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SURFACE VEHICLE INFORMATION REPORT

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Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems

RATIONALE

This Information Report provides a taxonomy describing the full range of levels of automation in on-road *motor vehicles*. It also includes operational definitions for advanced levels of automation and related terms. This document provides a foundation for further standards development activities and a common language for discussions within the broader "Automated/Autonomous Vehicle" community.

1. SCOPE

This Information Report provides a taxonomy for motor vehicle automation ranging in level from no automation to *full automation*. However, it provides detailed definitions only for the highest three levels of automation provided in the taxonomy (namely, *conditional*, *high* and *full automation*) in the context of *motor vehicles* (hereafter also referred to as "*vehicle*" or "*vehicles*") and their operation on public roadways. These latter levels of advanced automation refer to cases in which the *dynamic driving task* is performed entirely by an *automated driving system* during a given *driving mode* or *trip*. Popular, media, and legislative references to "autonomous" or "self-driving" vehicles encompass some or all of these levels of automation. These definitions can be used to describe the automation of (1) on-road *vehicles*, (2) particular systems within those vehicles, and (3) the operation of those vehicles. "On-road" refers to public roadways that collectively serve users of *vehicles* of all classes and automation levels (including no automation), as well as motorcyclists, pedal cyclists, and pedestrians.

This document does not provide complete definitions applicable to lower levels of automation (namely, no automation, assisted, or partial automation), but they are described as points of reference to help bound the full range of vehicle automation. Active safety and driver assistance systems that partially and/or temporarily automate certain aspects of *vehicle* operation (including systems that automatically intervene to avoid and/or mitigate an emergency situation and then immediately disengage), but otherwise rely on a *human driver* to operate the motor vehicle in real time, are also not included within the *conditional*, *high*, and *full automation* taxonomy types that are the focus of this document.

2. REFERENCES

2.1 Applicable Documents

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

Tom M. Gasser and Daniel Westhoff, *BASt-study: Definitions of Automation and Legal Issues in Germany*, 2012 Road Vehicle Automation Workshop, Transportation Research Board, July 25, 2012, onlinepubs.trb.org/onlinepubs/conferences/2012/Automation/presentations/Gasser.pdf at 6.

"Preliminary Statement of Policy Concerning Automated Vehicles," National Highway Traffic Safety Administration, May 30, 2013, http://www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+Transportation+Releases+Policy+on+Automated+Vehicle+Development

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Bryant Walker Smith, SAE Levels of Automaton, http://cyberlaw.stanford.edu/LoDA (December 18, 2013)

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

Michon, J.A., 1985. A CRITICAL VIEW OF DRIVER BEHAVIOR MODELS: WHAT DO WE KNOW, WHAT SHOULD WE DO? In L. Evans & R. C. Schwing (Eds.). Human behavior and traffic safety (pp. 485-520). New York: Plenum Press, 1985.

3. TAXONOMY OF AUTOMATED DRIVING

TABLE 1 - SUMMARY OF LEVELS OF *DRIVING* AUTOMATION FOR ON-ROAD VEHICLES

SAE's levels of *driving* automation are descriptive 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 driver assistance system, combination of driver assistance systems, or *automated driving system*, as appropriate. This table also shows how SAE's levels definitively correspond to those developed by the Germany Federal Highway Research Institute (BASt) and approximately correspond to those described by the National Highway Traffic Safety Administration in its May 30, 2013, paper titled "Preliminary Statement of Policy Concerning Automated Vehicles." (See section 6.3, below.)

SAE level	SAE name	SAE narrative definition	Execution of steering and acceleration/ deceleration	Monitoring of driving environment	Fallback performance of *dynamic driving task*	System capability (*driving modes*)	BASt level	NHTSA level
***Human driver* monitors the driving environment**								
0	**No Automation**	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a	Driver only	0
1	**Driver Assistance**	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes	Assisted	1
2	**Partial Automation**	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes	Partially automated	2
***Automated driving system* ("system") monitors the driving environment**								
3	**Conditional Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the *dynamic driving task* with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes	Highly automated	3
4	**High Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes	Fully automated	3/4
5	**Full Automation**	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**		

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TABLE 2 - ROLES OF HUMAN DRIVER AND SYSTEM BY LEVEL OF DRIVING AUTOMATION

Table 2 describes the various levels of *driving* automation, covering the full spectrum from no automation to full automation. The descriptions provided in column 2 indicate the role (if any) of a *human driver* in the *dynamic driving task*. The descriptions provided in column 3 indicate the role (if any) of the *automated driving system* in the *dynamic driving task*. These roles describe technical capability and not legality. As in Table 1, "system" refers to the driver assistance system, combination of driver assistance systems, or *automated driving system*, as appropriate.

Level of Driving Automation	**Role of *Human Driver***	**Role of System**
***HUMAN DRIVER* MONITORS DRIVING ENVIRONMENT**		
Level 0 - No Automation	• Monitors *driving* environment • Executes the *dynamic driving task* (steering, accelerating, braking)	• No active automation (but may provide warnings)
Level 1 - Driver Assistance	• Monitors *driving* environment • Executes either longitudinal (accelerating, braking) or lateral (steering) *dynamic driving task* • Constantly supervises *dynamic driving task* executed by driver assistance system • Determines when activation or deactivation of driver assistance system is appropriate, except for systems that automatically intervene in an emergency • Takes over immediately when required	• Executes portions of the *dynamic driving task* not executed by the *human driver* (either longitudinal or lateral) when activated • Can deactivate immediately with request for immediate takeover by the *human driver*
Level 2 - Partial Automation	• Monitors *driving* environment • Constantly supervises *dynamic driving task* executed by partial automation system • Determines when activation or deactivation of partial automation system is appropriate, except for systems that automatically intervene in an emergency • Takes over immediately when required	• Executes longitudinal (accelerating, braking) and lateral (steering) *dynamic driving task* when activated • Can deactivate immediately with request for immediate takeover by the *human driver*

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***AUTOMATED DRIVING SYSTEM* MONITORS DRIVING ENVIRONMENT**		
Level 3 - Conditional Automation	• Determines when activation of *automated driving system* is appropriate • Takes over upon request within lead time • May request deactivation of *automated driving system*	• Monitors *driving* environment when activated • Permits activation only under conditions (use cases) for which it was designed • Executes longitudinal (accelerating, braking) and lateral (steering) portions of the *dynamic driving task* when activated • Deactivates only after requesting *driver* takeover with a sufficient lead time • May, under certain, limited circumstances, transition to *minimal risk condition* if *human driver* does not take over • May momentarily delay deactivation when immediate human takeover could compromise safety
Level 4 - High Automation	• Determines when activation of *automated driving system* is appropriate • Takes over within lead time, if requested • May request deactivation of *automated driving system* • Some applications in this category may not entail a human driver.	• Monitors *driving* environment when activated • Permits activation only under conditions (use cases) for which it was designed • Executes longitudinal (accelerating, braking) and lateral (steering) portions of the *dynamic driving task* when activated • Initiates deactivation when design conditions are no longer met • Deactivates only after *human driver* takes over • Transitions to *minimal risk condition* if *human driver* does not take over • May momentarily delay deactivation when immediate human takeover could compromise safety
Level 5 - Full Automation	• May activate *automated driving system* • May request deactivation of *automated driving system* • This category may not entail a human driver.	• Monitors *driving* environment when activated • Executes longitudinal (accelerating, braking) and lateral (steering) portions of the *dynamic driving task* when activated • Deactivates only after *human driver* takes over or *vehicle* reaches its destination • Transitions to *minimal risk condition* as necessary if failure in the *automated driving system* occurs • May momentarily delay deactivation when immediate *human driver* takeover could compromise safety

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TABLE 3 - SIMPLIFIED TO HIGHLIGHT ROLES OF *HUMAN DRIVERS* AND *AUTOMATED DRIVING SYSTEM*

Table 3 mirrors Table 2, but focuses specifically on the relative roles of a *human driver* versus the system. As in Tables 1 and 2, "system" refers to the driver assistance system, combination of driver assistance systems, or *automated driving system*, as appropriate. The characteristics presented below represent minimum, rather than maximum capabilities, for each level of automation. For example, a particular *conditional automated driving system* might be capable of transitioning to a *minimal risk condition* in many but not all situations.

Level of Driving Automation	Execution of steering / acceleration / deceleration	Monitoring of driving environment	Transition time between *human driver* and system?	*Minimal risk condition* capable at all times?	*Human driver* necessary while system is engaged?	*Driving modes* of the *automated driving system*
***HUMAN DRIVER* MONITORS DRIVING ENVIRONMENT**						
Level 0 - No Automation	*Human driver*	*Human driver*	n/a	n/a	Yes	None
Level 1 – Driver Assistance	*Human driver* and System	*Human driver*	No	No	Yes	Some
Level 2 - Partial Automation	System	*Human driver*	No	No	Yes	Some
***AUTOMATED DRIVING SYSTEM* MONITORS DRIVING ENVIRONMENT**						
Level 3 - Conditional Automation	System	System	Yes	No	Yes	Some
Level 4 - High Automation	System	System	Yes	Yes	No	Some
Level 5 – Full Automation	System	System	Yes	Yes	No	All

4. DEFINITIONS

4.1 AUTOMATED DRIVING SYSTEM

The hardware and software that is collectively capable of performing all aspects of the *dynamic driving task* for a *vehicle* (whether part time or full time).

4.2 DRIVE

To operate a *vehicle* on a public or private roadway at any point at or between an origin and a destination, whether or not the *vehicle* is in motion.

4.3 DRIVING MODE

A type of *driving* scenario with characteristic *dynamic driving task* requirements (e.g., expressway merging, high speed cruising, low speed traffic jam, etc.).

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4.4 DYNAMIC DRIVING TASK

All of the real-time functions required to operate a *vehicle* in on-road traffic, excluding the selection of destinations and waypoints (i.e., navigation or route planning) and including without limitation:

- Object and event detection, recognition, and classification;
- Object and event response;
- Maneuver planning;
- Steering, turning, lane keeping, and lane changing;
- Acceleration and deceleration;
- Enhancing conspicuity (lighting, signaling and gesturing, etc.).

4.5 HUMAN DRIVER

The person who *drives* a particular *vehicle,* and who, in a vehicle equipped with an *automated driving system,* exchanges the *dynamic driving task* with such a system as necessary during vehicle operation.

4.6 MINIMAL RISK CONDITION

A low risk *motor vehicle* operating condition to which an *automated driving system* automatically resorts upon either a system failure or a failure of a *human driver* to respond appropriately to a request to take over the *dynamic driving task*.

NOTE: A *minimal risk condition* will vary according to the type and extent of a given failure. A *minimal risk condition* could entail automatically bringing the vehicle to a stop, preferably outside of an active lane of traffic (assuming availability).

4.7 MONITOR

The activities and/or automated routines that accomplish comprehensive object and event detection, recognition, classification, and response preparation, as needed to competently perform the *dynamic driving task*.

NOTE: When driving vehicles that are not equipped with *automated driving systems*, *human drivers* visually sample the road scene sufficiently to competently perform the *dynamic driving task*, 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* does not entail constant eyes-on-road time by the *human driver*.

4.8 MOTOR VEHICLE (and VEHICLE)

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. [Source: 49 U.S.C. § 30102(a)(6)]

4.9 REQUEST TO INTERVENE

Notification by the *automated driving system* to a *human driver* that s/he should promptly begin or resume performance of the *dynamic driving task*.

4.10 TRIP

The traversal of an entire travel pathway by a *vehicle* from the moment it is turned “on” at a point of origin to when it is turned “off” at a waypoint or destination.

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5. LEVELS OF DRIVING AUTOMATION

5.1 LEVEL 0 - NO AUTOMATION

The full-time performance by the *human driver* of all aspects of the *dynamic driving task.*

5.2 LEVEL 1 - DRIVER ASSISTANCE

The part-time or *driving mode*-dependent execution by a driver assistance system of either steering or acceleration/deceleration with the expectation that the *human driver* performs all other aspects of the *dynamic driving task.*

5.3 LEVEL 2 - PARTIAL AUTOMATION

The part-time or *driving mode*-dependent execution by one or more driver assistance systems of both steering and acceleration/deceleration with the expectation that the *human driver* performs all other aspects of the *dynamic driving task.*

5.4 LEVEL 3 - CONDITIONAL AUTOMATION

The part-time or *driving mode*-dependent performance by an *automated driving system* of all aspects of the *dynamic driving task* with the expectation that the *human driver* will respond appropriately to a *request to intervene*.

5.4.1 Notes

- *Conditional automation* requires a *human driver* to initiate an *automated driving system* at the appropriate point during a *trip* and requires a human driver to resume the *dynamic driving task* when s/he receives a *request to intervene* (e.g., due to a vehicle or system malfunction or a change in driving conditions that exceed the *automated driving system's driving mode*-dependent capability).

- As a technical matter, a *human driver* need not monitor the *automated driving system's* performance while it is engaged, but must be prepared to resume the *dynamic driving task* when the *automated driving system* issues a request to intervene.

- A *conditional automated driving system* will alert (i.e., by issuing a *request to intervene*) the *human driver* of the need to resume the *dynamic driving task* with sufficient time for a typical *human driver* to respond appropriately.

- An "appropriate" response by a *human driver* to a *request to intervene* may vary depending upon immediate circumstances (e.g., steering, braking, or simply maintaining current input levels), but otherwise entails the timely, safe and correct performance of the *dynamic driving task* for the prevailing circumstances.

5.4.2 Examples

EXAMPLE: A *vehicle* equipped with an *automated driving system* capable of performing the complete *dynamic driving task* in low-speed traffic, such as in stop-and-go urban or freeway traffic.

5.5 LEVEL 4 - HIGH AUTOMATION

The part-time, *driving mode*-dependent, or geographically-restricted performance by an *automated driving system* of all aspects of the *dynamic driving task*, even if a *human driver* fails to respond appropriately to a *request to intervene*.

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5.5.1 Notes

- *High automation* generally requires a *human driver* to engage an *automated driving system* at the appropriate point during a *trip* (e.g., a *human driver* may activate the *automated driving system* during a specific *driving mode,* such as freeway driving, for which the *high automated driving system* is designed).

  – Examples of exceptions to the general case:

    - A high automation parking application for which a human driver is not present in the vehicle during the maneuver.
    - A high automation shuttle system that is geographically restricted to operation on a closed or semi-closed campus (e.g., residential community, military base, etc.)

- As a technical matter, a *human driver* need not monitor the *automated driving system's* performance while it is engaged, but should in the general case be prepared to assume performance of the *dynamic driving task* when the *automated driving system* issues a *request to intervene*.

- A *high automated driving system* will alert a *human driver* several seconds in advance of the need to resume the *dynamic driving task (i.e., by issuing a request to intervene)*; however, the *automated driving system* is capable of restoring the vehicle to a *minimal risk condition* automatically if a *human driver* fails to resume the *dynamic driving task* when prompted. This capability to automatically restore the vehicle to a *minimal risk condition* is the only difference between *high automation* and *conditional automation*, above.

5.5.2 Examples

EXAMPLE 1: A *vehicle* equipped with an *automated driving system* capable of performing the complete *dynamic driving task* during a valet parking operation (i.e., curb-to-door or vice versa) without any human agency or monitoring. (Note: The presence of a *human driver* in the vehicle during the parking maneuver is not required as a technical matter.)

EXAMPLE 2: A *vehicle* equipped with an *automated driving system* capable of performing the complete *dynamic driving task* during sustained operation on a motorway or freeway. (Note: The presence of a *human driver* in the vehicle is required, as a technical matter, in order to perform the *dynamic driving task* before entering, and after leaving, the motor way or freeway.)

EXAMPLE 3: A *vehicle* equipped with an *automated driving system* capable of performing the complete *dynamic driving task* while following a pre-defined route within a confined geographical area, such as a campus shuttle. (Note: The presence of a *human driver* in the vehicle is not required, as a technical matter, while completing the prescribed delivery route.)

5.6 FULL AUTOMATION (LEVEL 5)

The unconditional, full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under, at minimum, all roadway and environmental conditions that can be managed by a *human driver*, including the ability to automatically bring the motor vehicle into a *minimal risk condition* in the event of a critical vehicle or system failure, or other emergency event.

5.6.1 Notes

- As a technical matter, a *human driver* need not monitor the *automated driving system's* performance.

- When the *automated driving system* reaches the limits of its functional capabilities, it will restore the *vehicle to a minimal risk condition* automatically.

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5.6.2 Examples

EXAMPLE: A *vehicle* with an *automated driving system* that, once programmed with a destination, is capable of fully performing the *dynamic driving task* throughout complete *trips* on public roadways, regardless of the starting and end points or intervening road, traffic, and weather conditions.

6. OTHER TERMS USED FOR HIGH OR FULL AUTOMATION

6.1 The following are common, but often confusing, vernacular terms for *high* or *full automation* of the *dynamic driving task*:

- Autonomous
- Self-driving
- Driverless
- Unmanned
- Robotic
- Autonomated

7. ADDITIONAL DISCUSSION

7.1 No automation, driver assistance, and partial automation

The three lower levels of *driving* automation are defined for the sake of taxonomical completeness. These levels of automation may feature certain driver assistance systems, including certain automatic emergency intervention systems, that operate with the expectation that the *human driver* monitors the driving environment. (In contrast, the *automated driving systems* that are characteristic of the three upper levels of *driving* automation operate with the expectation that the *human driver* need not, and therefore will not, continuously monitor the driving environment.)

7.2 Conditional, high and full automation

Conditional and *high automation* are the same, except that the former may or may not include limited automated capability to bring the vehicle to a *minimal risk condition*, while the latter always includes *minimal risk condition* capability. Both *conditional* and *high automation* entail that the *automated driving system* performs the *dynamic driving task* normally performed by a *human driver*, but only when enabled by one, and only for a limited period of time and/or in a specified geographical location, *driving mode*, or during specific, finite maneuvers. By contrast, *full automation* is capable of complete performance of the *dynamic driving task* throughout complete trips, and – at minimum – under all roadway and environmental conditions that can be managed by a human driver.

- During *conditional automated driving*, a *human driver* is present in the vehicle and is in a position to take over the *dynamic driving task* within a reasonable period of time after being prompted by the *automated driving system* with a *request to intervene*, or when the *human driver otherwise chooses* to resume the *dynamic driving task*.

- During *high automated driving*, the presence of a *human driver* in a position to assume the *dynamic driving task* is not always necessary as a technical matter, depending upon the application in question.

- During *full automated driving*, there is no need for a *human driver* to be present and in a position to assume the *dynamic driving task*, because the *automated driving system* is capable of performing all aspects of the *dynamic driving task*, including restoring the motor vehicle to a *minimal risk condition* in the event of a critical vehicle or system malfunction, or other emergency event, such as a weather condition requiring evacuation or other evasive action.

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For example, as a technical matter, a *high automated* parking application that automatically un-parks a vehicle and presents it curb-side for *human driver* entry would not require the presence of a *human driver* in a position to assume the *dynamic driving task* during the prescribed maneuver, because the maneuver is designed to be executed before human occupancy and because *high automation* applications are always capable of restoring the *motor vehicle* to a *minimal risk condition*.

However, a *high automation* application that a *human driver* engages under limited access freeway operation to automatically follow a lead vehicle at a fixed distance does require the presence of a *human driver* in a position to assume the *dynamic driving task* when prompted by the *automated driving system*, regardless of *minimal risk condition* capability, because such *driving mode*-dependent automation relies on the presence of a *human driver* both to initiate the application, and to take over when the application is terminated (whether voluntarily by a *human driver* or automatically by the *automated driving system*).

For both conditional and high automation, a *human driver* is expected to take over the *dynamic driving task* when prompted by the *automated driving system* to do so. (Note: for certain high automation applications, such as an automated campus shuttle that has no human driver, this would not apply, and the system would not provide prompts.) The reasons for such prompts being issued may vary according to design intent, but at a minimum, such prompts would be expected in situations that exceed the operational limits of the *automated driving system* or in the event of a critical vehicle or system malfunction. If the *automated driving system* detects a condition that calls for a *request to intervene*, it will prompt the *human driver* to resume the *dynamic driving task* and provide an adequate transition time. For example: A *conditional* or *high automated driving system* activated in a traffic jam on a freeway detects an upcoming construction area and signals to the *human driver* that s/he should resume the *dynamic driving task* in several seconds.

In cases where immediate release of the *dynamic driving task* by the *automated driving system* could compromise vehicle performance, the system may delay its release of (i.e., more gradually relinquish) the *dynamic driving task* to ensure a smooth transition to a *human driver's* resumption of the *dynamic driving task*. For example, if the vehicle is engaged in a tight turning maneuver, the *automated driving system* may not release steering control instantaneously, but instead do so gradually as the driver indicates through steering input that s/he is fully re-engaged in the *dynamic driving task*.

In the case of *high automation*, should a *human driver* fail to respond to a *request to intervene* by the *automated driving system*, it will automatically resort to a *minimal risk condition* by, for example, parking the vehicle on the road shoulder. *Full automated driving systems* may or may not include prompts for *human drivers*, depending upon design intent, but will in any case automatically restore the vehicle to a *minimum risk condition* when necessary (and with at least the level of performance that could be expected from a *human driver* under the same conditions).

The following are some examples of *conditional* or *high automated driving modes*:

- Automated parking: Parallel on-street or parking lot maneuvers performed without any real-time *human driver* input.
- Autopilot freeway: Combination of high speed lane keeping, adaptive cruise control (ACC), merging, passing, obstacle avoidance
- Autopilot neighborhood: Combination of slow speed lane keeping, ACC, merging, passing, obstacle avoidance
- Autopilot traffic jam: In a traffic jam the vehicle maintains its headway and lateral lane position

As noted above, *high automation* also includes shuttles that operate without a human driver in limited geographic areas.

At the highest level of driving automation, *full automation* provides the capability for a vehicle to "drive itself" without the need for intervention or monitoring by a *human driver* throughout complete *trips*, and under all on-road and environmental conditions that could be managed by a *human driver*. For a vehicle to be considered "fully automated," the *automated driving system* must perform the entire *dynamic driving task* between points of origin and destination determined by users. There may or may not be a *human driver* available and able to perform the *dynamic driving task*, and the *automated driving system* must be capable of returning the vehicle to a minimal risk condition automatically.

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Full automation represents the extreme end of the spectrum of automation in vehicle technology and forms the counterpart to no automation at the other end. There are technical challenges related to reliability and unique problems presented by operating vehicles equipped with *automated driving systems* on public roadways shared by vehicles without such systems, pedal cyclists and pedestrians. (It should also be noted that there are legal and institutional challenges related to all levels of *automated driving system* technology that remain to be resolved.)

7.3 Comparison with BASt and NHTSA Automation Hierarchies

The levels of automation described in this document are fairly consistent with, but not identical to, the levels of automation proposed by the German Federal Highway Research Institute (BASt) and to those described by the National Highway Traffic Safety Administration (NHTSA) in its "Preliminary Statement of Policy Concerning Automated Vehicles" (May 30, 2013).

These SAE levels differ substantively from the BASt levels principally insofar as the latter omit the 5th level of driving automation characterized by trip-level and geographically unconstrained on-road automated driving (i.e., an automated vehicle capable of all on-road driving – without geographical or modal limitation – that can be legally performed by a human driver). As noted above, this highest level of automation was included herein for the sake of completeness. It should also be noted that the SAE term *conditional automation* corresponds to the BASt term "highly automated" and that the SAE term *high automation* corresponds to the BASt term "fully automated." Notwithstanding these differences in terminology, the functional definitions for these BASt and SAE levels are the same.

With regard to the NHTSA's defined levels of automation the main functional difference is that the agency's definitions compress SAE levels 4 and 5 into NHTSA level 4. NHTSA's definitions for each level also contain normative content intended to provide preliminary guidance to US State governments that have adopted, or are considering adopting, statutory and/or regulatory requirements for automated vehicles. By contrast, the definitions provided in this document are descriptive only, deliberately avoiding normative terms and statements, and are not intended to be treated as requirements.

The following is a summary table that illustrates the close functional alignment among the three sets of driving automation levels from SAE, BASt, and NHTSA. Those who are already familiar with these levels may find this chart useful when considering differences in the descriptive text provided for each level by the three organizations, as it highlights the fact that, notwithstanding these differences, for practical purposes the three sets of levels are much more alike than different.

TABLE 4 - APPROXIMATE ALIGNMENT AMONG SAE, BAST, AND NHTSA LEVELS/TERMS

SAE	No Automation (Level 0)	Driver Assistance (Level 1)	Partial Automation (Level 2)	Conditional Automation (Level 3)	High Automation (Level 4)	Full Automation (Level 5)
BASt	Driver Only	Assisted	Partly Automated	Highly Automated	Fully Automated	(not addressed)
NHTSA	No Automation (Level 0)	Function Specific Automation (Level 1)	Combined Function Automation (Level 2)	Limited Self-Driving Automation (Level 3)	Full Self-Driving Automation (Level 4)	

In considering the differences between the SAE and NHTSA levels, it is helpful to bear in mind that NHTSA's level 4 straddles SAE levels 4-5 in a manner that is not as simple as BASt's decision to omit "full" automation. For example, certain *automated driving systems* that are geographically or environmentally limited are included in NHTSA's level 4 rating because they do not require the presence of a human driver, while SAE level 5 excludes such systems, because they are not capable of delivering the same degree of on-road mobility as a conventional vehicle driven by a human.

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7.4 Driving vs. Dynamic Driving Task

Driving entails a variety of decisions and actions, which may or may not involve the vehicle being in motion or even being in an active lane of traffic. The *dynamic driving task* 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.

The overall act of driving can be divided into three types of driver efforts: Strategical, Tactical, and Operational (Michon, 1985). Strategical effort involves trip planning, such as deciding where to go, how to travel, best routes to take, etc. Tactical effort involves maneuvering the vehicle in traffic during a trip, including deciding when and whether to overtake another vehicle or change lanes, selecting and maintaining 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 event in the vehicle's pathway.

The definition of *dynamic driving task* provided above (3.4) includes Tactical and Operational effort, but excludes Strategical effort.

The Object and Event detection, recognition, classification, and response form a continuum of activities often cited in the Driver Workload literature. However in the case of *automated driving systems*, this specifically also includes *driving* events associated with system actions (e.g., undiagnosed automation errors or automation state changes).

8. NOTES

8.1 Marginal Indicia

A change bar (I) 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.

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