loudspeaker that a particular stop sign should be ignored; another *driver* who flashes his/her head lamps to encourage overtaking, or a pedestrian using a dedicated short range communication (DSRC) system to announce his/her presence).

EXAMPLE 1: A Level 2 automated parking *feature* allows the *remote driver* to exit the *vehicle* near an intended parking space and to cause the *vehicle* to move into the parking space automatically by pressing and holding a special button on the key fob, while s/he is monitoring the driving environment to ensure that no one and nothing enters the *vehicle* pathway during the parking maneuver. If, during the maneuver, a dog enters the pathway of the *vehicle*, the *remote driver* releases the button on the key fob in order to cause the *vehicle* to stop automatically. (Note that the *remote driver* in this Level 2 example completes the *OEDR* subtask of the *DDT* during the parking maneuver.)

EXAMPLE 2: Identical situation to Example 1, except that the *remote driver* is sitting in the back seat, rather than standing outside the *vehicle*.

EXAMPLE 3: A Level 4 closed campus delivery *vehicle* that has experienced a *DDT* performance-relevant *system failure*, which forced it to resort to a *minimal risk condition* by parking on the side of a campus roadway, is returned to its designated marshalling yard by a *remote driver* who is able to *operate* the *vehicle* using wireless means.

3.31.2 PASSENGER

A *user* in a *vehicle* who has no role in the *operation* of that *vehicle*.

EXAMPLE 1: The person seated in the *driver*'s seat of a *vehicle* equipped with a Level 4 *ADS feature* designed to automate high-speed *vehicle operation* on access-controlled freeways is a *passenger* while this Level 4 *feature* is engaged. This same person, however, is a *driver* before engaging this Level 4 *ADS feature* and again after disengaging the *feature* in order to exit the controlled access freeway.

EXAMPLE 2: The in-*vehicle users* of an *ADS-DV* shuttle on a university campus are *passengers*.

EXAMPLE 3: The in-*vehicle users* of a Level 5 *ADS*-equipped *dual-mode vehicle* are *passengers* whenever the Level 5 *ADS* is engaged.

3.31.3 [DDT] FALLBACK-READY USER

The *user* of a *vehicle* equipped with an engaged Level 3 *ADS feature* who is properly qualified and able to *operate* the *vehicle* and is receptive to *ADS*-issued requests to intervene and to evident *DDT* performance-relevant *system failures* in the *vehicle* compelling him or her to perform the *DDT fallback*.

NOTE 1: *DDT* performance by a Level 3 *ADS* assumes that a *fallback-ready user* is available to perform the *DDT* as required. There is no such assumption at Levels 4 and 5.

NOTE 2: A *DDT fallback-ready user* who transitions to performing part or all of the *DDT* becomes a *driver* (in-*vehicle* or remote).

3.31.3.1 IN-VEHICLE FALLBACK-READY USER

A *fallback-ready user* of a *conventional vehicle* with an engaged Level 3 *ADS feature* who is seated in the *driver*'s seat.

EXAMPLE: A Level 3 *ADS sub-trip feature* designed to perform the *DDT* in congested traffic on certain freeways encounters emergency responders who are rerouting traffic to the exit due to a serious crash; the *ADS* issues a *request to intervene*. The *in-vehicle fallback-ready user* becomes a *driver* and performs the *fallback* by manually *operating* the *vehicle*.

3.31.3.2 REMOTE FALLBACK-READY USER

A *fallback-ready user* of a Level 3 *ADS*-equipped *vehicle* in *driverless operation* who is not in the *driver*'s seat.

EXAMPLE: A Level 3 *ADS-DV* encounters a crash scene for which emergency personnel are re-routing traffic; the *ADS* issues a *request to intervene*. The *remote fallback-ready user* becomes a *remote driver* and performs the *fallback* by remotely *operating* the *vehicle*.

3.31.4 DRIVERLESS OPERATION DISPATCHER

A *user*(s) who *dispatch*es an *ADS*-equipped *vehicle*(s) in *driverless operation*.

NOTE: A dispacher(s) may also perform other fleet operations functions.

3.31.5 REMOTE ASSISTANT

A human(s) who provides remote assistance to an ADS-equipped vehicle in driverless operation.

NOTE: A remote assistant(s) may also perform other fleet operations functions.

3.32 [MOTOR] VEHICLE

A machine designed to provide conveyance on public streets, roads, and highways.

NOTE 1: As used in this document, [motor] *vehicle* refers to motorized *vehicles* and excludes those *operated* only on rail lines. For reference, 49 U.S.C. § 30102(a)(6) defines [motor] vehicle as follows: "[motor] *vehicle* means a *vehicle* driven or drawn by mechanical power and manufactured primarily for use on public streets, roads, and highways, but does not include a *vehicle operated* only on a rail line."

NOTE 2: Types of [motor] *vehicles* discussed in this Recommended Practice include *ADS*-equipped *vehicles*, *ADS-dedicated vehicles*, *dual-mode vehicles*, and *conventional vehicles*. *ADS-dedicated vehicles* and dual-mode *vehicles* are always *ADS-equipped vehicles*. *Conventional vehicles* may or may not be *ADS-equipped vehicles*.

3.32.1 CONVENTIONAL VEHICLE

A *vehicle* designed to be *operated* by an *in-vehicle driver* during part or all of every *trip*.

NOTE 1: A *conventional vehicle* may be equipped with one or more Level 1 or 2 *driving automation system features* that support the *driver* in performing the *DDT*, but do not perform the complete *DDT*. A *conventional vehicle* may also be equipped with a Level 3 and/or Level 4 *ADS sub-trip feature*(s) that requires an *in-vehicle driver* to *operate* the *vehicle* during portions of each *trip* (see 3.7.2).

NOTE 2: While it may be counterintuitive to call a *vehicle* equipped with an *ADS* "conventional," it is appropriate in this context because an *in-vehicle driver* is required for at least part of every *trip*. As emphasized below, this taxonomy classifies the *driving automation* level of *features* rather than of *vehicles* (although, in the special case of an *ADS-DV*, the classification of the *ADS feature* and the *vehicle* are effectively the same).

EXAMPLE 1: A *vehicle* with no *driving automation system features* that is designed to be *operated* by an *in-vehicle driver* throughout all *trip*s.

EXAMPLE 2: A *vehicle* equipped with Level 1 adaptive cruise control, Level 1 lane centering, and a Level 3 *ADS feature* designed to perform the complete *DDT* during traffic jams on fully access-controlled freeways. The Level 3 *ADS* traffic jam *feature* requires the *user* to *operate* the *vehicle* on the way to the freeway before engaging the *feature*, as well as again *operating* the *vehicle* upon exiting the freeway in order to complete the *trip*.

EXAMPLE 3: A *vehicle* equipped with a Level 4 valet parking *feature* designed to allow the *user* to exit the *vehicle* near a parking lot and then *dispatch* it to a parking space.

3.32.2 [ADS-EQUIPPED] DUAL-MODE VEHICLE

An *ADS*-equipped *vehicle* designed to enable either *driverless operation* under routine/normal *operating* conditions within its given *ODD* (if any), or *operation* by an *in-vehicle driver*, for complete *trip*s.

NOTE 1: When *operated* by the *ADS*, *dual-mode vehicles* enable *driverless operation*, although a human *driver* could also be present in the *driver*'s seat.

NOTE 2: An *ADS sub-trip feature* that is usable during only part of a *trip*, such as a *feature* designed to perform the complete *DDT* during traffic jams on freeways, would not be sufficient to classify its host *vehicle* as a *dual-mode vehicle* because it would not be capable of *driverless operation* for a complete *trip*.

NOTE 3: A *vehicle* equipped with a Level 5 *feature* in which at any time the *driver* can choose to engage the *feature*, or can choose to *operate* the *vehicle* manually, would be classified as a *dual-mode vehicle*.

3.32.3 ADS-DEDICATED VEHICLE (ADS-DV)

An *ADS*-equipped *vehicle* designed for *driverless operation* under routine/normal *operating* conditions during all *trip*s within its given *ODD* (if any).

NOTE 1: In contrast to previous versions of this document, which specified that an *ADS-DV* was limited to Levels 4 and 5, this revised definition of an *ADS-DV* also allows for the possibility of a Level 3 *ADS-DV* if the *remote fallback-ready user* can be receptive to both *ADS*-issued requests to intervene and to evident *DDT* performance-relevant *system failures* in the *vehicle*. Once either of these conditions occurs, the *remote fallback-ready user* begins to perform the *DDT fallback* in (virtually) real time using wireless means. (See also 3.24 and 3.22.)

NOTE 2: An *ADS-DV* might be designed without *user* interfaces designed to be operable by an in-*vehicle driver*, such as braking, accelerating, steering, and transmission gear selection input devices, or it might be designed so that these devices are inoperative under routine/normal *operating* conditions.

NOTE 3: *ADS-DVs* might be *operated* temporarily by a human *driver*: (1) to manage transient deviations from the *ODD*, (2) to address a *system failure*, or (3) while in a marshalling yard before or after being repaired/serviced or *dispatched*.

EXAMPLE 1: A Level 4 *ADS-DV* designed to *operate* exclusively within a corporate campus where it picks up and discharges *passengers* along a specific route specified by the *ADS-DV dispatch*er.

EXAMPLE 2: A Level 4 *ADS-DV* designed to *operate* exclusively within a geographically prescribed central business district where it delivers supplies using roads (but not necessarily routes) specified by the *ADS-DV dispatch*er.

EXAMPLE 3: A Level 5 *ADS-DV* capable of *operating* on all mapped roads in the US that are navigable by a human *driver*. The *user* simply inputs a destination, and the *ADS-DV* automatically navigates to that destination.

4. TAXONOMY OF DRIVING AUTOMATION

The terms defined above inform a taxonomy of *driving automation* consisting of six discrete and mutually exclusive levels (see 8.3 and 8.4). Central to this taxonomy are the respective roles of the (human) *user* and the *driving automation system* in relation to each other. Because changes in the functionality of a *driving automation system* change the role of the (human) *user*, they provide a basis for categorizing such system *features*. For example:

- If the *driving automation system* performs the *sustained* longitudinal and/or lateral *vehicle* motion control subtasks of the *DDT*, the *driver* does not do so, although s/he is expected to complete the *DDT*. This division of roles corresponds to Levels 1 and 2.

- If the *driving automation system* performs the entire *DDT*, the *user* does not do so. However, if a *DDT fallback-ready user* is expected to take over the *DDT* when a *DDT* performance-relevant *system failure* occurs or when the *driving automation system* is about to leave its *operational design domain* (*ODD*), then that *user* is expected to be receptive and able to resume *DDT* performance when alerted to the need to do so. This division of roles corresponds to Level 3.

- Lastly, if a *driving automation system* can perform the entire *DDT* and *DDT fallback* either within a prescribed *ODD* (Level 4) or in all *driver*-manageable on-road *operating* situations (Level 5) then any *users* present in the *vehicle* while the *ADS* is engaged are *passengers*.

Although the *vehicle* fulfills a role in this *driving automation* taxonomy (see scope), it does not change the role of the *user* in performing the *DDT*. By contrast the role played by the *driving automation system* complements the role of the *user* in performing the *DDT*, and in that sense changes it.

In this way, *driving automation system*s are categorized into levels based on:

a. Whether the *driving automation system* performs either the longitudinal or the lateral *vehicle* motion control subtask of the *DDT*.

b. Whether the *driving automation system* performs both the longitudinal and the lateral *vehicle* motion control subtasks of the *DDT* simultaneously.

c. Whether the *driving automation system* also performs the *OEDR* subtask of the *DDT*.

d. Whether the *driving automation system* also performs *DDT fallback*.

e. Whether the *driving automation system* is limited by an *ODD*.

Table 1 summarizes the six levels of *driving automation* in terms of these five elements.

SAE's levels of *driving automation* are descriptive and informative, rather than normative, and technical rather than legal. Elements indicate minimum rather than maximum capabilities for each level. In this table, "system" refers to the *driving automation system* or *ADS*, as appropriate.

Table 1 - Summary of levels of driving automation

				DDT (1)			
	Level	**Name**	**Narrative Definition**	**Sustained Lateral and Longitudinal *Vehicle* Motion Control**	***OEDR***	***DDT Fallback***	***ODD***
Driver Performs Part or All of the *DDT*							
	0	No Driving Automation	The performance by the *driver* of the entire *DDT*, even when enhanced by *active safety systems*.	*Driver*	*Driver*	*Driver*	n/a
Driver Support	**1**	*Driver* Assistance	The *sustained* and *ODD*-specific execution by a *driving automation system* of either the lateral or the longitudinal *vehicle* motion control subtask of the *DDT* (but not both simultaneously) with the expectation that the *driver* performs the remainder of the *DDT*.	*Driver* and System	*Driver*	*Driver*	Limited
	2	Partial Driving Automation	The *sustained* and *ODD*-specific execution by a *driving automation system* of both the lateral and longitudinal *vehicle* motion control subtasks of the *DDT* with the expectation that the *driver* completes the *OEDR* subtask and supervises the *driving automation system*.	System	*Driver*	*Driver*	Limited

Table 1 - Summary of levels of driving automation (continued)

	Level	Name	Narrative Definition	*DDT* [1] Sustained Lateral and Longitudinal *Vehicle* Motion Control	*DDT* [1] *OEDR*	*DDT Fallback*	*ODD*
ADS **("System") Performs the Entire** ***DDT*** **(While Engaged)**							
Automated Driving	**3**	Conditional Driving Automation	The *sustained* and *ODD*-specific performance by an *ADS* of the entire *DDT* with the expectation that the *DDT fallback-ready user* is receptive to *ADS*-issued requests to intervene, as well as to *DDT* performance-relevant *system failures* in other *vehicle* systems, and will respond appropriately.	System	System	*Fallback-ready user* (becomes the *driver* during *fallback*)	Limited
Automated Driving	**4**	High Driving Automation	The *sustained* and *ODD*-specific performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will need to intervene.	System	System	System	Limited
Automated Driving	**5**	Full Driving Automation	The *sustained* and unconditional (i.e., not *ODD*-specific) performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will need to intervene.	System	System	System	Unlimited

[1] The *DDT* does not include strategic aspects of the driving task, such as determining destination(s) and deciding when to travel.

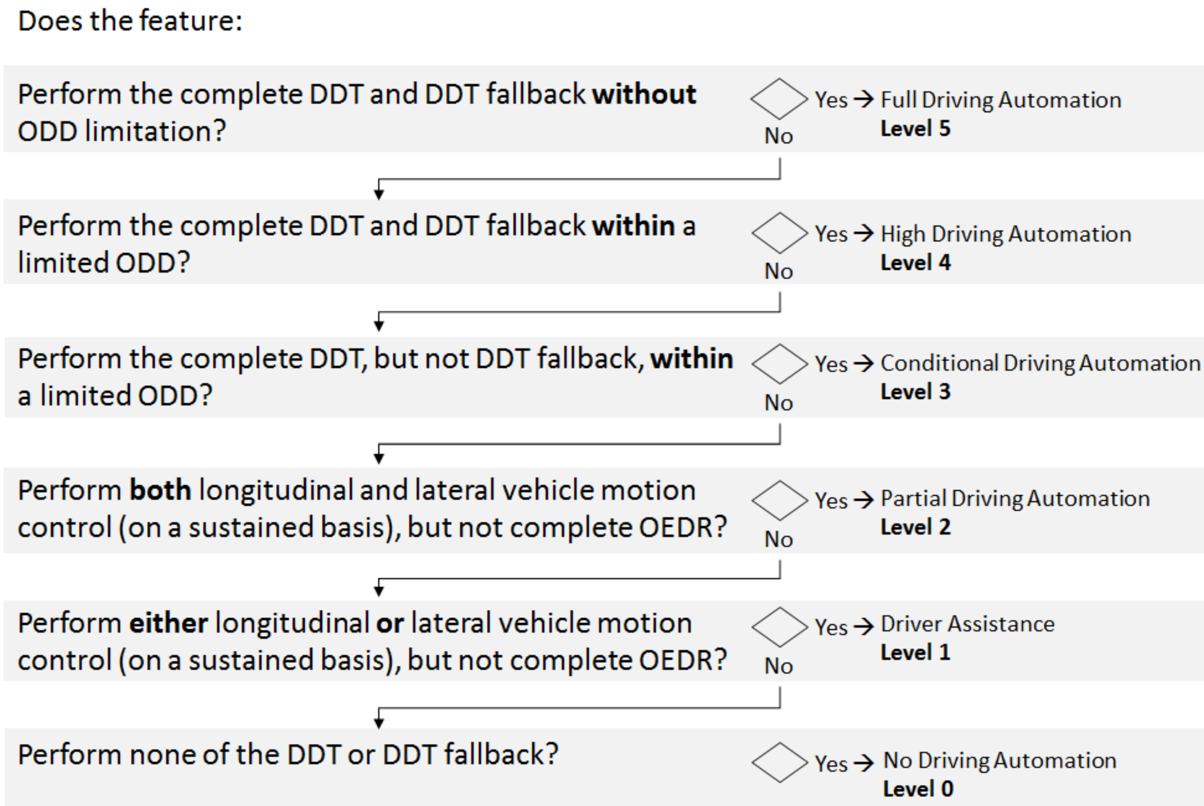


Figure 10 - Simplified logic flow diagram for assigning driving automation level to a feature

Figure 10 shows a simplified logic diagram for classifying *driving automation features*. Note that the information required to answer the questions posed in this figure cannot be empirically derived (see 8.2).

Table 2 details the six levels of *driving automation* with reference to the roles (if any) that the *user* and the *driving automation system* play in performing the *DDT* and the *DDT fallback*. (NOTE: This assignment of roles refers to technical aspects of *vehicle operation* rather than to legal aspects.)

The descriptions provided in column 2 of Table 2 indicate the role (if any) of the *user* in performing part or all of the *DDT* and/or performing the *DDT fallback*, while the descriptions provided in column 3 indicate the role (if any) of the *driving automation system* in performing the same. As in Table 1, “system” refers to the *driving automation system* or *ADS*, as appropriate.

Note that the foregoing roles are determined by the design of the *driving automation system* in combination with the instructions provided to the *user*, regardless of malfunction in a particular *driving automation system* or a *user*’s mis-performance of his or her role in a given circumstance (see 8.2).

Table 2 - Roles of human user and driving automation system by level of driving automation

Level of Driving Automation	Role of User	Role of Driving Automation System
LEVELS 0 TO 2: DRIVER PERFORMS PART OR ALL OF THE *DDT*		
Level 0 - No Driving Automation	• *Driver* (at all times): • Performs the entire *DDT*	• *Driving automation* system (if any): • Does not perform any part of the *DDT* on a *sustained* basis (although other *vehicle* systems may provide warnings or momentary emergency intervention)
Level 1 - *Driver* Assistance	*Driver* (at all times): • Performs the remainder of the *DDT* not performed by the *driving automation system* • Supervises the *driving automation system* and intervenes as necessary to maintain *operation* of the *vehicle* • Determines whether/when engagement or disengagement of the *driving automation system* is appropriate • Immediately performs the entire *DDT* whenever required or desired	*Driving automation* system (while engaged): • Performs part of the *DDT* by executing either the longitudinal **or** the lateral *vehicle* motion control subtask • Disengages immediately upon *driver* request
Level 2 - Partial Driving Automation	*Driver* (at all times): • Performs the remainder of the *DDT* not performed by the *driving automation system* • Supervises the *driving automation system* and intervenes as necessary to maintain *operation* of the *vehicle* • Determines whether/when engagement and disengagement of the *driving automation system* is appropriate • Immediately performs the entire *DDT* whenever required or desired	*Driving automation* system (while engaged): • Performs part of the *DDT* by executing both the lateral **and** the longitudinal *vehicle* motion control subtasks • Disengages immediately upon *driver* request
LEVELS 3 TO 5: *ADS* PERFORMS THE ENTIRE *DDT* WHILE ENGAGED		
Level 3 - Conditional Driving Automation	*Driver* (while the *ADS* is not engaged): • Verifies *operational* readiness of the *ADS*-equipped *vehicle* • Determines whether to engage the *ADS* • Becomes the *DDT fallback-ready user* when the *ADS* is engaged *DDT fallback-ready user* (while the *ADS* is engaged): • Is receptive to a *request to intervene* and responds by performing *DDT fallback* in a timely manner • Is receptive to *DDT* performance-relevant *system failures* in *vehicle* systems and, upon occurrence, performs the *DDT fallback* in a timely manner • Determines whether and how to achieve a *minimal risk condition* • Becomes the *driver* upon disengagement of the *ADS*	*ADS* (while not engaged): • Permits engagement/*operation* only within its *ODD* *ADS* (while engaged): • Performs the entire *DDT* within its *ODD* • Determines whether *ODD* limits are about to be exceeded and, if so, issues a timely *request to intervene* to the *DDT fallback-ready user* • Determines whether there is a *DDT* performance-relevant *system failure* of the *ADS* and, if so, issues a timely *request to intervene* to the *DDT fallback-ready user* • Disengages an appropriate time after issuing a *request to intervene* • Disengages immediately upon *user* request

Level of Driving Automation	Role of User	Role of Driving Automation System
Level 4 - High Driving Automation	*Driver*/*dispatch*er (while the *ADS* is not engaged): • Verifies *operational* readiness of the *ADS*-equipped *vehicle* • Determines whether to engage the *ADS* • Becomes a *passenger* when the *ADS* is engaged only if physically present in the *vehicle* *Passenger*/*dispatch*er (while the *ADS* is engaged): • Need not perform the *DDT* or *DDT fallback* • Need not determine whether and how to achieve a *minimal risk condition* • May perform the *DDT* after the *ADS* reaches its *ODD* limit (see 5.5 NOTE 2) • May request that the *ADS* disengage • May become the *driver* after a requested disengagement	*ADS* (while not engaged): • Permits engagement/*operation* only within its *ODD* *ADS* (while engaged): • Performs the entire *DDT* within its *ODD* • May prompt the *passenger* to resume *operation* of the *vehicle* when approaching an *ODD* limit. • Performs *DDT fallback* and transitions automatically to a *minimal risk condition* when: ○ A *DDT* performance-relevant *system failure* occurs ○ A *user* requests that it achieve a *minimal risk condition* ○ The *vehicle* is about to exit its *ODD* • Disengages, if appropriate, only after: ○ It achieves a *minimal risk condition* or ○ A *driver* is performing the *DDT* • May delay *user*-requested disengagement
Level 5 - Full Driving Automation	*Driver*/*dispatch*er (while the *ADS* is not engaged): • Verifies *operational* readiness of the *ADS*-equipped *vehicle* (1) • Determines whether to engage the *ADS* • Becomes a *passenger* when the *ADS* is engaged only if physically present in the *vehicle* *Passenger*/*dispatch*er (while the *ADS* is engaged): • Need not perform the *DDT* or *DDT fallback* • Need not determine whether and how to achieve a *minimal risk condition* • May request that the *ADS* disengage and may achieve a *minimal risk condition* after it is disengaged • May become the *driver* after a requested disengagement	*ADS* (while not engaged): • Permits engagement of the *ADS* under all *driver*-manageable on-road conditions *ADS* (while engaged): • Performs the entire *DDT* • Performs *DDT fallback* and transitions automatically to a *minimal risk condition* when: ○ A *DDT* performance-relevant *system failure* occurs or ○ A *user* requests that it achieve a *minimal risk condition* • Disengages, if appropriate, only after: ○ It achieves a *minimal risk condition* or ○ A *driver* is performing the *DDT* • May delay a *user*-requested disengagement

(1) This function might be performed by a person or entity other than a *driver* or *dispatch*er, depending on the *usage specification* or deployment concept (see 3.6, NOTE 1).

Table 3 describes a *user*'s role with respect to an engaged *driving automation system operating* at a particular level of *driving automation* at a particular point in time. A *user* occupying a given *vehicle* can have one of three possible roles during a particular *trip*: (1) *driver*, (2) *in-vehicle fallback-ready user*, or (3) *passenger*. A remote *user* of a given *vehicle* (i.e., who is not seated in the *driver*'s seat of the *vehicle* during use) can also have one of three possible roles during a particular *trip*: (1) *remote driver*, (2) *remote fallback-ready user*, or (3) *driverless operation dispatcher*.

Table 3 - User roles while a driving automation system is engaged

	No Driving Automation	Engaged Level of Driving Automation				
	0	**1**	**2**	**3**	**4**	**5**
In-*Vehicle User*	*Driver*			In-*vehicle fallback-ready user*	*Passenger*	
Remote *User*	*Remote driver*			Remote *fallback-ready user*	*Driverless operation dispatcher/remote assistant*	

NOTE: A *vehicle* equipped with a Level 4 or 5 *ADS* may also support a *driver* role. For example, in order to complete a given *trip*, a *user* of a *vehicle* equipped with a Level 4 *ADS feature* designed to *operate* the *vehicle* during high-speed freeway conditions will generally choose to perform the *DDT* when the freeway ends; otherwise the *ADS* will automatically perform *DDT fallback* and achieve a *minimal risk condition* as needed. However, unlike at Level 3, this *user* is not a *DDT fallback-ready user* while the *ADS* is engaged.

5. LEVELS OR CATEGORIES OF DRIVING AUTOMATION

As discussed above, the level of *driving automation* is based on the functionality of the *driving automation system feature*, as determined by an allocation of roles in *DDT* and *DDT fallback* performance between that *feature* and the (human) *user* (if any). The manufacturer of a *driving automation system feature* determines that *feature's* requirements, *operational design domain* (*ODD*), and *operating* characteristics, including the level of *driving automation*, as defined below. The manufacturer also defines the proper use of that *feature*.

The lower two levels of *driving automation* (1 and 2) refer to cases in which the (human) *driver* continues to perform part of the *DDT* while the *driving automation system* is engaged. These are therefore referred to as "*driver* support" *features*. (See Table 2.)

The upper three levels of *driving automation* (3 to 5) refer to cases in which the *automated driving system* (*ADS*) performs the entire *DDT* on a *sustained* basis while it is engaged. These are therefore referred to as "automated driving" *features* (or the *vehicles* equipped with them). (See Table 2.)

5.1 Level or Category 0 - No Driving Automation

The performance by the *driver* of the entire *DDT*, even when enhanced by *active safety systems*.

5.2 Level or Category 1 - Driver Assistance

The *sustained* and *ODD*-specific execution by a *driving automation system* of either the lateral or the longitudinal *vehicle* motion control subtask of the *DDT* (but not both simultaneously) with the expectation that the *driver* performs the remainder of the *DDT*.

NOTE 1: A Level 1 *driver support feature* performing either the lateral or the longitudinal *vehicle* motion control subtask of the *DDT* is capable of only limited *OEDR* within its dimension (lateral or longitudinal), meaning that there are some events that the *driving automation system* is not capable of recognizing or responding to. Therefore, the *driver* must supervise the *driving automation system* performance by completing the *OEDR* subtask of the *DDT* as well as performing the other dimension of *vehicle* motion control. See Figure 2 (discussing the three primary subtasks of the *DDT*).

NOTE 2: The term "driver assistance" as a modifier is also commonly used to describe automotive *features* that are not considered to be *driving automation system features*, because they do not provide *sustained* performance of part or all of the *DDT*.

NOTE 3: The term "Advanced Driver Assistance Systems" (ADAS) is commonly used to describe a broad range of *features*, including those that provide warnings and/or momentary intervention, such as forward collision warning (FCW) systems, lane keeping assistance (LKA) systems, and automatic emergency braking (AEB) systems, as well as some convenience *features* that involve Level 1 *driver support features*, such as ACC and certain parking assistance *features*. As such, the term ADAS is too broad and imprecise for use in a technical definitions document.

5.3 Level or Category 2 - Partial Driving Automation

The *sustained* and *ODD*-specific execution by a *driving automation system* of both the lateral and longitudinal *vehicle* motion control subtasks of the *DDT* with the expectation that the *driver* completes the *OEDR* subtask and supervises the *driving automation system*.

NOTE: A Level 2 *driver support feature* is capable of only limited *OEDR*, meaning that there are some events that it is not capable of recognizing or responding to. Therefore, the *driver* supervises the *feature's* performance by completing the *OEDR* subtask of the *DDT*. See Figure 2 (discussing the three primary subtasks of the *DDT*).

5.4 Level or Category 3 - Conditional Driving Automation

The *sustained* and *ODD*-specific performance by an *ADS* of the entire *DDT* under routine/normal operation (see 3.27) with the expectation that the *DDT fallback-ready user* is receptive to *ADS*-issued requests to intervene, as well as to *DDT* performance-relevant *system failures* in other *vehicle* systems, and will respond appropriately.

NOTE 1: Unlike Level 1 and 2 *driver support features*, all Level 3 and 4 *ADS features* are designed to monitor and enforce their *ODD* limitations while engaged, and to prevent engagement or *operation* outside of their prescribed *ODD*.

NOTE 2: The *DDT fallback-ready user* need not supervise a Level 3 *ADS* while it is engaged but is expected to be prepared to either resume *DDT* performance when the *ADS* issues a *request to intervene* or to perform the *fallback* and achieve a *minimal risk condition* if the failure condition precludes continued *vehicle operation*.

NOTE 3: A Level 3 *ADS*'s *DDT fallback-ready user* is also expected to be receptive to evident *DDT* performance-relevant *system failures* in *vehicle* systems that do not necessarily trigger an *ADS*-issued *request to intervene*, such as a broken body or suspension component.

NOTE 4: In the event of a *DDT* performance-relevant *system failure* in a Level 3 *ADS*, or in the event that the *ADS* exits its *ODD*, the *ADS* will issue a *request to intervene* within sufficient time for the *fallback-ready user* (whether in-*vehicle* or remote) to respond appropriately.

NOTE 5: An "appropriate" response by a *DDT fallback-ready user* to a *request to intervene* may entail either bringing the *vehicle* to a *minimal risk condition* or continuing to *operate* the *vehicle* after the *ADS* has disengaged.

NOTE 6: Although automated *DDT fallback* performance is not expected of Level 3 *ADS features*, a Level 3 *feature* may be capable of performing the *DDT fallback* and achieving a *minimal risk condition* under certain, limited conditions.

EXAMPLE: An *ADS feature* capable of performing the entire *DDT* in low-speed, stop-and-go freeway traffic.

5.5 Level or Category 4 - High Driving Automation

The *sustained* and *ODD*-specific performance by an *ADS* of the entire *DDT* and *DDT fallback*'.

NOTE 1: The *user* does not need to supervise a Level 4 *ADS feature* or be receptive to a *request to intervene* while the *ADS* is engaged. A Level 4 *ADS* is capable of automatically performing *DDT fallback*, as well as achieving a *minimal risk condition* if a *user* does not resume performance of the *DDT*. This automated *DDT fallback* and *minimal risk condition* achievement capability is the primary difference between Level 4 and Level 3 *ADS features*. This means that an in-*vehicle user* of an engaged Level 4 *ADS feature* is a *passenger* who need not respond to *DDT* performance-relevant *system failures*.

NOTE 2: Level 4 *ADS features* may be designed to *operate* the *vehicle* throughout complete *trip*s (see 3.7.3), or they may be designed to *operate* the *vehicle* during only part of a given *trip* (see 3.7.2), For example, in order to complete a given *trip*, a *user* of a *vehicle* equipped with a Level 4 *ADS feature* designed to *operate* the *vehicle* during high-speed freeway conditions will need to perform the *DDT* when the freeway ends in order to complete his or her intended *trip*; the *ADS*, however, will automatically perform the *DDT fallback* and achieve a *minimal risk condition* if the *user* fails to take over when the freeway ends (e.g., because s/he is sleeping). Unlike at Level 3, the Level 4 *feature user* is not a *DDT fallback-ready user* while the *ADS* is engaged (see Example 2 below), and thus is not expected to respond to a *request to intervene* in order to perform the fallback. Nevertheless, in the case that a Level 4 *sub-trip feature* reaches its *ODD* limit, the *ADS* may issue an alert to the *passenger* that s/he should resume driving in order to complete their *trip*. (Note that in this latter case, the alert in question is not a *request to intervene*, because it does not signal the need for *fallback* performance.)

EXAMPLE 1: A Level 4 *ADS feature* capable of performing the entire *DDT* during valet parking (i.e., curb-to-door or vice versa) without any *driver* supervision.

EXAMPLE 2: A Level 4 *ADS feature* capable of performing the entire *DDT* during *sustained operation* on a motorway or freeway (i.e., within its *ODD*). (Note: The presence of a *user* in the *driver*'s seat who is capable of performing the *DDT* is envisioned in this example, as *driver* performance of the *DDT* would have been necessary before entering, and would again be necessary after leaving, the motorway or freeway. Thus, such a *feature* would alert the *user* that s/he should resume *vehicle operation* shortly before exiting the *ODD*, but if the *user* fails to respond to such an alert, the *ADS* will nevertheless perform the *DDT fallback* and achieve a *minimal risk condition* automatically.)

EXAMPLE 3: A *driverless operation dispatcher* may engage a Level 4 *ADS-DV* capable of following a pre-defined route within a confined geographical area (e.g., residential community, military base, university campus).

5.6 Level or Category 5 - Full Driving Automation

The *sustained* and unconditional (i.e., not *ODD*-specific) performance by an *ADS* of the entire *DDT* and *DDT fallback*.

NOTE 1: “Unconditional/not *ODD*-specific” means that the *ADS* can *operate* the *vehicle* on-road anywhere within its region of the world and under all road conditions in which a *conventional vehicle* can be reasonably *operated* by a typically skilled human *driver*. This means, for example, that there are no design-based weather, time-of-day, or geographical restrictions on where and when the *ADS* can *operate* the *vehicle*. However, there may be conditions not manageable by a *driver* in which the *ADS* would also be unable to complete a given *trip* (e.g., white-out snow storm, flooded roads, glare ice, etc.) until or unless the adverse conditions clear. At the onset of such unmanageable conditions the *ADS* would perform the *DDT fallback* to achieve a *minimal risk condition* (e.g., by pulling over to the side of the road and waiting for the conditions to change).

NOTE 2: In the event of a *DDT* performance-relevant *system failure* (of an *ADS* or the *vehicle*), a Level 5 *ADS* automatically performs the *DDT fallback* and achieves a *minimal risk condition*.

NOTE 3: The *user* does not need to supervise a Level 5 *ADS*.

EXAMPLE: A *vehicle* with an *ADS* that, once programmed with a destination, is capable of *operating* the *vehicle* throughout complete *trip*s on public roadways, regardless of the starting and end points or intervening road, traffic, and weather conditions.

6. SIGNIFICANCE OF OPERATIONAL DESIGN DOMAIN (ODD)

Conceptually, the role of a *driving automation system* vis-à-vis a *user* in performance of part or all of the *DDT* is orthogonal to the specific conditions under which it performs that role. For example, a specific implementation of adaptive cruise control may be intended to *operate* only at high speeds, only at low speeds, or at all speeds. For simplicity, however, this taxonomy collapses these two axes into a single set of levels of *driving automation*. Levels 1 through 4 expressly contemplate *ODD* limitations. In contrast, Level 5 (like Level 0) does not have *ODD* limitations (subject to the discussion in 8.8).

Accordingly, accurately describing a *feature* (other than at Levels 0 and 5) requires identifying both its level of *driving automation* and its *operational design domain* (*ODD*). As provided in the definitions above, this combination of level of *driving automation* and *ODD* is called a *usage specification*, and a given *feature* satisfies a given *usage specification*.

Because of the wide range of possible *ODD*s, a wide range of possible *features* may exist at each level (e.g., Level 4 includes parking, high-speed, low-speed, geo-fenced, etc.). For this reason, this taxonomy provides less detail about the *ODD* attributes that may define a given *feature* than about the respective roles of a *driving automation system* and its *user*.

ODD is especially important to understanding why a given *ADS* is not Level 5 merely because it *operates* an *ADS-dedicated vehicle*. Unlike a Level 5 *ADS*, a Level 3 or 4 *ADS* has a limited *ODD*. Geographic, speed, environmental or other *ODD* restrictions on an *ADS-DV* may reflect technological limitations of its *ADS*, or they may reflect *vehicle* design limitations.[1]

Level 1 to Level 4 *features* are subject to limited *ODD*s. These limitations generally reflect the technological capability of the *driving automation system*. For example, Level 4 *ADS-DVs* that *operate* in enclosed courses have existed for many decades as people movers and airport shuttles. The *ODD* for such *vehicles* is very simple, well-controlled, and physically enclosed (*vehicle operates* on a fixed course; physical barriers prevent encroachment; protected from external events, weather, etc.). This highly structured and simple *ODD* makes it technologically less challenging to achieve Level 4 *driving automation*. However, a Level 3 *ADS feature* that *operates* a *vehicle* on open roads in mixed traffic, and does so in environments that include inclement weather, faces a significantly higher technological bar in terms of *ADS* capability by virtue of the more complex and unstructured *ODD* (see Figure 11).

Note also that the *ODD* for a given *driving automation system feature* potentially encompasses a broad set of parameters that define the limits of that *feature's* functional capability to *operate* in design-specified on-road environments. It includes variables as widely ranging as specific road types, weather conditions, lighting conditions, geographical restrictions, and the presence or absence of certain road *features*, such as lane markings, road side traffic barriers, median *strips*, etc. As such, a given *driving automation system feature* has only one *ODD*, but that *ODD* may be quite varied and multi-faceted. Even though the *ODD* is composed of multiple variables, it would be incorrect to say that a *driving automation feature* has multiple *ODD*s. A *feature* will *operate* as designed (see 3.26) only when all the *ODD*-defining variables satisfy design criteria. Figure 12 illustrates the orthogonality of *ODD* relative to levels of *driving automation*.

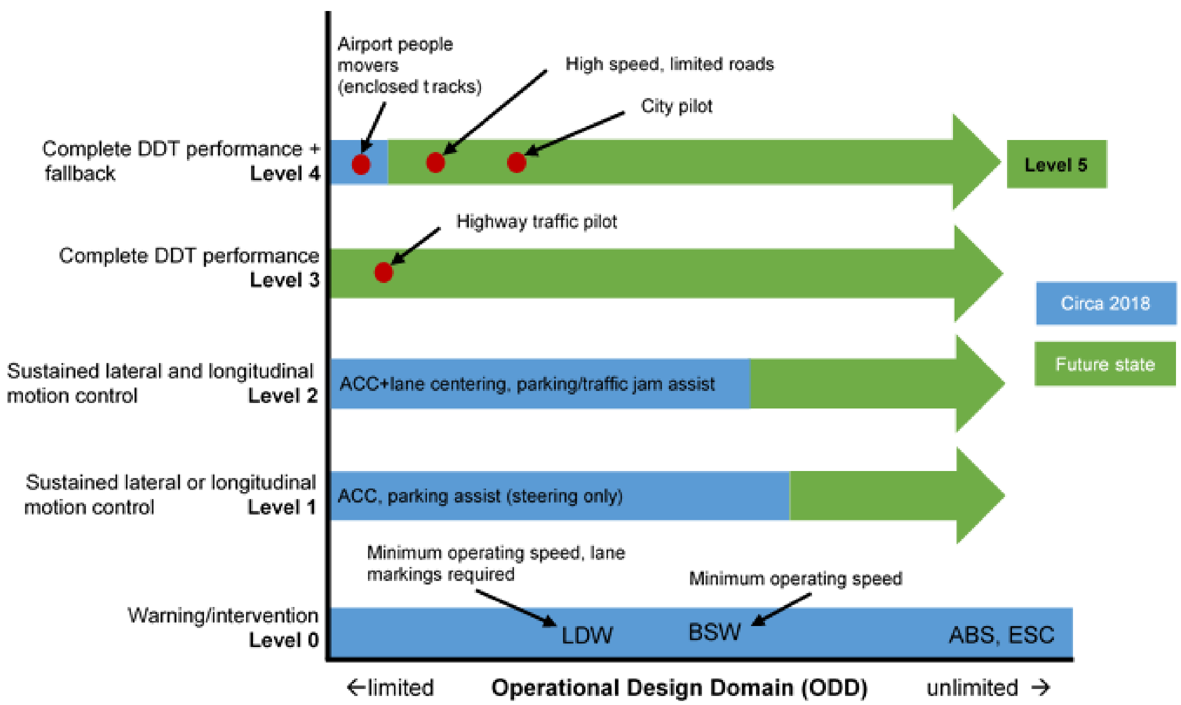


Figure 11 - ODD relative to driving automation levels

[1] It should be noted that *ODD* determinations may also reflect business considerations unrelated to technological limitations, such as revenue potential and risk management strategies, as determined by the manufacturer of the *ADS* and/or *ADS*-equipped *vehicle*.

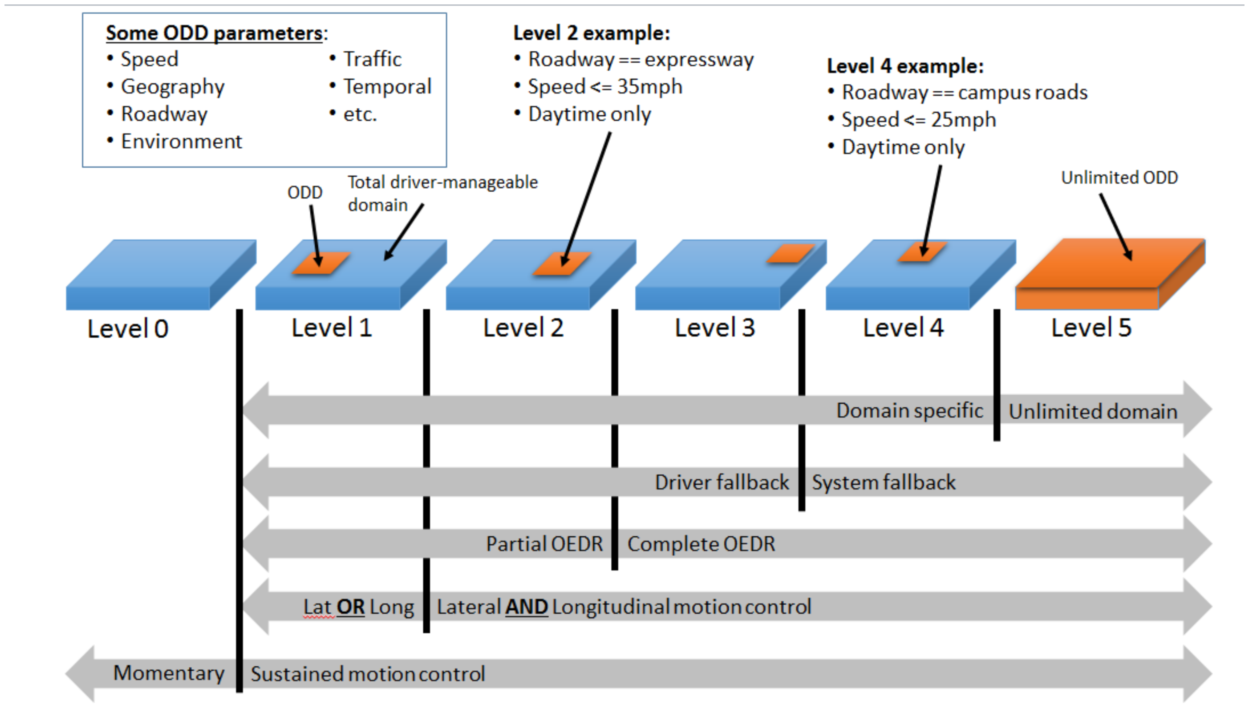


Figure 12 - ODD relative to driving automation levels

7. DEPRECATED TERMS

For the sake of clarity, this section identifies certain deprecated terms that are not used in this document either because they are functionally imprecise (and therefore misleading) and/or because they are frequently misused by application to lower levels of *driving automation* (i.e., Levels 1 and 2) in which the *driving automation system* does not perform the entire *DDT*.

7.1 Autonomous, Driving Modes(s), Self-Driving, Unmanned, Robotic

Vernacular terms such as those above are sometimes used—inconsistently and confusingly—to characterize *driving automation system*s and/or *vehicles* equipped with them. Because automation is the use of electronic or mechanical devices to replace human labor, based on the Oxford English Dictionary, automation (modified by “driving” to provide context) is the appropriate term for systems that perform part or all of the *DDT*. The use of other terms can lead to confusion, misunderstanding, and diminished credibility.

7.1.1 Autonomous

This term has been used for a long time in the robotics and artificial intelligence research communities to signify systems that have the ability and authority to make decisions independently and self-sufficiently. Over time, this usage was casually broadened to not only encompass decision making, but to represent the entire system functionality, thereby becoming synonymous with automated. This usage obscures the question of whether a so-called “autonomous *vehicle*” depends on communication and/or co*operation* with outside entities for important functionality (such as data acquisition and collection). Some *driving automation system*s may indeed be autonomous if they perform all of their functions independently and self-sufficiently, but if they depend on communication and/or co*operation* with outside entities, they should be considered cooperative rather than autonomous. Some vernacular usages associate autonomous specifically with full *driving automation* (Level 5), while other usages apply it to all levels of *driving automation*, and some state legislation has defined it to correspond approximately to any *ADS* at or above Level 3 (or to any *vehicle* equipped with such an *ADS*).

Additionally, in jurisprudence, autonomy refers to the capacity for self-governance. In this sense, also, “autonomous” is a misnomer as applied to automated driving technology, because even the most advanced *ADS*s are not “self-governing.” Rather, *ADS*s *operate* based on algorithms and otherwise obey the commands of *users*.

For these reasons, this document does not use the popular term “autonomous” to describe *driving automation*.

7.1.2 Driving Mode(s)

In the first version of this document, the term "driving mode" was used in place of "*operational design domain* (*ODD*)." However, "driving mode" is an imprecise term and excludes many of the conditions that characterize an *ODD*. For these reasons, we recommend against the use of "driving mode(s)" to describe the *ODD* of a given *driving automation system feature*.

7.1.3 Self-Driving

The meaning of this term can vary based on unstated assumptions about the meaning of driving and *driver*. It is variously used to refer to situations in which no *driver* is present, to situations in which no *user* is performing the *DDT*, and to situations in which a *driving automation system* is performing any part of the *DDT*.

7.1.4 Unmanned

This term is frequently misused to describe any *vehicle* equipped with a Level 2 or higher *driving automation system*. The term "unmanned" suggests the absence of a person in a *vehicle*, which can also be misleading because it does not distinguish between a *vehicle operated* by a *remote driver* and an *ADS-operated vehicle* in which there are no occupants that have the ability to *operate* the *vehicle*.

7.1.5 Robotic

This term is sometimes used to connote Level 4 or 5 *driving automation*, such as a closed-campus *ADS-DV* or a "robotic taxi," but it is technically vague because any automation technology could be considered to be "robotic," and as such it conveys no useful information about the *ADS* or *vehicle* in question.

7.2 Automated or Autonomous Vehicle

This document recommends against using terms that make *vehicles*, rather than driving, the object of automation, because doing so tends to lead to confusion between *vehicles* that can be *operated* by a (human) *driver* or by an *ADS* and *ADS-DVs*, which are designed to be *operated* exclusively by an *ADS*. It also fails to distinguish other forms of vehicular automation that do not involve automating part or all of the *DDT*.

Moreover, a given *vehicle* may be equipped with a *driving automation system* that is capable of delivering multiple *driving automation features* that *operate* at different levels; thus, the level of *driving automation* exhibited in any given instance is determined by the *feature*(s) engaged.

As such, the recommended usage for describing a *vehicle* with *driving automation* capability is "Level [1 or 2] *driving automation system*-equipped *vehicle*" or "Level [3, 4, or 5] *ADS*-equipped *vehicle*." The recommended usage for describing a *vehicle* with an engaged system (versus one that is merely available) is "Level [1 or 2] *driving automation system*-engaged *vehicle*" or "Level [3, 4, or 5] *ADS-operated vehicle*."

7.3 Control

In colloquial discourse, the term "control" is sometimes used to describe the respective roles of a (human) *driver* or a *driving automation system* (e.g., "the *driver* has control"). The authors of this document strongly discourage, and have therefore deliberately avoided, this potentially problematic colloquial usage. Because the term "control" has numerous technical, legal, and popular meanings, using it without careful qualification can confuse rather than clarify. In law, for example, "control," "actual physical control," and "ability to control" can have distinct meanings that bear little relation to engineering control loops. Similarly, the statement that the (human) *driver* "does not have control" may unintentionally and erroneously suggest the loss of all human authority.

The preferred terms "*DDT* performance" (as explained in the definition of *DDT* above) and "*operate*" (also a defined term, above) reduce potential confusion by specifically describing what the (human) *driver* or *driving automation system* actually does in terms of performing part or all of the *DDT*. This document does use the terms lateral *vehicle* motion control and longitudinal *vehicle* motion control, both of which are explicitly defined in terms of specific engineering functions.

If "control" is to be used in a particular *driving automation* context, it should be carefully qualified. To this end, the one using the term "should first describe the control system they actually intend: the goals, inputs, processes, and outputs to the extent they are determined by a human designer and the authority of the human or computer agents to the extent they are not." Refer to Smith, B.W., "Engineers and Lawyers Should Speak the Same Robot Language," in Robot Law (2015), available at newlypossible.org.

8. ADDITIONAL DISCUSSION

8.1 This document is not a specification and imposes no requirements.

This document provides a logical taxonomy for classifying *driving automation features* (and *ADS*-equipped *vehicles*), along with a set of terms and definitions that support the taxonomy and otherwise standardize related concepts, terms and usage in order to facilitate clear communications. As such, it is a convention based upon reasoned agreement, rather than a technical specification.

By itself, this document imposes no requirements, nor confers or implies any judgment in terms of system performance. Therefore, while it may be appropriate to state, for example, that a given *ADS feature* does not meet the definition of Level 4 because it occasionally relies on a *remote fallback-ready user* to perform the *fallback* (and is therefore a Level 3 *feature*), it is not appropriate to conclude that the *feature* in question is therefore "non-compliant" or "unsafe."

8.2 Levels are Assigned, Rather than Measured, and Reflect the Design Intent for the Driving Automation System *Feature* as Defined by its Manufacturer

As a practical matter, it is not possible to describe or specify a complete test or set of tests which can be applied to a given *ADS feature* to conclusively identify or verify its level of *driving automation*. The level assignment rather expresses the design intention for the *feature* and as such tells potential *users* or other interested parties that the *feature* can be expected to function such that the roles of the *user* versus the *driving automation system* while the *feature* is engaged are consistent with the assigned level, as defined in this document. The level assignment is typically based on the manufacturer's knowledge of the *feature's*/system's design, development, and testing, which inform the level assignment. An *ADS feature's* capabilities and limitations are expected to be communicated to prospective *users* through various means, such as in an owner's manual, which explains the *feature* in more detail, such as how it should and should not be used, what limitations exist (if any), and what to do (if anything) in the event of a *DDT* performance-relevant *system failure* in the *driving automation system* or *vehicle*.

As such, the manifestation of one or more performance deficiencies in either the *driving automation system* or in the *user*'s use of it does not automatically change the level assignment. For example:

- An *ADS feature* designed by its manufacturer to be Level 5 would not automatically be demoted to Level 4 simply by virtue of encountering a particular road on which it is unable to *operate* the *vehicle*.

- The *user* of an engaged Level 3 *ADS feature* who is seated in the *driver*'s seat of an equipped *vehicle* is the *DDT fallback-ready user* even if s/he is no longer receptive to a *request to intervene* because s/he has improperly fallen asleep.

The level of a *driving automation system feature* corresponds to the *feature's* production design intent. This applies regardless of whether the *vehicle* on which it is equipped is a production *vehicle* already deployed in commerce, or a test *vehicle* that has yet to be deployed. As such, it is incorrect to classify a Level 4 design-intended *ADS feature* equipped on a test *vehicle* as Level 2 simply because on-road testing requires a test *driver* to supervise the *feature* while engaged, and to intervene if necessary to maintain *operation*.

8.3 Level Assignments are Nominal, Rather than Ordinal, and are Never Fractional

While numbered sequentially 0 through 5, the levels of *driving automation* do not specify or imply hierarchy in terms of relative merit, technology sophistication, or order of deployment. Thus, this taxonomy does not specify or imply that, for example, Level 4 is "better" than Level 3 or Level 2.

Also, while it is possible to have a relatively high-functioning *ADS feature*, such as a Level 3 *feature* that is capable of automatically achieving a *minimal risk condition* in most, but not all, foreseeable conditions within its *ODD*, it would violate the definitions to refer to such a *feature* as a “low-functioning” or “partial” Level 4 *ADS feature*. Similarly, it is incorrect to describe *driving automation features* using fractional levels, such as 2.5 or 4.7. Qualified or fractional levels would render the meaning of the levels ambiguous by removing the clarity otherwise provided by the strict apportionment of roles between the *user* and the *driving automation system* in performance of the *DDT* and fallback for a given *vehicle*.

8.4 Levels are Mutually Exclusive

The levels in this taxonomy are intentionally discrete and mutually exclusive. As such, it is not logically possible for a given *feature* to be assigned more than a single level. For example, a low-speed *driving automation feature* described by the manufacturer as being capable of performing the complete *DDT* in dense traffic on fully access-controlled freeways cannot be both Level 3 and Level 4, because either it is capable of automatically performing the *DDT fallback* and achieving a *minimal risk condition* whenever needed, or it relies (at least sometimes) on the *driver* to respond to a *request to intervene* and either perform the *DDT* or achieve a *minimal risk condition* on his or her own.

It is, however, quite possible for a *driving automation system* to deliver multiple *features* at different levels, depending on the *usage specification* and/or *user* preferences. For example, a *vehicle* may be equipped with a *driving automation system* capable of delivering, under varying conditions, a Level 1 ACC *feature*, a Level 2 highway driving assistance feature, a Level 3 freeway traffic jam *feature*, and a Level 4 automated valet parking *feature*—in addition to allowing the *user* to *operate* the *vehicle* at Level 0 with no *driving automation features* engaged. From the standpoint of the *user*, these various *features* engage sequentially, rather than simultaneously, even if the *driving automation system* makes use of much of the same underlying hardware and software technology to deliver all four *driving automation features*.

8.5 DDT Performance, *Fallback* Performance, and *Minimal Risk Condition* Achievement are Separate Functions

When discussing handling of a *system failure* or out-of-*operational design domain* (out-of-*ODD*) condition for a Level 3, 4, or 5 *ADS*, this document distinguishes among the following three, separate functions: (i) *DDT* performance, (ii) *DDT fallback* performance, and (iii) *minimal risk condition* achievement.

i. *DDT* performance occurs under routine/normal *operating* conditions for the *ADS feature*. That is, the *feature* performs the complete *DDT* while functioning normally and within its *ODD*, if any.

ii. *DDT fallback* occurs when an *ADS* is unable to continue to perform the complete *DDT* (i.e., under routine/normal operation). For Level 3 *ADS features*, a human *fallback-ready user* (in-*vehicle* or remote) is expected to respond to a *request to intervene* or a kinesthetically apparent *vehicle* failure by either resuming *DDT* performance if the *vehicle* remains operable, or by achieving a *minimal risk condition* if the *vehicle* is not operable. For a Level 4 or 5 *ADS*, the *feature* or system performs the *fallback* by automatically achieving a *minimal risk condition* by, for example, pulling onto the road shoulder, turning on hazard lamps, disabling the propulsion system, and summoning roadside assistance. (Note: that some Level 3 *features* may be designed to automatically perform the *fallback* and achieve a *minimal risk conditio*n in some circumstances, such as when an obstacle-free, adjacent shoulder is present, but not in others, such as when no such road shoulder is available.) When the *ADS* performs the *fallback*, it maneuvers the *vehicle* into a *minimal risk condition*, which concludes the *fallback* response. However, when a *fallback-ready user* performs the *fallback*, s/he may simply continue *operating* the *vehicle* manually, rather than achieving a *minimal risk condition*, when the *vehicle* is operable.

iii. *Fallback* performance and *minimal risk condition* achievement at Levels 4 and 5 require that the *ADS* is still functional after occurrence of a *DDT* performance-relevant *system failure* or out-of-*ODD* condition. If the *ADS* is not functional, a *failure mitigation strategy* may apply (see 3.11 and 8.6). The *minimal risk condition* depends on both the *vehicle* condition and its *operating* environment at the time that *fallback* is triggered and could follow a degraded mode strategy that considers the relative risks associated with continuing *operation*, pulling off the road, or stopping in place.

8.6 DDT *Fallback* versus *Failure Mitigation Strategy*

ADS-equipped *vehicles* may have an additional *failure mitigation strategy* designed to bring the *vehicle* to a controlled stop wherever the *vehicle* happens to be. For example, if the *in-vehicle fallback-ready user* of a Level 3 sub-*trip* traffic jam *feature* fails to respond to a *request to intervene* after traffic clears (an out-of-*ODD* condition), the *vehicle* may have a *failure mitigation strategy* designed to bring the *vehicle* to a controlled stop in its present lane of travel and turn on the hazard lamps. Figure 13 displays a sample use case sequence.

Level 4 and Level 5 *ADS*-equipped *vehicles* may also have a *failure mitigation strategy* of stop-in-place under certain rare, catastrophic failure conditions that render the *ADS* non-functional through, for example, loss of backup power after initial power failure or incapacitation of the *ADS*'s computing capability, which render it incapable of performing the *fallback* and achieving a *minimal risk condition*. Figure 14 displays a sample use case sequence.

Failure mitigation performed by the *vehicle* is different from *minimal risk condition* achievement and is not part of the *fallback* function assigned to a Level 4 or 5 *ADS*, because it occurs after the *ADS* has disengaged or been incapacitated by a rare, catastrophic event, and, as such, it is also not within the scope of this taxonomy.

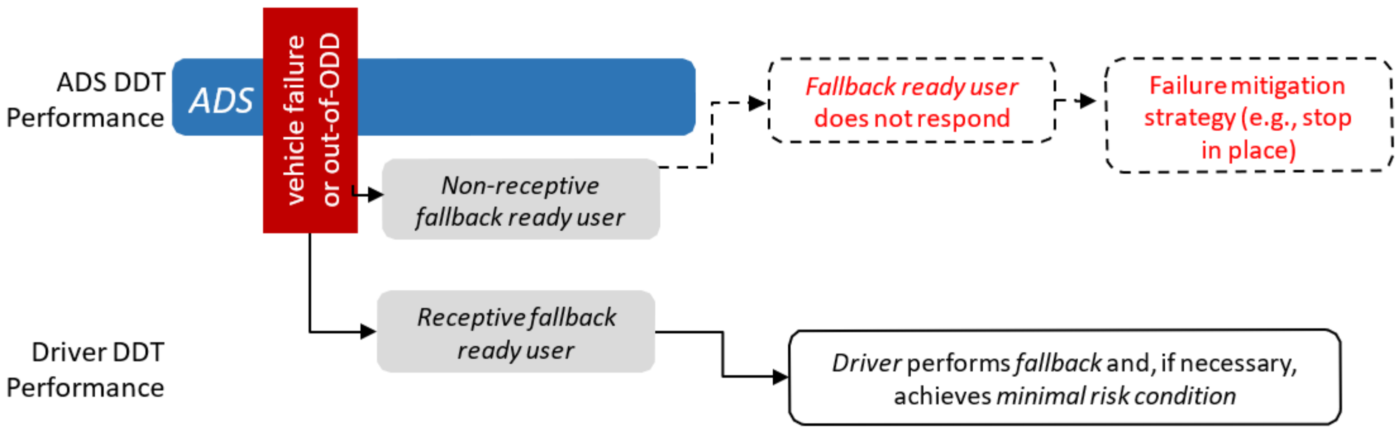


Figure 13 - Use case sequence for a Level 3 feature showing ADS engaged, occurrence of a failure or out-of-ODD condition, and the fallback-ready user performing the fallback, or, if the fallback-ready user fails to do so, a failure mitigation strategy, such as stop-in-lane
(Note: Dashed lines represent failure mitigation strategy.)

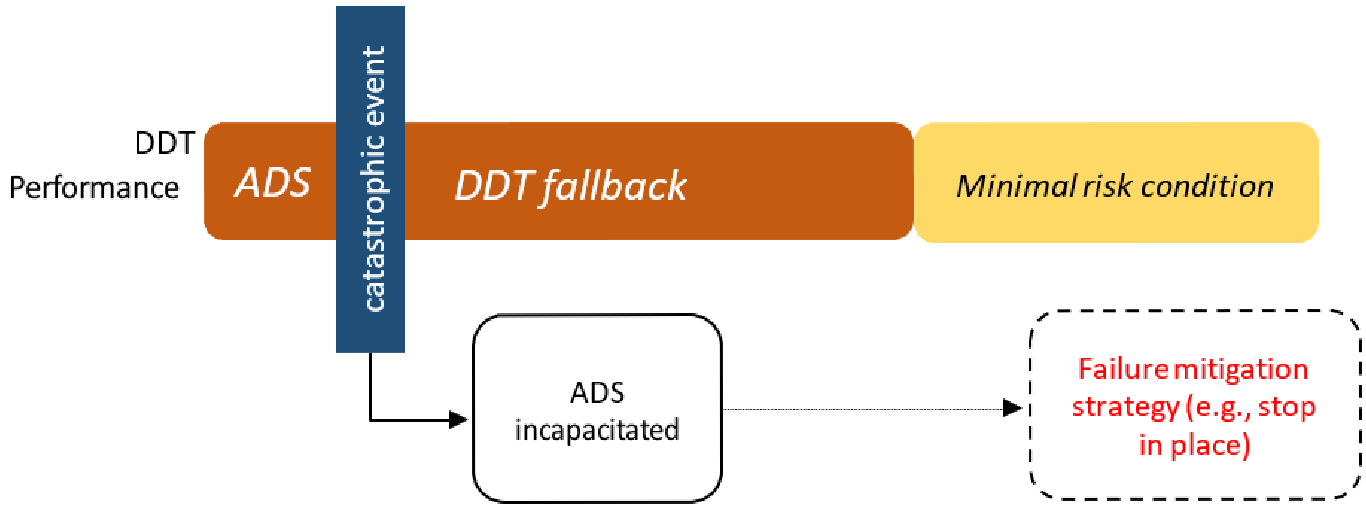


Figure 14 - Use case sequence at Level 4 showing ADS engaged, a catastrophic event (e.g., complete power failure) and the system achieving a minimal risk condition
(Note: Dashed lines represent failure mitigation strategy.)

8.7 Level 5 "Full Driving Automation" is the Inverse Analog of Level 0 "No Driving Automation"

As specified herein, Level 5 is distinguished from Level 4 by the fact that it is not *operational*ly limited to a specific *operational design domain* and can rather *operate* on-road anywhere that a typically skilled human *driver* can reasonably *operate* a *conventional vehicle*.

For example, referring to Level 4 *ADS-DVs* designed for low-speed *operation* within a particular geo-fenced city center as “full automation” or “fully automated” is incorrect and should be avoided. This distinction recognizes the fact that, for a *user* who is unable to *operate* a *conventional vehicle*, only a Level 5 *ADS*-equipped *vehicle* would be capable of fulfilling all of the same mobility needs that are otherwise fulfilled by a *conventional vehicle* for a *user* who is able to *operate* a *vehicle*.

8.8 Practical Considerations Regarding Level 5

There are technical and practical considerations that mitigate the literal meaning of the stipulation that a Level 5 *ADS* must be capable of ‘*operating* the *vehicle* on-road anywhere that a typically skilled human *driver* can reasonably *operate* a *conventional vehicle*,’ which might otherwise be impossible to achieve. For example, an *ADS*-equipped *vehicle* that is capable of *operating* a *vehicle* on all roads throughout the US, but, for legal or business reasons, cannot *operate* the *vehicle* across the borders in Canada or Mexico can still be considered Level 5, even if geo-fenced to *operate* only within the U.S. The rationale for this exception is that such a geo-fenced limitation (i.e., U.S., only) would not be due to limitations on the technological capability of the *ADS*, but rather to legal or business constraints, such as legal restrictions in Canada and Mexico/Central America that prohibit Level 5 deployment, or the inability to make a business case for expansion to those markets.

8.9 User Request to Perform the DDT when a Level 3, 4, or 5 ADS is Engaged

Vehicles equipped with an engaged Level 3 *ADS feature* are expected to relinquish the *DDT* upon request by a *DDT fallback-ready user*. This expectation is a logical consequence of the *DDT fallback-ready user*’s need to be able to perform the *DDT fallback* whenever required, including in cases when a *DDT* performance-relevant *vehicle system failure* has occurred that the *ADS* may not be monitoring (such as a broken suspension component).

Some *ADS*-equipped *vehicles* may not be designed to allow for *driver operation* (i.e., *ADS-dedicated vehicles*). In these types of *vehicles*, *passengers* may be able to demand a *vehicle* stop by, for example, pulling an emergency stop lever, and in response, the *ADS* would either achieve a *minimal risk condition* (e.g., given availability of an adjacent shoulder), or execute a stop-in-path maneuver.

However, other *vehicles* equipped with Level 4 or 5 *ADS features* may also be designed for *driver operation* (i.e., at any lower level, including Level 0). A *user* may request to *operate* these *vehicles* while the *ADS* is engaged without having been issued an alert by the *ADS*. In these cases, the *ADS* may delay relinquishing the *DDT* to ensure a smooth transition to the *driver*’s performance of the *DDT*, or to prevent a hazardous condition.

For example:

- A *vehicle* being *operated* by a Level 4 *ADS* highway pilot *feature* that is negotiating a tight curve may not immediately disengage upon the *user*’s request but may instead do so gradually as the *user* indicates through steering input that s/he is fully re-engaged in the *DDT*.

- A Level 4 *ADS feature* designed to *operate* a *vehicle* in a high-speed convoy with small gaps between *vehicles* may delay relinquishing performance of the *DDT* to a *user* upon his or her request to resume driving until after the *ADS* has safely maneuvered the *vehicle* out of the convoy, since (human) *drivers* may not be capable of safely *operating* a *vehicle* in a close-coupled convoy.

8.10 Possible Automation of Some Strategic Aspects of Driving

Strategic aspects of *vehicle operation* (decisions regarding whether, when, and where to go, as well as how to get there) are excluded from the definition of *DDT*, because they are considered *user*-determined aspects of the broader driving task, even when partially automated, such as through route navigation software. However, for certain advanced *ADS features*, such as *ADS-dedicated vehicles* that are *operated* as a ride-hailing or delivery service fleet, timing, route planning and even destination selection may also be automated in accordance with purposes defined by the *user*, namely, a *driverless operation dispatcher* or a *dispatching entity*.

8.11 Driving versus DDT

Driving entails a variety of decisions and actions, which may or may not involve a *vehicle* being in motion, or even being in an active lane of traffic. The overall act of driving can be divided into three types of *driver* effort: strategic, tactical, and *operational* (Michon, 1985). Strategic effort involves *trip* planning, such as deciding whether, when and where to go, how to travel, best routes to take, etc. Tactical effort involves maneuvering the *vehicle* in traffic during a *trip*, including deciding whether and when to overtake another *vehicle* or change lanes, selecting an appropriate speed, checking mirrors, etc. *Operational* effort involves split-second reactions that can be considered pre-cognitive or innate, such as making micro-corrections to steering, braking and accelerating to maintain lane position in traffic or to avoid a sudden obstacle or hazardous event in the *vehicle*'s pathway.

The definition of *DDT* provided above (3.10) includes tactical and *operational* effort but excludes strategic effort. It is that portion of driving that specifically entails *operating* a *vehicle* in an active lane of traffic when the *vehicle* is either in motion or imminently so. (It should be noted that these terms—strategic, tactical and *operational*—may have different meanings in other contexts but are defined as above for the purposes of this document.) Indeed, this Recommended Practice defines "*operate*" to include both *operational* and tactical efforts.

Object and event detection, recognition, classification, and response (aka, *OEDR*) form a continuum of activities often cited in the *driver* workload literature. In the case of *driving automation system*s, *OEDR* also includes events associated with system actions or outcomes, such as undiagnosed *driving automation system* errors or state changes.

8.12 Crash Avoidance *Features* Found on Some Conventional Vehicles Designed for Human Operation are Subsumed by an ADS

Crash avoidance *features*, including intervention-type *active safety systems*, may be included in *vehicles* equipped with *driving automation system*s at any level. For *ADS*-equipped *vehicles* (i.e., Levels 3 to 5) that perform the complete *DDT*, crash avoidance capability is part of *ADS* functionality.

8.13 Placing this Document in the Broader Context of Driver Assistance, Driving Automation, and Active Safety *Features*

In the broadest view of *driver* assistance and *driving automation*, various *features* can be categorized according to three overarching *operational* concepts (referred to as "Principles of *Operation*") described in the technical paper, "The Principles of Operation Framework: A Comprehensive Classification Concept for Automated Driving Functions." *Features* that provide status information (e.g., state of electric propulsion system charge, oil pressure, weather conditions, etc.), or that alert *drivers* to actual or potential hazards (e.g., lane departure or blind spot warnings) fall under Principle of Operation A (status alerts and warnings). *Features* that provide *sustained* automation of part or all of the *DDT* fall under Principle of Operation B (*Sustained driving automation*). And *features* that provide momentary, intermittent *vehicle* motion control action (not *sustained*—e.g., automatic emergency braking) fall under Principle of Operation C (crash avoidance intervention). A given *vehicle* may be equipped with several *features* that *operate* according to different Principles of Operation.

This document provides a taxonomy for *driving automation system features* that fall under Principle of Operation B according to the aforementioned categories. *Driving automation* system *features* perform part or all of the *DDT* on a *sustained* basis and, as such, fundamentally alter or eliminate the role of the *driver* in *operating* the *vehicle*. *Features* that fall into Principles of Operation A or C are not classifiable under the taxonomy described in this document, either because they do not directly affect *vehicle* motion control (A), or because they do not provide *sustained* performance of part or all of the *DDT* (C). It should be noted, however, that an individual *feature* may incorporate the functionality according to more than one Principle of Operation, such as a crash avoidance *feature* (C) that provides a warning to the *driver* (A) when it is engaged. Similarly, the crash avoidance capabilities otherwise provided by *features* that fall under Principle of Operation C on *vehicles operated* by human *drivers* are nevertheless performed as part of the *sustained driving automation* (B) provided by *ADS-operated vehicles*. For example, automatic emergency braking (AEB), which automatically brakes the *vehicle* to avoid a collision with a *vehicle*/object in its forward path, is not a standalone *feature* on an *ADS-DV*. However, emergency braking in response to the actions of other road *users* and to objects and events in traffic is included in the *ADS*'s overall *driving automation* capabilities.

8.14 Comparison of SAE J3016 Driving Automation Levels with BASt Levels

Prior to the initial publication of SAE J3016 in January 2014, the German Federal Highway Research Institute (Bundesanstalt für Strassenwesen, a.k.a. BASt) published "Legal consequences of an increase in *vehicle* automation" (Gasser, T.M., et al., July 23, 2013). After thorough review of this document, including discussions with the authoring organization, SAE Task Force members were persuaded that the BASt levels were in line with the Task Force's operating principles, namely, that SAE J3016 should be:

- Descriptive rather than normative, which is to say it should provide functional definitions.
- Consistent with current industry practice.
- Consistent with prior art—we should start with what has already been done and change only what is necessary.
- Useful across disciplines, including engineering, law, media, public discourse.
- Clear and cogent, which is to say we should avoid or define ambiguous terms.

In keeping with these guiding principles, SAE largely adopted the BASt levels, but with several adjustments:

- Added a sixth level (namely, Level 5 - full *driving automation*) not described in the BASt levels.
- Modified level names accordingly.
- Added supporting terms and definitions, such as *DDT*, *minimal risk condition*, etc.
- Described categorical distinctions that provide for a step-wise progression through the levels.
- Provided explanatory text and examples to aid the reader in understanding the levels, definitions, and their derivation.

After SAE J3016 was published in January 2014, the International Organization of Motor Vehicle Manufacturers (Organisation Internationale des Constructeurs d'Automobiles, a.k.a., OICA) adopted the BASt levels and aligned them (in English) with SAE J3016, including adding a sixth level to represent "full *driving automation*."

9. NOTES

9.1 Revision Indicator

A change bar (l) located in the left margin is for the convenience of the *user* in locating areas where technical revisions, not editorial changes, have been made to the June 2018 issue of SAE J3016 in the preparation of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY THE JOINT WORKING GROUP OF THE SAE ON-ROAD AUTOMATED DRIVING (ORAD) COMMITTEE AND ISO TC204 WORKING GROUP 14