SURFACE VEHICLE RECOMMENDED PRACTICE	**J3016™**	**JUN2018**
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	Superseding J3016 SEP2016	

(R) Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles

RATIONALE

This revision of Recommended Practice J3016 adds several new terms and definitions, corrects a few errors, and adds further clarification (especially in Section 8) to address frequently misunderstood concepts. 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 Recommended Practice does not provide specifications, or otherwise impose requirements on, *driving automation systems* (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, public discourse.

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

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The document contains updates that reflect 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 Recommended Practice are also defined herein. Bracketed text within a term name indicates optional inclusion when using term (i.e., braketed text may be unncessary, given the usage context).

1. SCOPE

This SAE Recommended Practice describes *motor vehicle driving automation systems* 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. 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 *users* of *vehicles* of all classes and *driving automation* levels (including no *driving automation*), as well as motorcyclists, pedal cyclists, and pedestrians.

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 and automated emergency braking, and certain types of driver assistance systems, such as lane keeping assistance, 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 and, rather, merely 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*.

It should, however, be noted that crash avoidance *features*, including intervention-type *active safety systems*, may be included in *vehicles* equipped with *driving automation systems* at any level. For *Automated Driving System (ADS) features* (i.e., levels 3-5) that perform the complete *DDT*, crash avoidance capability is part of *ADS* functionality.

2. REFERENCES

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

2.1 Applicable Documents

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

SAE J670   Vehicle Dynamics Terminology (J670:JAN2008)

SAE J3063   Active Safety Systems Terms & Definitions (J3063:NOV2015)

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

Gasser, Tom 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 L. Evans & R. C. Schwing (Eds.). Human behavior and traffic safety (pp. 485-520). New York: Plenum Press, 1985.

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.

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

3. DEFINITIONS

3.1 ACTIVE SAFETY SYSTEM (SAE J3063:NOV2015)

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 3.8) refers to any level 1-5 *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 3-5-specific term, "*Automated Driving System*," the latter term should be capitalized when spelled out and reduced to its acronym, *ADS*, as much as possible, while the former term should not be.

3.3   ADS-DEDICATED VEHICLE (ADS-DV)

A *vehicle* designed to be operated exclusively by a level 4 or level 5 *ADS* for all *trips* within its given *ODD* limitations (if any).

NOTE 1:   After considerable debate, the restriction of *ADS-DV* to *driving automation* levels 4 and 5, only, remains unchanged in this version of J3016. Further discussion of possibly including level 3 with a remote *fallback-ready user* into this definition will be addressed in the next revision of J3016 which will be done jointly with ISO.

NOTE 2:   An *ADS-DV* is a truly "driverless" *vehicle*. However, the term "driverless vehicle" is not used herein because it has been, and continues to be, widely misused to refer to any *vehicle* equipped with a *driving automation system*, even if that *system* is not capable of always performing the entire *DDT* (within given ODD limitations, if any) and thus requires a (human) *driver* for all or part of a given *trip* (see Section 7). Instead, this document defines the term "*driverless operation*," which encourages specificity in usage to avoid imprecision and misunderstanding.

NOTE 3:   An *ADS-DV* might be designed without *user* interfaces designed to be operable by a *conventional* human *driver*, such as braking, accelerating, steering, and transmission gear selection input devices.

NOTE 4:   *ADS-DVs* might be *operated* temporarily by a *conventional* or *remote 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 *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 dispatcher*.

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 dispatcher.*

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.

3.4   [DRIVERLESS OPERATION] DISPATCHING ENTITY

An entity that dispatches 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.

3.5   CONVENTIONAL VEHICLE

A *vehicle* designed to be *operated* by a *conventional 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*, as well as level 3 and 4 *ADS features* that require a *conventional driver* to *operate* the *vehicle* during portions of each *trip*.

NOTE 2:   While it may be counterintuitive to call a *vehicle* equipped with an *ADS* "*conventional*," it is appropriate in this context because a *conventional driver* is required for at least part of every *trip*. As emphasized below, J3016 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* and the *vehicle* are effectively the same).

EXAMPLE 1:   A *vehicle* with no *driving automation system features* that is designed to be *operated* by a *conventional driver* throughout all *trips.*

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 drive the *vehicle* to the freeway before engaging the *feature*, as well as again driving the *vehicle* upon exiting the freeway in order to complete the *trip*.

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

3.6   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 trips 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*. Consideration of whether a more appropriate term and definition should be specified for this concept will be taken up in the next revision of J3016, which will be developed jointly with ISO.

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*.

3.7   DRIVING AUTOMATION

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

3.8   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 1-5 *driving automation*.

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

3.9   [DRIVING AUTOMATION SYSTEM] FEATURE or APPLICATION

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

NOTE 2:   Each *feature* satisfies a *usage specification*.

NOTE 3:   *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.

3.10 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*.

3.11 DRIVERLESS OPERATION [OF AN ADS-EQUIPPED VEHICLE]

Operation of an *ADS*-equipped *vehicle* in which either no on-board *user* is present, or in which on-board *users* are not *drivers* or *fallback-ready users*.

NOTE 1:   *ADS-DVs* are always *dispatched* in *driverless operation* (subject to NOTE 4 in 3.3).

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

EXAMPLE: A level 4 *ADS-DV* is *dispatched* in *driverless operation* for purposes of providing transportation service. On-board *passengers* are neither *drivers* nor *fallback-ready users*.

3.12 [ADS-EQUIPPED] DUAL-MODE VEHICLE

A type of *ADS*-equipped *vehicle* designed for both *driverless operation* and operation by a *conventional driver* for complete *trips*.

NOTE 1:   An *ADS*-equipped *dual-mode vehicle* may be designed such that it can be *dispatched* in *driverless operation*.

NOTE 2:   An *ADS 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*.

3.13 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:

Lateral vehicle motion control via steering (operational);

Longitudinal vehicle motion control via acceleration and deceleration (operational);

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

Object and event response execution (operational and tactical);

Maneuver planning (tactical); and

Enhancing conspicuity via lighting, signaling and gesturing, etc. (tactical).

NOTE 1:   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 3.20).

NOTE 2:   In this document, reference is made to "complete(ing) the *DDT*." This means fully performing all of the subtasks of the *DDT*, whether by the (human) *driver*, by the *driving automation system*, or by both.

NOTE 3:   Figure 1 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.
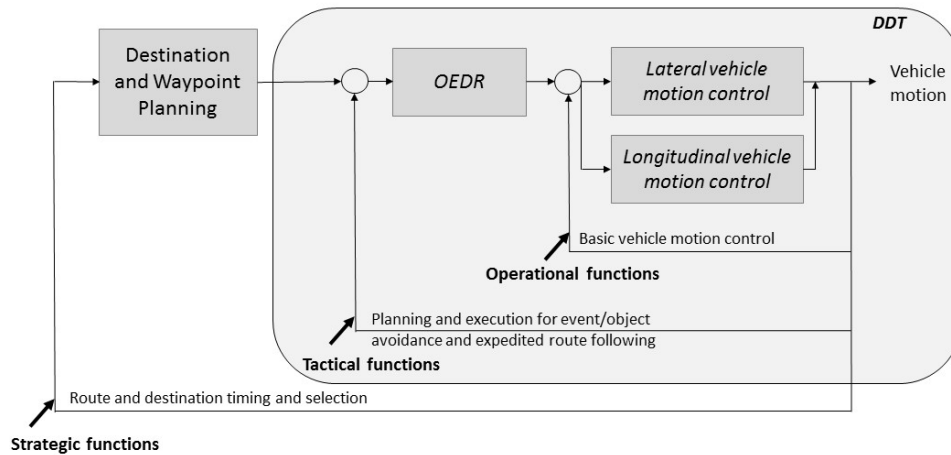
Figure 1 - Schematic (not a control diagram) view of driving task showing DDT portion

For purposes of *DDT* performance, level 1 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 encompasses automation of the innermost loop (*lateral* and *longitudinal vehicle motion control* and limited *OEDR* associated with *vehicle motion control*), and levels 3-5 encompass 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).

3.14   [DYNAMIC DRIVING TASK (DDT)] FALLBACK

The response by the *user* to either perform the *DDT* or achieve a *minimal risk condition* after occurrence of a *DDT performance-relevant system failure(s)* or 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.

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 *MRC*, but it cannot guarantee automated achievement of *MRC* in all cases within its *ODD*. Moreover, automated *MRC* 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 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 *conventional* or *remote*) may allow a *user* to perform the *DDT fallback* if s/he chooses to do so. 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").

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. (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. (Note that in this example, the *ADS-DV* automatically achieves a *minimal risk condition.*)

The following Figures 2 through 7 illustrate *DDT fallback* at various levels of *driving automation.*
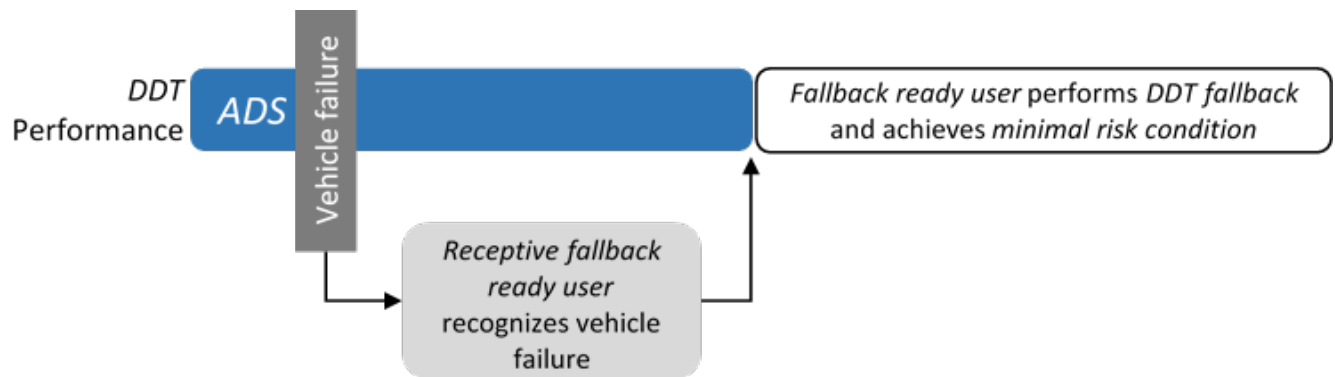

Figure 2

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 3

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 4

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 5

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.*
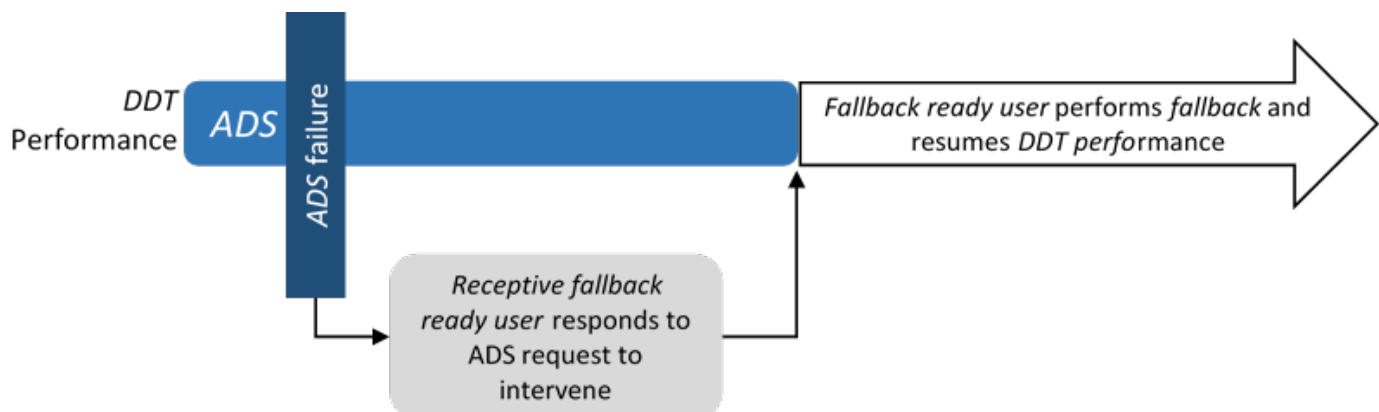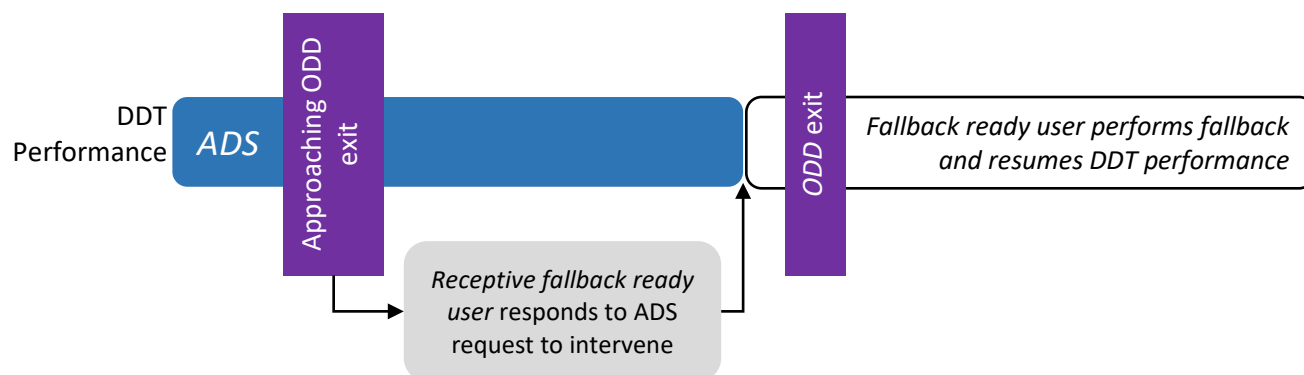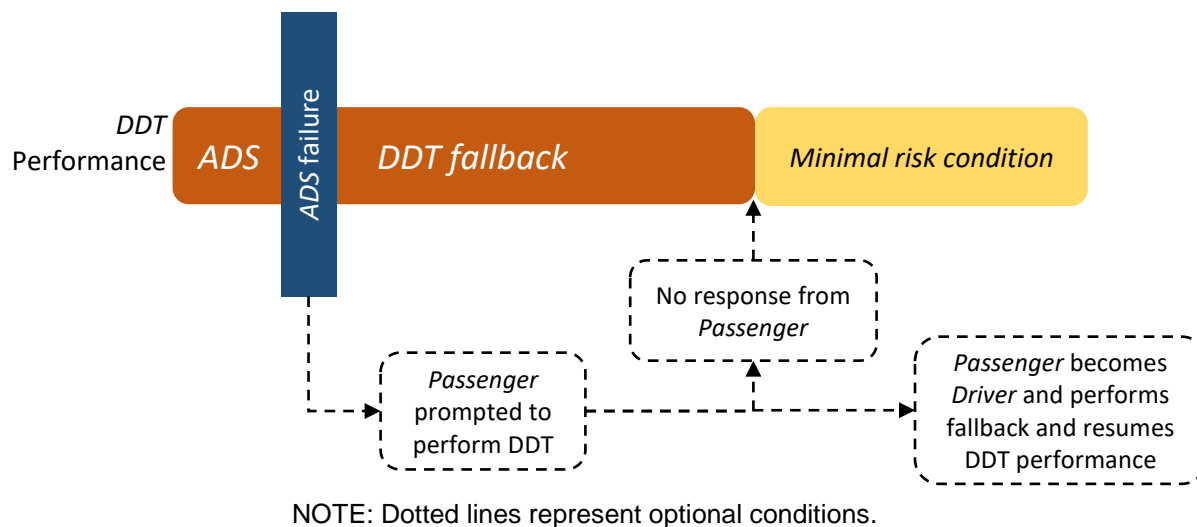
NOTE: Dotted lines represent optional conditions.

Figure 6

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*.
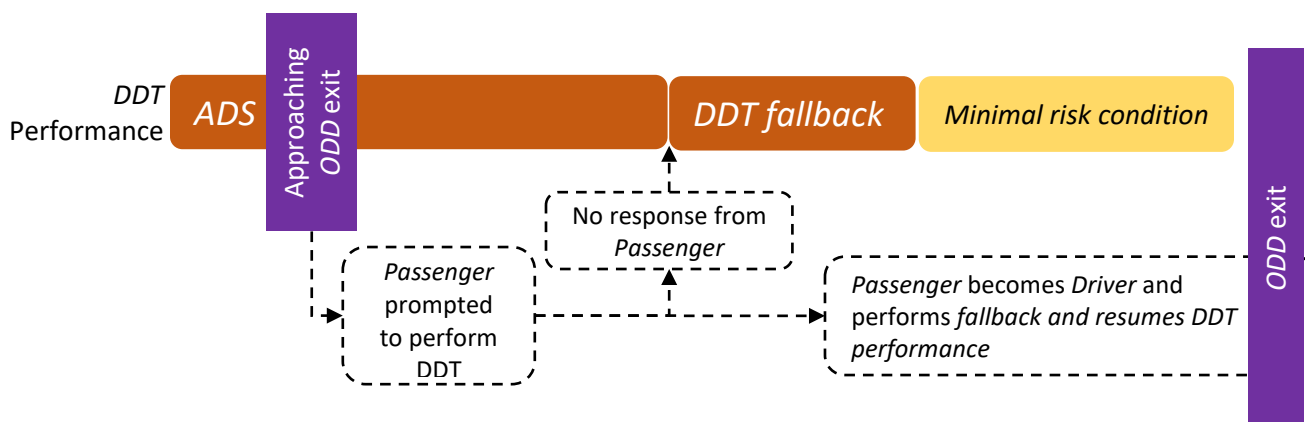
Figure 7

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*.

3.15   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 8).

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.

3.16 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 8).

NOTE: *Longitudinal vehicle motion control* includes maintaining set speed as well as detecting a preceding *vehicle* in the path of the subject *vehicle*, maintaining an appropriate gap to the preceding *vehicle* and applying propulsion or braking inputs to cause the *vehicle* to maintain that speed or gap.

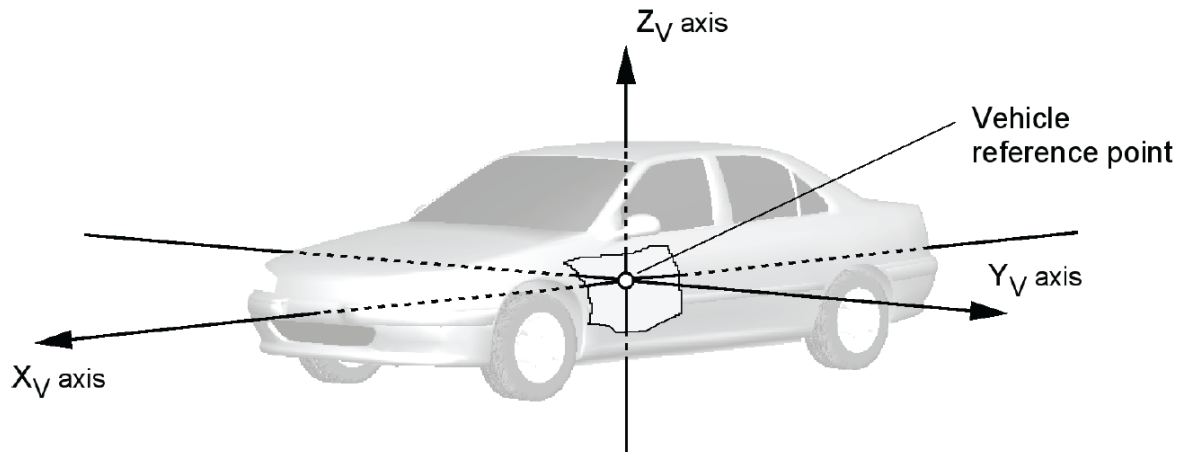
A. VEHICLE AXIS SYSTEM – Z-UP

Figure 8 - Diagram showing vehicle axes of motion (SAE J670:JAN2008)

3.17 MINIMAL RISK CONDITION

A 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 completed.

NOTE 1:   At levels 1 and 2, the *conventional 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 drivable.

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*.

3.18 [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 the 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 *driving automation system* 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 *driving automation system* 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 broken tie rod, 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* s*ystem 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*.

3.19 MONITOR

A general term referencing 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 3.23).

3.19.1   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 serve 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.

3.19.2   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*.

3.19.3   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 *ADSs monitor vehicle performance*. However, for level 3 *ADSs*, as well as for level 1 and 2 *driving automation systems*, the human *driver* is assumed to be *receptive* to *vehicle* conditions that adversely affect performance of the *DDT* (see definition of *receptivity* at 3.23).

EXAMPLE 1:   While a level 2 *driving automation system* 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 *driving automation system* 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*.

3.19.4   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 1-2, the *driver monitors* the *driving automation system*'s performance.

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

EXAMPLE 1:   A *conventional driver* verifies that an engaged ACC system 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 ensure that the feature is responsive to pedestrians and obstacles.

3.20   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*).

3.21   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 3-5) to perform the entire *DDT* for a given *vehicle* during a *trip*.

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* 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 3.29).

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

EXAMPLE 1:   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 2:   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 3:   An *ADS-dedicated* commercial truck is designed to pick up parts from a geofenced 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.

3.23   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 0-2 *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*.

NOTE 3:   *Monitoring* includes *receptivity*.

EXAMPLE 1:   While a level 3 *ADS* is performing the *DDT* in stop-and-go traffic, the left-front tie rod breaks. The *DDT fallback-ready user* feels that the *vehicle* has pulled dramatically 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.

3.24   REQUEST TO INTERVENE

Notification by an *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 drivable.

3.25   SUPERVISE [DRIVING AUTOMATION SYSTEM PERFORMANCE]

The *driver* activities, performed while *operating* a *vehicle* with an engaged level 1 or 2 *driving automation system 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.

3.26   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, automated emergency braking) are not classifiable (other than at level 0) under the SAE J3016 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 SAE J3016 taxonomy.

3.27   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.

3.28   USAGE SPECIFICATION

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

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

EXAMPLE 1:   Level 3 *driving automation* in high-volume traffic on designated fully access-controlled freeways.

EXAMPLE 2:   Level 4 *driving automation* in designated urban centers.

3.29   [HUMAN] USER

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

NOTE 1:   The following four terms (1 – *driver*, 2 – *passenger*, 3 – *DDT fallback-ready user*, and 4 – *driverless operation dispatcher*) 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*.

3.29.1   [HUMAN] DRIVER

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

NOTE: In a vehicle equipped with a *driving automation system*, a *driver* may assume or resume performance of part or all of the *DDT* from the *driving automation system* during a given *trip*.

3.29.1.1   [CONVENTIONAL] DRIVER

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

NOTE: A *conventional* driver is assumed to be 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*.

3.29.1.2   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* can 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 3.29.4), 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 her head lamps to encourage overtaking, or a pedestrian using a dedicated short range communication (DSRC) system to announce 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.

3.29.2   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 controlled-access 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* 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.

3.29.3   [DDT] FALLBACK-READY USER

The *user* of a *vehicle* equipped with an engaged level 3 *ADS feature* who is 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 *DDT 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.*

EXAMPLE: A level 3 *ADS* that is performing the *DDT* in congested traffic on a freeway encounters emergency responders who are rerouting traffic to the exit due to a serious crash; the *ADS* issues a *request to intervene* to the *DDT fallback-ready user* instructing him or her to resume performing the *DDT* (i.e., to become a *driver*).

3.29.4   DRIVERLESS OPERATION DISPATCHER

A user(s) who dispatches an ADS-equipped vehicle(s) in driverless operation.

3.30   VEHICLE

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

NOTE 1:   As used in this document, *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 *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*.

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* or in all driver-manageable on-road driving situations (unlimited ODD), then any *users* present in the *vehicle* while the *ADS* is engaged are *passengers*. This division of roles corresponds to levels 4 and 5.

The *vehicle* also fulfills a role in this *driving automation* taxonomy, but the role of the *vehicle* does not change the role of the *user* in performing the *DDT*.

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

a. Whether the driving automation system performs <u>either</u> the longitudinal <u>or</u> the lateral vehicle motion control subtask of the DDT.

b. Whether the *driving automation system* performs <u>both</u> the *longitudinal* <u>and</u> 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.*
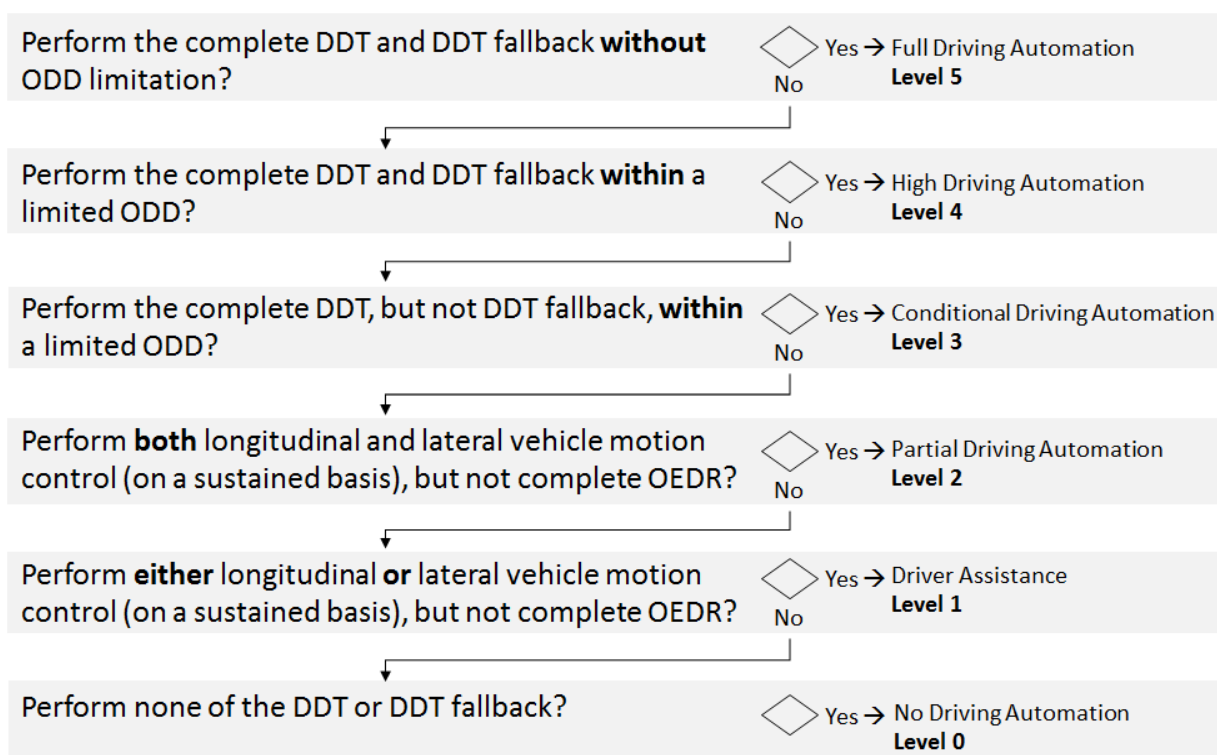
Table 1 summarizes the six levels of *driving automation* in terms of these five elements.

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

Level	Name	Narrative definition	DDT		DDT fallback	ODD
			Sustained lateral and longitudinal vehicle motion control	OEDR		
		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
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
		ADS ("*System*") performs the entire *DDT* (while engaged)				
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
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 respond to a *request to intervene*.	*System*	*System*	***System***	Limited
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 respond to a *request to intervene*.	*System*	*System*	*System*	**Unlimited**

Does the feature:

Perform the complete DDT and DDT fallback **without** ODD limitation? Yes → Full Driving Automation **Level 5** No

Perform the complete DDT and DDT fallback **within** a limited ODD? Yes → High Driving Automation **Level 4** No

Perform the complete DDT, but not DDT fallback, **within** a limited ODD? Yes → Conditional Driving Automation **Level 3** No

Perform **both** longitudinal and lateral vehicle motion control (on a sustained basis), but not complete OEDR? Yes → Partial Driving Automation **Level 2** No

Perform **either** longitudinal **or** lateral vehicle motion control (on a sustained basis), but not complete OEDR? Yes → Driver Assistance **Level 1** No

Perform none of the DDT or DDT fallback? Yes → No Driving Automation **Level 0**

Figure 9 - Simplified logic flow diagram for assigning driving automation level to a feature

Figure 9 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 driver and driving automation system by level of driving automation

Level of *Driving Automation*	Role of *User*	Role of *Driving Automation System*
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 support, such as 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 safe *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* • S*upervises* the *driving automation system* and intervenes as necessary to maintain safe *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

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 when engagement of *ADS* is appropriate • 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 *DDT fallback* in a timely manner • Determines whether and how to achieve a *minimal risk condition* • Becomes the *driver* upon requesting disengagement of the *ADS*	*ADS (*while not engaged): • Permits engagement only within its *ODD* *ADS* (while engaged): • Performs the entire *DDT* • 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 *driver* request

Level 4 - High Driving Automation	*Driver/dispatcher* (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/dispatcher (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 fallback* following a *request to intervene*
	
	• 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 only within its *ODD*
		
		ADS (while engaged):
		
		• Performs the entire *DDT*
		
		• May issue a timely *request to intervene*
		
		• Performs *DDT fallback* and transitions automatically to a *minimal risk condition* when*:*
		
		  ▪ A *DDT performance-relevant system failure* occurs or
		
		  ▪ A *user* does not respond to a *request to intervene* 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 *user*-requested disengagement

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[1] Verifying operational readiness might be performed by a person or entity other than a *driver* or *dispatcher*, depending on the *usage specification* or deployment concept (see 3.6, NOTE 1).

| Level 5 - Full Driving Automation | *Driver/dispatcher* (while the *ADS* is not engaged):

• Verifies operational readiness of the *ADS*-equipped *vehicle²*

• Determines whether to engage the *ADS*

• Becomes a *passenger* when the *ADS* is engaged only if physically present in the *vehicle*

Passenger/dispatcher (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 fallback* following a *request to intervene*

• 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* does not respond to a *request to intervene 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 |

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) *DDT 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) *DDT fallback-ready user* or (3) *driverless operation dispatcher*.

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

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

> 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.

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² This function might be performed by a person or entity other than a *driver* or *dispatcher*, depending on the *usage specification* or deployment concept (see 3.6, NOTE 1).

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*, as determined by an allocation of roles in *DDT* and *DDT fallback* performance between that *system* and the (human*) user* (if any). The manufacturer of a *driving automation system* determines that *system'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 *system*.

The lower two levels of *driving automation* (1-2) refer to cases in which the (human) *driver* continues to perform part of the *DDT* while the *driving automation system* is engaged.

The upper three levels of *driving automation* (3-5) refer to cases in which the *Automated Driving System (ADS)* performs the entire the *DDT* on a *sustained* basis while it is engaged.

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: A level 1 *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 1 (discussing the three primary subtasks of the *DDT*).

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 *driving automation* feature is capable of only limited *OEDR*, meaning that there are some events that the *driving automation system* is not capable of recognizing or responding to. Therefore, the *driver* *supervises* the *driving automation system* performance by completing the *OEDR* subtask of the *DDT*. See Figure 1 (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* 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:   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 the *DDT* when the *ADS* issues a *request to intervene* or to perform the *fallback* and achieve a *minimal risk condition* if the failure condition precludes normal operation.

NOTE 2:   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 a suspension component.

NOTE 3:   In the event of a *DDT performance-relevant system failure* in a level 3 *ADS* or in the event that the *ADS* will soon exit its *ODD*, the *ADS* will issue a *request to intervene* within sufficient time for a typical person to respond appropriately to the driving situation at hand.

NOTE 4:   An "appropriate" response by a *DDT fallback-ready user* to a *request to intervene* may entail bringing the *vehicle* to a *minimal risk condition* or continuing to *operate* the *vehicle* after the *ADS* has disengaged.

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*, without any expectation that a *user* will respond to a *request to intervene*.

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 the *user* of an engaged level 4 *ADS feature* is a *passenger* who need not respond to *requests to intervene* or to *DDT performance-relevant system failures*.

NOTE 2:   Level 4 *ADS features* may be designed to *operate* the *vehicle* throughout complete *trips* (e.g., a closed campus shuttle *feature*), or they may be designed to *operate* the *vehicle* during only part of a given *trip*, after *ODD* requirements are met (e.g., a high-speed freeway cruising *feature*), 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 (see Example 2, below).

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* without any expectation that a *user* will respond to a *request to intervene*.

NOTE 1:   "Unconditional/not *ODD*-specific" means that the *ADS* can *operate* the *vehicle* under all *driver*-manageable road conditions within its region of the world. 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*, nor be *receptive* to a *request to intervene* while it is engaged.

EXAMPLE: A *vehicle* with an *ADS* that, once programmed with a destination, is capable of *operating* the *vehicle* throughout complete *trips* 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: A specific implementation of adaptive cruise control, for example, may be intended to operate only at high speeds, only at low speeds, or at all speeds.

For simplicity, however, SAE J3016's 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 does not have ODD limitations, (subject to the discussion in 8.8).

Accordingly, accurately describing a *feature* (other than at level 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 in each level (e.g., level 4 includes parking, high-speed, low-speed, geo-fenced, etc.). For this reason, SAE J3016 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 4 *ADS* has a limited *ODD*. Geographic or environmental restrictions on an *ADS-DV* may reflect the *ODD* limitations of its *ADS* (or they may reflect *vehicle* design limitations).

Level 1 to level 4 *features* are subject to limited *ODDs*. These limitations 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*.

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 d*riving 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 *ODDs*. A *feature* will *operate* as designed only when all the *ODD*-defining variables satisfy design criteria.

Figure 10 illustrates the orthogonality of *ODD* relative to levels of *driving automation*.
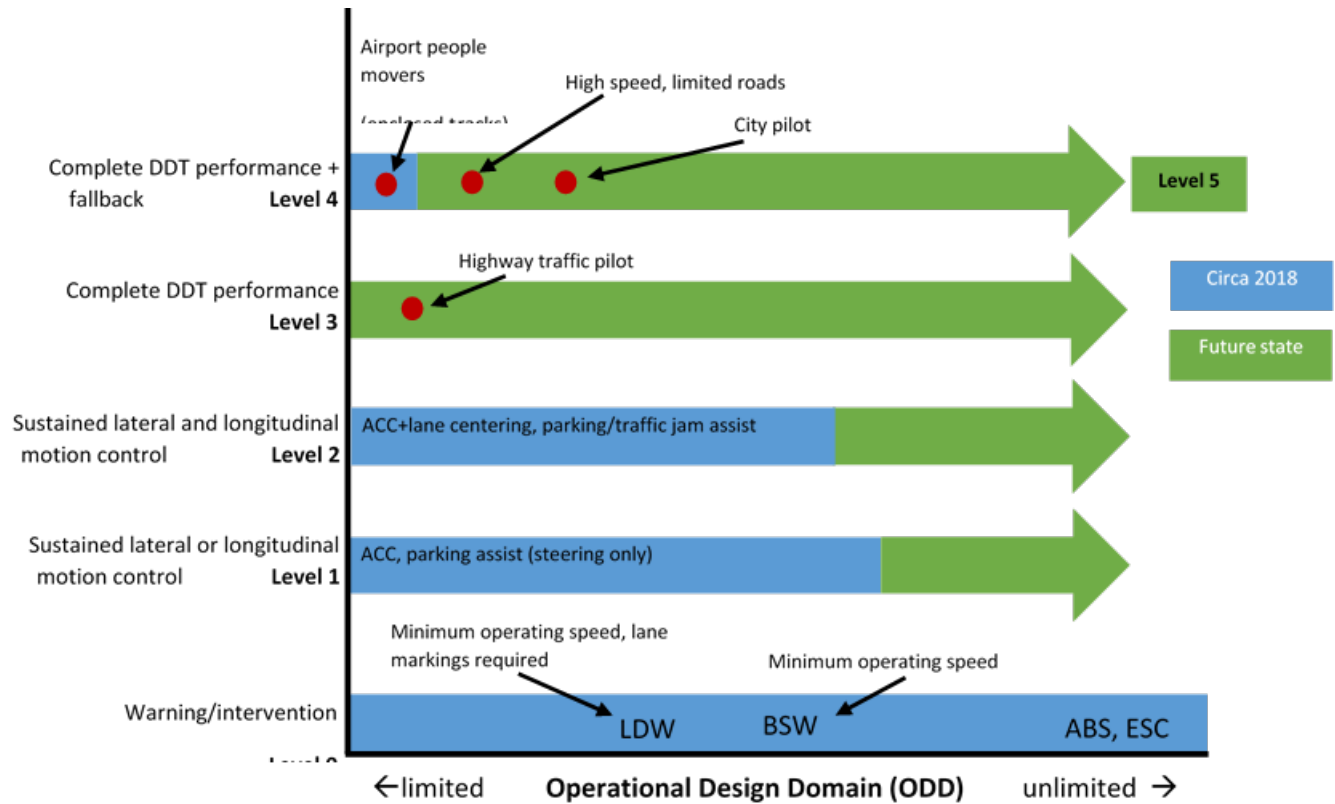
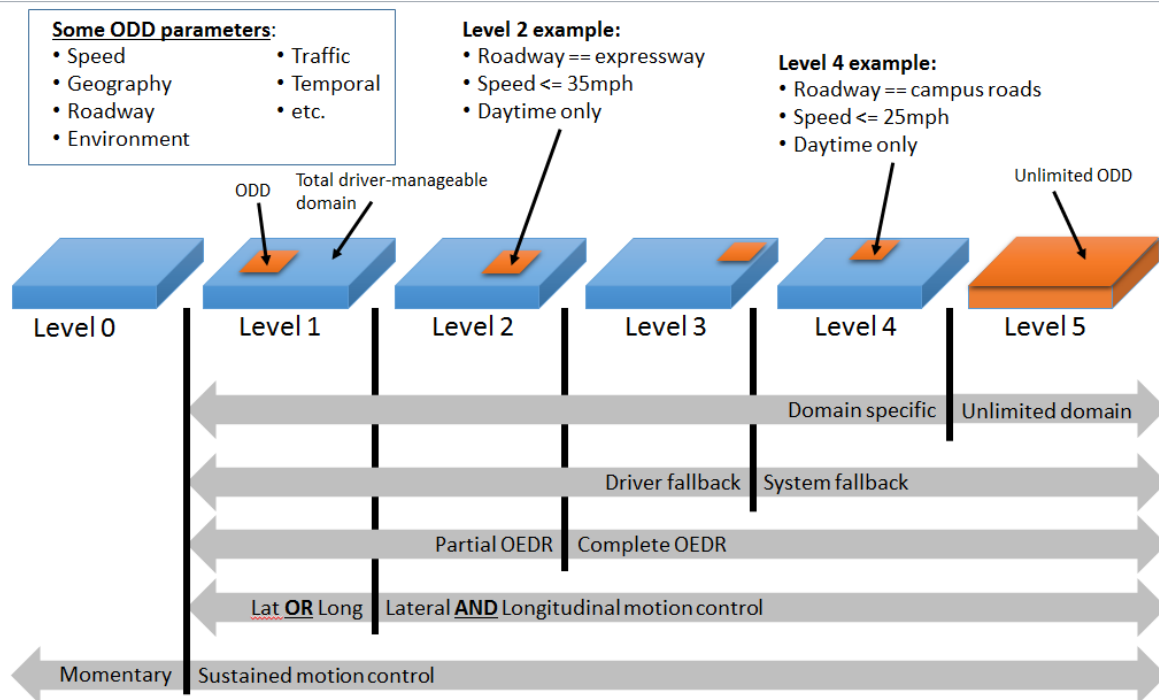*Figure 10 - ODD relative to driving automation levels*

Figure 11 - 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 Recommended Practice 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 systems* 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 cooperation with outside entities for important functionality (such as data acquisition and collection). Some *driving automation systems* may indeed be autonomous if they perform all of their functions independently and self-sufficiently, but if they depend on communication and/or cooperation 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 *ADSs* are not "self-governing." Rather, *ADSs* 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* remotely *operated* by a human *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 Recommended Practice 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 Recommended Practice 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 Recommended Practice 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." See Bryant Walker Smith, Engineers and Lawyers Should Speak the Same Robot Language, in Robot Law (2015), available at newlypossible.org.

8.   ADDITIONAL DISCUSSION

8.1   J3016 is not a specification and imposes no requirements.

J3016 provides a logical taxonomy for classifying *driving automation features* (and *ADS-dedicated 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, J3016 is a convention based upon reasoned agreement, rather than a technical specification.

By itself, J3016 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 safe operation.

8.3	Level assignments are nominal, rather than ordinal, and are never fractional.

While numbered sequentially 0 through 5, J3016 levels do not specify or imply hierarchy in terms of relative merit, technology sophistication, or order of deployment. Thus, J3016 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 J3016 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 SAE J3016 levels, such as 2.5 or 4.7. Qualified or fractional J3016 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*, the SAE J3016 framework 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 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 entire *DDT* (i.e., under normal operating conditions), For level 3 *ADS features*, the human *fallback-ready user* is expected to respond to a *request to intervene* or a kinesthetically-apparent *vehicle* failure by either resuming manual driving if the *vehicle* remains drivable, or by achieving a *minimal risk condition* if the *vehicle* is not drivable. 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 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.) 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 driving manually, rather than achieving a *minimal risk condition*, when the *vehicle* is drivable.

iii.   Fallback performance and minimal risk condition achievement 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 8.6, below). 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

Vehicles equipped with level 2 and level 3 *driving automation features* may have an additional failure mitigation strategy designed to bring the *vehicle* to a controlled stop wherever the *vehicle* happens to be, if the *driver* fails to *supervise* the *feature's* performance (level 2), or if the *fallback-ready user* fails to perform the *fallback* when prompted (level 3). For example, if the *fallback-ready user* of a level 3 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 12 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*.

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 SAE J3016.
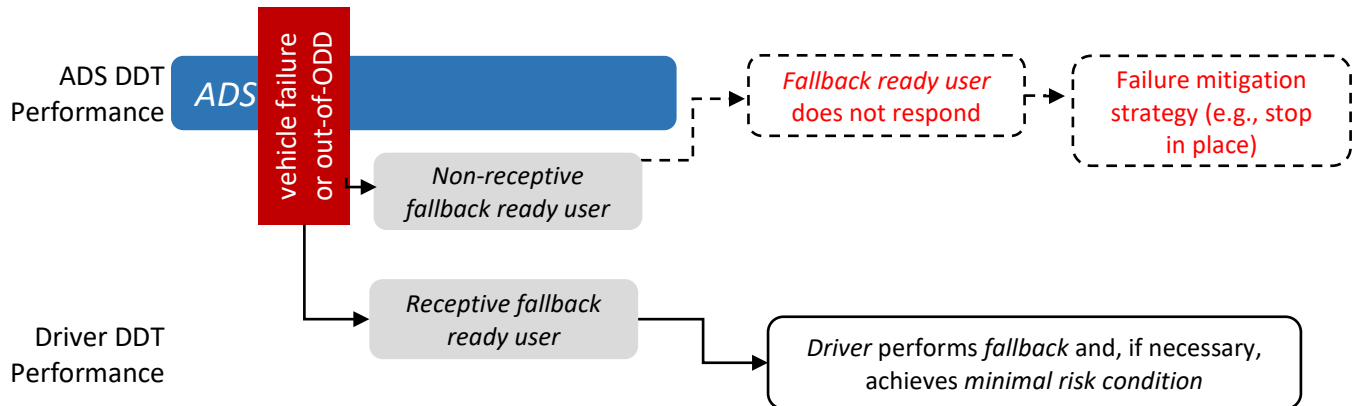
Figure 12 - Use case sequence for a level 3 feature showing ADS engaged, occurrence of a failure or out-of-ODD condition, and the fallback-ready user performing the fallback, or, if the fallback-ready user fails to do so, a failure mitigation strategy, such as stop-in-lane (Note: Dotted lines represent failure mitigation strategy.)
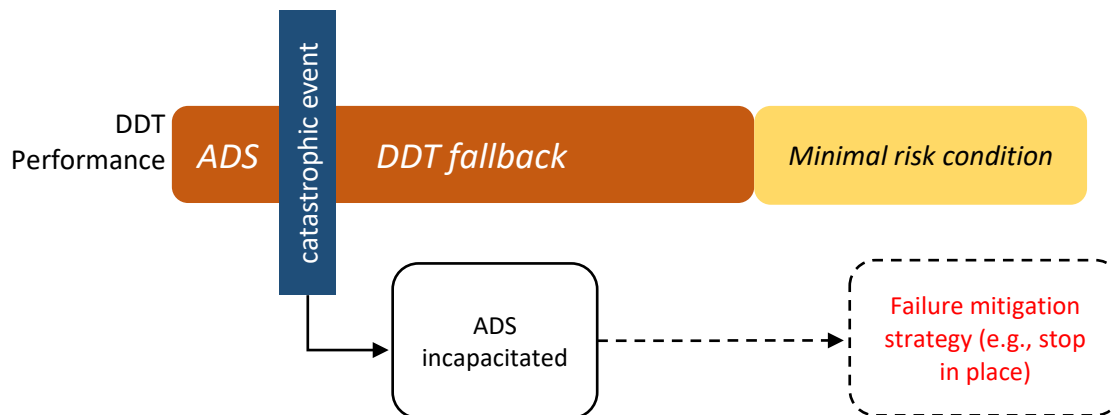
Figure 13 - Use case sequence at Level 4 showing ADS engaged, a catastrophic event (e.g., complete power failure) and the system achieving a minimal risk condition (Note: Dotted lines represent failure mitigation strategy.)

8.7 Level 5 "*full driving automation*" is the inverse analog of level 0 "*no driving automation*".

As specified in J3016, level 5 is distinguished from level 4 by the fact that it is not operationally 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 border in Canada or Mexico can still be considered level 5, even if geo-fenced to *operate* only within the US. The rationale for this exception is that the geo-fenced limitation (i.e., US, only) is not due to limitations on the technological capability of the *ADS*, but rather is due 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 achieve a *minimal risk condition*.

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 a *request to intervene* by the *ADS*. In these cases, the *ADS* may delay relinquishing of 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. However, for certain advanced *ADS* applications, such as some *ADS-dedicated vehicle* applications, timing, route planning and even destination selection may also be automated in accordance with purposes defined by the *user* (i.e., a *driverless operation dispatcher)* or by 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 (3.13) 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 systems*, *OEDR* also includes *driving* 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 systems* at any level. For *ADS*-equipped *vehicles* (i.e., levels 3-5) that perform the complete *DDT*, crash avoidance capability is part of *ADS* functionality.

8.13 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" (Tom M. Gasser 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 previous issue 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 SAE ON-ROAD AUTOMATED VEHICLE STANDARDS COMMITTEE