SAE Technical Standards Board Rules provide that: “This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user.”

SAE reviews each technical report at least every five years at which time it may be revised, reaffirmed, stabilized, or cancelled. SAE invites your written comments and suggestions.

Copyright © 2018 SAE International

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of SAE. SAE hereby grants a limited, royalty free license to any interested person or entity to print or download from the SAE international website, and then store and display, a single copy of this publication in paper form or in electronic form on a website, computer, or e-room for reference, reading or review by any interested person or entity. Provided this notice appears on the publication and the publication cannot be, or is prohibited from being, removed, recorded, copied, downloaded, printed, or transmitted.

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
http://www.sae.org

SAE WEB ADDRESS:

SAE values your input. To provide feedback on this Technical Report, please visit http://standards.sae.org/J2016_201806

SURFACE VEHICLE RECOMMENDED PRACTICE

J 3016™
JUN2018

Issued 2014-01
Revised 2018-06
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.
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 unnecessary, 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


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

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


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](image)

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.
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.

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.

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

A. VEHICLE AXIS SYSTEM – Z-UP

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 system failure in one of its computing modules. The ADS transitions to DDT fallback by engaging a redundant computing module(s) to achieve a minimal risk condition.

3.19 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 ODDs 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 daytime 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 either the longitudinal or the lateral vehicle motion control subtask of the DDT.

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

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

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

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

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

SAE’s levels of driving automation are descriptive and informative, rather than normative, and technical rather than legal. Elements indicate minimum rather than maximum capabilities for each level. In this table, “system” refers to the driving automation system or ADS, as appropriate.
### Table 1 - Summary of levels of driving automation

<table>
<thead>
<tr>
<th>Level</th>
<th>Name</th>
<th>Narrative definition</th>
<th>DDT</th>
<th>OEDR</th>
<th>DDT fallback</th>
<th>ODD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Driver performs part or all of the DDT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>No Driving Automation</td>
<td>The performance by the driver of the entire DDT, even when enhanced by active safety systems.</td>
<td>Driver</td>
<td>Driver</td>
<td>Driver</td>
<td>n/a</td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance</td>
<td>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.</td>
<td>Driver and System</td>
<td>Driver</td>
<td>Driver</td>
<td>Limited</td>
</tr>
<tr>
<td>2</td>
<td>Partial Driving Automation</td>
<td>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.</td>
<td>System</td>
<td>Driver</td>
<td>Driver</td>
<td>Limited</td>
</tr>
<tr>
<td></td>
<td>ADS (&quot;System&quot;) performs the entire DDT (while engaged)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Conditional Driving Automation</td>
<td>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.</td>
<td>System</td>
<td>System</td>
<td>Fallback-ready user (becomes the driver during fallback)</td>
<td>Limited</td>
</tr>
<tr>
<td>4</td>
<td>High Driving Automation</td>
<td>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.</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Limited</td>
</tr>
<tr>
<td>5</td>
<td>Full Driving Automation</td>
<td>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.</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Unlimited</td>
</tr>
</tbody>
</table>
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>
<thead>
<tr>
<th>Level of Driving Automation</th>
<th>Role of User</th>
<th>Role of Driving Automation System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DRIVER PERFORMS PART OR ALL OF THE DDT</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| **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  
  - Supervises 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

<table>
<thead>
<tr>
<th>Level 3 – Conditional Driving Automation</th>
<th>Driver (while the ADS is not engaged):</th>
<th>ADS (while not engaged):</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Verifies operational readiness of the ADS-equipped vehicle</td>
<td>• Permits engagement only within its ODD</td>
</tr>
<tr>
<td></td>
<td>• Determines when engagement of ADS is appropriate</td>
<td>ADS (while engaged):</td>
</tr>
<tr>
<td></td>
<td>• Becomes the DDT fallback-ready user when the ADS is engaged</td>
<td>• Performs the entire DDT</td>
</tr>
<tr>
<td>DDT fallback-ready user (while the ADS is engaged):</td>
<td></td>
<td>• Determines whether ODD limits are about to be exceeded and, if so, issues a timely request to intervene to the DDT fallback-ready user</td>
</tr>
<tr>
<td></td>
<td>• Is receptive to a request to intervene and responds by performing DDT fallback in a timely manner</td>
<td>• 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</td>
</tr>
<tr>
<td></td>
<td>• Is receptive to DDT performance-relevant system failures in vehicle systems and, upon occurrence, performs DDT fallback in a timely manner</td>
<td>• Disengages an appropriate time after issuing a request to intervene</td>
</tr>
<tr>
<td></td>
<td>• Determines whether and how to achieve a minimal risk condition</td>
<td>• Disengages immediately upon driver request</td>
</tr>
<tr>
<td></td>
<td>• Becomes the driver upon requesting disengagement of the ADS</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level 4 – High Driving Automation</th>
<th>Driver/dispatcher (while the ADS is not engaged):</th>
<th>ADS (while not engaged):</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Verifies operational readiness of the ADS-equipped vehicle</td>
<td>• Permits engagement only within its ODD</td>
</tr>
<tr>
<td></td>
<td>• Determines whether to engage the ADS</td>
<td>ADS (while engaged):</td>
</tr>
<tr>
<td></td>
<td>• Becomes a passenger when the ADS is engaged only if physically present in the vehicle</td>
<td>• Performs the entire DDT</td>
</tr>
<tr>
<td>Passenger/dispatcher (while the ADS is engaged):</td>
<td></td>
<td>• May issue a timely request to intervene</td>
</tr>
<tr>
<td></td>
<td>• Need not perform the DDT or DDT fallback</td>
<td>• Performs DDT fallback and transitions automatically to a minimal risk condition when:</td>
</tr>
<tr>
<td></td>
<td>• Need not determine whether and how to achieve a minimal risk condition</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• May perform the DDT fallback following a request to intervene</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• May request that the ADS disengage and may achieve a minimal risk condition after it is disengaged</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• May become the driver after a requested disengagement</td>
<td>• Disengages, if appropriate, only after:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>May delay user-requested disengagement</td>
</tr>
</tbody>
</table>

---

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 vehicle
- 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

<table>
<thead>
<tr>
<th>No Driving Automation 0</th>
<th>Engaged Level of Driving Automation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>In-vehicle user</strong></td>
<td>Driver</td>
</tr>
<tr>
<td><strong>Remote User</strong></td>
<td>Remote Driver</td>
</tr>
</tbody>
</table>

**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.

---

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 conditions are met or exceeded. However, 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 ODDs, 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 driving automation system feature has only one ODD, but that ODD may be quite varied and multi-faceted. Even though the ODD is composed of multiple variables, it would be incorrect to say that a driving automation feature has multiple 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

Some ODD parameters:
- Speed
- Geography
- Roadway
- Environment

Level 0 example:
- Domain specific
- Unlimited ODD

Level 1 example:
- Driver fallback
- System fallback

Level 2 example:
- Partial OEDR
- Complete OEDR

Level 3 example:
- Lateral OR Longitudinal motion control

Level 4 example:
- Lat OR Long

Level 5 example:
- Sustained motion control

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 \textit{ADS feature} does not meet the definition of level 4 because it occasionally relies on a \textit{remote fallback-ready user} to perform the \textit{fallback} (and is therefore a level 3 \textit{feature}), it is not appropriate to conclude that the \textit{feature} in question is therefore 'non-compliant' or 'unsafe.'

8.2 Levels are assigned, rather than measured, and reflect the design intent for the \textit{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 \textit{ADS feature} to conclusively identify or verify its level of \textit{driving automation}. The level assignment rather expresses the design intention for the \textit{feature} and as such tells potential \textit{users} or other interested parties that the \textit{feature} can be expected to function such that the roles of the \textit{user} versus the \textit{driving automation system} while the \textit{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 \textit{feature}'s/system's design, development, and testing, which inform the level assignment. An \textit{ADS feature}'s capabilities and limitations are expected to be communicated to prospective \textit{users} through various means, such as in an owner's manual, which explains the \textit{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 \textit{DDT performance-relevant system failure} in the \textit{driving automation system} or \textit{vehicle}.

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

- An \textit{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 \textit{operate} the \textit{vehicle}.

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

The level of a \textit{driving automation system feature} corresponds to the \textit{feature}'s production design intent. This applies regardless of whether the \textit{vehicle} on which it is equipped is a production \textit{vehicle} already deployed in commerce, or a test \textit{vehicle} that has yet to be deployed. As such, it is incorrect to classify a level 4 design-intended \textit{ADS feature} equipped on a test \textit{vehicle} as level 2 simply because on-road testing requires a test \textit{driver} to \textit{supervise} the \textit{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 \textit{ADS feature}, such as a level 3 \textit{feature} that is capable of automatically achieving a \textit{minimal risk condition} in most, but not all, foreseeable conditions within its \textit{ODD}, it would violate the J3016 definitions to refer to such a \textit{feature} as a "low-functioning" or "partial" level 4 \textit{ADS feature}. Similarly, it is incorrect to describe \textit{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 \textit{user} and the \textit{driving automation system} in performance of the \textit{DDT} and \textit{fallback} for a given \textit{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 \textit{feature} to be assigned more than a single level. For example, a low-speed \textit{driving automation feature} described by the manufacturer as being capable of performing the complete \textit{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 \textit{DDT fallback} and achieving a \textit{minimal risk condition} whenever needed, or it relies (at least sometimes) on the \textit{driver} to respond to a \textit{request to intervene} and either perform the \textit{DDT} or achieve a \textit{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 BASL Levels

Prior to the initial publication of SAE J3016 in January 2014, the German Federal Highway Research Institute (Bundesanstalt für Strassenwesen, a.k.a. BASL) 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 BASL 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 BASL levels, but with several adjustments:

- Added a sixth level (namely, level 5 – full driving automation) not described in the BASL 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