SURFACE VEHICLE
RECOMMENDED PRACTICE

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

RATIONALE

This Recommended Practice 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. Standardizing levels of driving automation and supporting terms serves several purposes, including:

- Clarifying the role of the (human) driver, if any, during driving automation system engagement.
- Answering questions of scope when it comes to developing laws, policies, regulations, and standards.
- Providing a useful framework for driving automation specifications and technical requirements.
- 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:

- Be descriptive and informative rather than normative.
- Provide functional definitions.
- Be consistent with current industry practice.
- Be consistent with prior art to the extent practicable.
- Be useful across disciplines, including engineering, law, media, public discourse.
- Be clear and cogent and, as such, it should avoid or define ambiguous terms.

The current revision 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 Consortium and by the Crash Avoidance Metrics Partnership (CAMP) Automated Vehicle Research (AVR) Consortium, respectively.
These revisions, while substantial, preserve the original SAE J3016:JAN2014 level names, numbers, and functional distinctions, as well as the supporting terms. However, this version of J3016:

- Clarifies and rationalizes taxonomical differentiator(s) for lower levels (levels 0-2).
- Clarifies the scope of the J3016 driving automation taxonomy (i.e., explains to what it does and does not apply).
- Modifies existing, and adds new, supporting terms and definitions.
- Adds more rationale, examples, and explanatory text throughout.

Italicized terms used in this Recommended Practice are also defined herein.

1. SCOPE

This Recommended Practice provides a taxonomy for motor vehicle driving automation systems that perform part or all of the dynamic driving task (DDT) on a sustained basis and that range in level from no driving automation (level 0) to full driving automation (level 5). It provides detailed definitions for these six levels of driving automation 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) driver, the driving automation system, and other vehicle systems and components. These other vehicle systems (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. “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 ADS-equipped vehicles (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


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 3.5) 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.

NOTE 1: 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 and thus involves a (human) driver for part of a given trip. This is the only category of ADS-operated vehicle that requires neither a conventional nor remote driver during routine operation.

NOTE 2: An ADS-DV might be designed without user interfaces, such as braking, accelerating, steering, and transmission gear selection input devices designed to be operable by a human driver.

NOTE 3: A level 4 ADS-DV by design does not operate outside of its ODD (subject to note 4 below).

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 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 parts and 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 roads that are navigable by a human driver. The user simply inputs a destination, and the ADS-DV automatically navigates to that destination.

3.4 DRIVING AUTOMATION

The performance of part or all of the DDT on a sustained basis.

3.5 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)

3.6 [DRIVING AUTOMATION SYSTEM] FEATURE or APPLICATION

A driving automation system’s design-specific functionality at a specific level of driving automation within a particular ODD.

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.
3.7 DRIVING MODE

A type of vehicle operation with characteristic DDT requirements (e.g., expressway merging, high-speed cruising, low-speed traffic jam, etc.).

NOTE: In the previous version of this document, the term driving mode was used more extensively. In this updated version, operational design domain is the preferred term for many of these uses.

3.8 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:

1. Lateral vehicle motion control via steering (operational);
2. Longitudinal vehicle motion control via acceleration and deceleration (operational);
3. Monitoring the driving environment via object and event detection, recognition, classification, and response preparation (operational and tactical)
4. Object and event response execution (operational and tactical);
5. Maneuver planning (tactical); and
6. 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 3.15).

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 8.4.

![Figure 1 - Schematic view of driving task showing DDT portion](image-url)
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).

3.9 [DYNAMIC DRIVING TASK (DDT)] FALLBACK

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

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 operational design domain (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: 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 3: At levels 4 and 5, the ADS must be capable of performing the DDT fallback, as well as 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 8.3).

NOTE 4: 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 6 illustrate DDT fallback at various levels of driving automation.

**Figure 2 - Use case sequence at Level 3 showing ADS engaged, a vehicle failure and the user resuming control**

**Figure 3 - Use case sequence at Level 3 showing ADS engaged, and ADS failure and the user resuming control**

**Figure 4 - Use case sequence at Level 3 showing ADS engaged, exiting the ODD and the user resuming control**
3.10 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.

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.

3.11 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.

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.
3.12 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 driver may or may not achieve a minimal risk condition in response to a vehicle fault condition or driving automation system failure.

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.

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 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 2 driving automation system feature that allows a user to stand outside of the vehicle and initiate an automated parking maneuver via wireless device automatically brings the vehicle to a stop within its current travel path when it experiences a DDT performance-relevant system failure.

EXAMPLE 2: 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 the active lane of traffic before coming to a stop.

EXAMPLE 3: A level 4 ADS feature designed to operate a vehicle at high speeds on freeways receives a request by a passenger to stop and automatically removes the vehicle from the active lane of traffic before coming to a stop.

EXAMPLE 4: 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.
3.13 (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 sustaining DDT performance (partial or complete).

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 dis-engages, 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.

3.14 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 driver, 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 ACC system is expected to monitor 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 3.18 below.
3.14.1 MONITOR THE USER

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

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

NOTE 2: User monitoring is primarily useful for levels 2 and 3, as below these levels evidence from the field has not identified significant incidence of misuse or abuse of driving automation technology, and above these levels the ADS is always capable of achieving a minimal risk condition automatically, so user misuse/abuse is not relevant.

3.14.2 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.

3.14.3 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 3.18).

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 the vehicle achieves a minimal risk condition.

3.14.4 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 it is free of pedestrians and obstacles.

3.15 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).

3.16 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 an “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 3.24).

3.17 OPERATIONAL DESIGN DOMAIN (ODD)

The specific conditions under which a given driving automation system or feature thereof is designed to function, including, but not limited to, driving modes.

NOTE 1: An ODD may include geographic, roadway, environmental, traffic, speed, and/or temporal limitations. A given ADS may be designed to operate, for example, only within a geographically-defined military base, only under 25 mph, and/or only in daylight.

NOTE 2: An ODD may include one or more driving modes. For example, a given ADS may be designed to operate a vehicle only on fully access-controlled freeways and in low-speed traffic, high-speed traffic, or in both of these driving modes.

NOTE 3: In the previous version of this document, the term driving mode was used more extensively. In this updated version, ODD is the preferred term for many of these uses.

NOTE 4: Section 6 discusses the significance of ODDs in the context of the levels of driving automation.

3.18 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.

3.19 REQUEST TO INTERVENE

Notification by an ADS to a driver indicating that s/he should promptly perform the DDT fallback.

3.20 SUPERVISE (DRIVING AUTOMATION SYSTEM PERFORMANCE)

The driver activities, performed while operating a vehicle with an engaged level 1 or 2 driving automation system, to monitor the driving automation system’s performance, respond to inappropriate actions taken by that system, and to otherwise complete the DDT.

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

3.21 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 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 J3016 taxonomy.

3.22 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.

3.23 USAGE SPECIFICATION

A particular level of driving automation within a particular ODD.

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.

NOTE 1: Each feature satisfies a usage specification.
3.24 (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 - 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.

3.24.1 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.

3.24.1.1 (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.

3.24.1.2 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 dispatcher (see 3.24.4), although a 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 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: This example is identical 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.
3.24.2 PASSENGER

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

NOTE: A passenger cannot be remote to the vehicle in which s/he is a passenger.

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 a closed-campus shuttle on a university campus equipped with an engaged level 4 ADS are passengers.

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

3.24.3 (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.

NOTE 3: A DDT fallback-ready user may be remote to the ADS-equipped vehicle for which s/he serves as the DDT fallback-ready user.

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).

3.24.4 (ADS-EQUIPPED VEHICLE) DISPATCHER

A user(s) who verifies the operational readiness of the vehicle and ADS and engages or disengages the ADS.

NOTE 1: Unless the destination(s) is pre-programmed in the ADS, a dispatcher may also specify the destination(s).

NOTE 2: Only vehicles equipped with a level 4 or 5 ADS designed to operate a vehicle throughout a trip are potentially subject to being dispatched.

NOTE 3: Ensuring operational readiness includes such things as ensuring that conspicuity systems are clean and working, maintaining correct tire pressure and fluid levels, as well as ensuring that on-board diagnostic system checks for the vehicle and ADS indicate the absence of a DDT performance-relevant system failure.

EXAMPLE: 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 marshalling yard by a dispatcher who becomes a remote driver and is able to perform the DDT using wireless means.
3.25 VEHICLE

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

NOTE: 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."

4. TAXONOMY OF DRIVING AUTOMATION

The terms defined above inform a taxonomy of driving automation consisting of six discrete and mutually exclusive levels (see section 8.2). 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 systems. 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:

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

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

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

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

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

Table 1 (below) summarizes the six levels of driving automation in terms of these five elements.
Table 1 - Summary of levels of driving automation

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 Automated Driving System (ADS), as appropriate.

<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></td>
<td></td>
<td><strong>Sustained lateral and longitudinal vehicle motion control</strong></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></td>
<td><strong>ADS (“System”)</strong> performs the entire DDT (while engaged)**</td>
<td>System</td>
<td></td>
<td>Fallback-ready user (becomes the driver during fallback)</td>
<td>Limited</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></td>
<td>System</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></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></td>
<td>System</td>
<td>Unlimited</td>
</tr>
</tbody>
</table>
Figure 8 - Simplified logic flow diagram for assigning driving automation level to a feature

Figure 8 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 8.1).

Table 2 (below) 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 their role in a given circumstance. (See 8.1.)
### Table 2 - Roles of human driver and driving automation system by level of driving automation

<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>DRIVER PERFORMS THE DYNAMIC DRIVING TASK (DDT)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Level 0 - No Driving Automation</strong></td>
<td>Driver (at all times):</td>
<td>Driving Automation System (if any):</td>
</tr>
<tr>
<td></td>
<td>• Performs the entire DDT</td>
<td>• 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)</td>
</tr>
<tr>
<td><strong>Level 1 - Driver Assistance</strong></td>
<td>Driver (at all times):</td>
<td>Driving Automation System (while engaged):</td>
</tr>
<tr>
<td></td>
<td>• Performs the remainder of the DDT not performed by the driving automation system</td>
<td>• Performs part of the DDT by executing either the longitudinal or the lateral vehicle motion control subtask</td>
</tr>
<tr>
<td></td>
<td>• Supervises the driving automation system and intervenes as necessary to maintain safe operation of the vehicle</td>
<td>• Disengages immediately upon driver request</td>
</tr>
<tr>
<td></td>
<td>• Determines whether/when engagement or disengagement of the driving automation system is appropriate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Immediately performs the entire DDT whenever required or desired</td>
<td></td>
</tr>
<tr>
<td><strong>Level 2 - Partial Driving Automation</strong></td>
<td>Driver (at all times):</td>
<td>Driving Automation System (while engaged):</td>
</tr>
<tr>
<td></td>
<td>• Performs the remainder of the DDT not performed by the driving automation system</td>
<td>• Performs part of the DDT by executing both the lateral and the longitudinal vehicle motion control subtasks</td>
</tr>
<tr>
<td></td>
<td>• Supervises the driving automation system and intervenes as necessary to maintain safe operation of the vehicle</td>
<td>• Disengages immediately upon driver request</td>
</tr>
<tr>
<td></td>
<td>• Determines whether/when engagement and disengagement of the driving automation system is appropriate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Immediately performs the entire DDT whenever required or desired</td>
<td></td>
</tr>
<tr>
<td>Level 3 – Conditional Driving Automation</td>
<td>Driver (while the ADS is not engaged):</td>
<td>ADS (while not engaged):</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>---------------------------------------</td>
<td>--------------------------</td>
</tr>
<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></td>
</tr>
<tr>
<td></td>
<td>• Becomes the DDT fallback-ready user when the ADS is engaged</td>
<td></td>
</tr>
<tr>
<td>DDT fallback-ready user (while the ADS is engaged):</td>
<td>• Is receptive to a request to intervene and responds by performing DDT fallback in a timely manner</td>
<td></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>• 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>• Determines whether and how to achieve a minimal risk condition</td>
<td>• Disengages an appropriate time after issuing a request to intervene</td>
</tr>
<tr>
<td></td>
<td>• Becomes the driver upon requesting disengagement of the ADS</td>
<td>• Disengages immediately upon driver request</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></td>
</tr>
<tr>
<td></td>
<td>• Becomes a passenger when the ADS is engaged only if physically present in the vehicle</td>
<td></td>
</tr>
<tr>
<td>Passenger/dispatcher (while the ADS is engaged):</td>
<td>• Need not perform the DDT or DDT fallback</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Need not determine whether and how to achieve a minimal risk condition</td>
<td>• Performs the entire DDT</td>
</tr>
<tr>
<td></td>
<td>• May issue a timely request to intervene</td>
<td>• Performs DDT fallback and transitions automatically to a minimal risk condition when:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• A DDT performance-relevant system failure occurs or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• A user does not respond to a request to intervene or</td>
</tr>
</tbody>
</table>
Table 3, below, 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) 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><strong>In-vehicle User</strong></td>
<td>Driver</td>
</tr>
<tr>
<td></td>
<td>DDT fallback-ready user</td>
</tr>
<tr>
<td></td>
<td>Passenger</td>
</tr>
<tr>
<td><strong>Remote User</strong></td>
<td>Remote Driver</td>
</tr>
<tr>
<td></td>
<td>DDT fallback-ready user</td>
</tr>
<tr>
<td></td>
<td>Dispatcher</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.

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 resume the DDT when the ADS issues a request to intervene, such as when a DDT performance-relevant system failure occurs.

NOTE 2: A level 3 ADS’s DDT fallback-ready user is also expected to be receptive to evident DDT performance-relevant system failures in vehicle systems that do not necessarily trigger an ADS-issued request to intervene, such as a broken body or a suspension component.

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

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

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

5.5 LEVEL or CATEGORY 4 - HIGH DRIVING AUTOMATION

The sustained and ODD-specific performance by an ADS of the entire DDT and DDT fallback, without any expectation that a user will respond to a request to intervene.

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

NOTE 2: Level 4 ADS features may be designed to operate the vehicle throughout complete trips (e.g., a closed campus shuttle feature), or they may be designed to operate the vehicle during only part of a given trip, after ODD requirements are met (e.g., a high-speed freeway cruising feature). For example, in order to complete a given trip, a user of a vehicle equipped with a level 4 ADS feature designed to operate the vehicle during high-speed freeway conditions will generally choose to perform the DDT when the freeway ends; otherwise the ADS will automatically perform DDT fallback and achieve a minimal risk condition as needed. However, unlike at level 3, this user is not a DDT fallback-ready user while the ADS is engaged. (see Example 2, below).

EXAMPLE 1: A level 4 ADS feature capable of performing the entire DDT during valet parking (i.e., curb-to-door or vice versa) without any driver supervision.
EXAMPLE 2: A level 4 ADS feature capable of performing the entire DDT during sustained operation on a motorway or freeway (i.e., within its ODD). (Note: The presence of a user in the driver’s seat who is capable of performing the DDT is envisioned in this example, as driver performance of the DDT would have been necessary before entering, and would again be necessary after leaving, the motorway or freeway. Thus, such a feature would alert the user that s/he should resume vehicle operation shortly before exiting the ODD, but if the user fails to respond to such an alert, the ADS will nevertheless perform the DDT fallback and achieve a minimal risk condition automatically.)

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

5.6 LEVEL [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 on-road conditions. 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 be unable to complete a given trip (i.e., 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, 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 expressly disavows any such limitations.

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 an 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).

Figure 9 illustrates the orthogonality of ODD relative to levels of driving automation.
Figure 10 - Illustrates the significance of ODD relative to the levels.

Figure 11 - ODD relative to 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, Self-Driving, Driverless, 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 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.

7.1.3 Driverless and Unmanned

These terms are frequently misused to describe any vehicle equipped with a level 2 or higher driving automation system. Because “driver” can have many meanings, “driverless” can confuse rather than clarify. (Under J3016’s definitions, an engaged level 3, 4, or 5 ADS displaces a (human) driver.) 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.

7.1.4 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 (vs. 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 Level are assigned, rather than measured

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

- An \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 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.

8.2 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 driving automation \textit{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 \textit{driving automation system} to deliver multiple \textit{features} at different levels, depending on the \textit{usage specification} and/or \textit{user preferences}. For example, a \textit{vehicle} may be equipped with a \textit{driving automation system} capable of delivering, under varying conditions, a level 1 ACC \textit{feature}, a level 2 highway assistance \textit{feature}, a level 3 freeway traffic jam \textit{feature}, and a level 4 automated valet parking \textit{feature} – in addition to allowing the \textit{user} to \textit{operate} the \textit{vehicle} at level 0 with no \textit{driving automation features} engaged. From the standpoint of the \textit{user}, these various \textit{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 \textit{driving automation features}.

8.3 User request to perform the DDT when a level 3, 4 or 5 ADS is engaged

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

Some \textit{vehicles} equipped with level 4 or 5 \textit{driving automation features} may not be designed to allow for \textit{driver operation} (i.e. ADS-DV). In these types of \textit{vehicles}, \textit{passengers} may be able to demand a \textit{vehicle} stop by, for example, pulling an emergency stop lever, and in response, the \textit{ADS} would achieve a \textit{minimal risk condition}.

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

For example:

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

- A level 4 \textit{ADS feature} designed to \textit{operate} a \textit{vehicle} in a high-speed convoy with small gaps between \textit{vehicles} may delay relinquishing performance of the \textit{DDT} to a \textit{user} upon his or her request to resume driving until after the \textit{ADS} has safely maneuvered the \textit{vehicle} out of the convoy, since (human) \textit{drivers} may not be capable of safely operating a \textit{vehicle} in a close-coupled convoy.
8.4 Driving vs. 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 (3.4) 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.

8.5 Comparison of J3016 driving automation levels with BASt and NHTSA levels

Prior to the initial publication of J3016 in January 2014, there were two published documents that described levels of driving automation with respect to motor vehicles and/or driving: The US National Highway Traffic Safety Administration (NHTSA)’s “Preliminary Statement of Policy Concerning Automated Vehicles” (May 30, 2013) and the German Federal Highway Research Institute’s (Bundesanstalt für Strassenwesen, a.k.a. BASt) “Legal consequences of an increase in vehicle automation” Tom M. Gasser et al. (July 23, 2013). After thorough review of both documents, including discussions with both authoring organizations, SAE Task Force members were persuaded that the BASt levels were more in line with the Task Force’s operating principles, namely, that SAE J3016 should be:

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

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

- Added a sixth level (namely, level 5 – full driving automation) not described in the BASt levels.
- Modified level names accordingly.
- Added supporting terms and definitions, such as DDT, minimal risk condition, etc.
- Described categorical distinctions that provide for a step-wise progression through the levels.
- Provided explanatory text and examples to aid the reader in understanding the levels, definitions, and their derivation.
After SAE J3016 was published in January, 2014, the International Organization of Motor Vehicle Manufacturers (Organisation Internationale des Constructeurs d’Automobiles, a.k.a., OICA) adopted the BASt levels and aligned them (in English) with SAE J3016, including adding a sixth level to represent "full driving automation."

However, BASt/SAE/OICA levels differ more fundamentally from the levels described by the National Highway Traffic Safety Administration (NHTSA) in its “Preliminary Statement of Policy Concerning Automated Vehicles” (May 30, 2013). NHTSA’s levels were intended to provide preliminary policy guidance to U.S. state and local governments contemplating legislation and/or regulation related to “automated/autonomous vehicles.” As such, NHTSA’s level descriptions are written in loosely descriptive terms using normative language and therefore do not provide the degree of definitional and functional clarity that are ultimately required to support the technical and policy discussions that lead to standards, norms and/or legal requirements.

Moreover, NHTSA’s levels purport to apply to vehicles, rather than to driving automation, which, as explained above, leads to confusion. The NHTSA levels also include features and functions that do not serve to automate part or all of the DDT on a sustained basis, such as anti-lock brake systems (ABS), electronic stability control (ESC), and lane keeping assistance systems (LKAS). These intervention-type active safety systems are not driving automation system features, because, DDT performance (partial or complete) is not sustained between and across external events during driving. Rather, these active safety systems are momentarily activated during a specific driving safety hazard scenario and then quickly cut out again, and activation of such systems also does not change the driver's role in terms of performing the DDT. (See Scope above.)

Finally, it should 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 ADS-equipped vehicles (i.e., levels 3-5) that perform the complete DDT, crash avoidance capability is part of ADS functionality.

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.