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Automated Vehicle Safety Consortium™
A Program of SAE ITC

Automated Vehicle Safety Consortium™ Best Practice

AVSC Best Practice for In-Vehicle Fallback Test Driver Selection, Training, and Oversight Procedures for Automated Vehicles Under Test

Rationale

AVSC Best Practice for in-vehicle fallback test driver (safety operator) selection, training, and oversight procedures for automated vehicles under test provides a detailed view of the safety considerations for training automated vehicle (AV) test personnel. It outlines recommended criteria and processes for selecting and training test personnel providing oversight during AV testing and in-cabin procedures. It also provides pre-work shift and post-work shift recommendations. It supports and operationalizes the general principle that "In-vehicle fallback test drivers (IFTDs) will be thoroughly trained on the automated driving system, the operational design domain, and controlling the vehicle."

Preface

The Automated Vehicle Safety Consortium™ (AVSC) is an industry program of SAE Industry Technologies Consortia (SAE ITC®) developing principles that will inform and help lead to industry-wide standards for advancing automated driving systems. The members of this consortium have long been focused on the development of safe, reliable, and high-quality vehicles, and are committed to applying these same principles to Level 4 and Level 5 automated vehicles so communities, government entities, and the public can be confident that these vehicles will be deployed safely.

The Consortium recognizes the need to establish safety principles for the operation of automated vehicles (AVs). These technology-neutral principles are key considerations for safely deploying AVs on public roads. Members of the AVSC intend to support these principles and practices in their processes and publish them in an effort to establish a suggested level for other industry participants to meet. These principles will serve as a basis to enhance and expedite the formal industry standards development process through SAE International and other global standards development bodies. Effectively implementing these principles can help inform the development of sound and effective automated driving system regulations and safety assurance testing protocols that will engender public confidence in the safety and efficacy of automated driving system (ADS)-operated vehicles.

Comment and open discussion on the topics are welcome in appropriate industry forums. As discussion unfolds, AVSC documents will be revised as significant information and/or new approaches come to light that would increase public trust.

Introduction

In 2016, the National Highway Transportation Safety Administration (NHTSA) published *Accelerating the Next Revolution in Roadway Safety*, the first of three published documents for automated vehicle guidance. This guidance was amended in 2017 and re-confirmed in 2018, suggesting that developers "demonstrate to the public (particularly States and consumers) that entities are: (1) considering the safety aspects of ADSs; (2) communicating and collaborating with DOT; (3) encouraging the self-establishment of industry safety norms for ADSs; and (4) building public trust, acceptance, and confidence through transparent testing and deployment of ADSs. It also allows companies an opportunity to showcase their approach to safety, without needing to reveal proprietary intellectual property."[1]

This document supports NHTSA's guidance by demonstrating (1) safety considerations related to the training process for IFTDs; (2) a public statement to the Department of Transportation (DOT) regarding safety training; (3) a baseline against which industry can improve and develop formal, open standards; and (4) increasing public trust, acceptance, and confidence by providing additional transparency.

States with concerns over IFTD should request a summary of training provided[2]. This document can be used as a template against which those summaries could be compared.

AVSC Best Practice for in-vehicle fallback test driver (safety operator) selection, training, and oversight procedures for automated vehicles under test provides a detailed view of the safety considerations for training AV test personnel. It outlines recommended criteria and processes for selecting and training test personnel providing oversight during AV testing and in-cabin procedures. It also provides pre-work shift and post-work shift recommendations. In-vehicle fallback test drivers will be thoroughly trained on the automated driving system, the operational design domain, and controlling the vehicle.

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1. Scope

This Automated Vehicle Safety Consortium (AVSC) *Best Practice for in-vehicle fallback test driver (safety operator) selection, training, and oversight procedures for automated vehicles under test* (AVSC00001201911) **addresses the qualifications and training for on-board human oversight of testing for automated driving system (ADS)-operated vehicles**. It provides an outline with criteria commonly agreed to by members of the AVSC. It applies to humans within the vehicle responsible for the safe oversight of development and testing SAE Level 4 and Level 5 automated driving systems on public roads. Where applicable, the outline provides recommended timeframes for rest periods and active supervision of testing based on developer experience with the complexity of their systems and research involving human limitations. This AVSC Best Practice does not provide specifications, or otherwise impose requirements, on the safe oversight of driving automation systems (i.e., SAE Level 1 or Level 2). It does not apply to ADS at SAE Level 3. This document should be considered as operational requirements for IFTDs supervising the test and development of SAE L4/L5 ADS-operated vehicles on public roads. It does not address ADS behaviors or reliability, which should be evaluated using sub-system testing, computer simulation, and controlled track testing prior to operating vehicles on public roads.

For the purposes of this document, "ADS Testing Organization" refers to vehicle manufacturers, ADS developers, or other organizations responsible for testing ADS-operated vehicles.

[1] *Automated Driving Systems 2.0: A vision for safety*, 2017. National Highway Transportation Safety Administration (p.16).
[2] *Automated Driving Systems 2.0: A vision for safety*, 2017. National Highway Transportation Safety Administration (p.24).

1.1 Purpose

The guidance provided in this document is intended for use by the technical community (developers, manufacturers, testers, etc.), as well as States and other infrastructure owner-operators (IOOs) and the general public. These stakeholders can compare the best practices identified against their procedures or use them as a benchmark. The information should be considered baseline operational criteria for human oversight for safe testing of SAE L4/L5 ADS-operated vehicles. Individual developers should tailor programs and documentation for the technologies, behaviors, and operating domains for their ADS-operated vehicles. States and IOOs can utilize this document as a reference to develop questions to pose to developers and technology companies wanting to operate in their jurisdictions; companies should respond with detailed documentation on their practices. Finally, the public will benefit from the consistent communication of the process and type of training completed by IFTDs. The document outlines the processes and types of training for ADS-operated vehicles, including:

1. Driver selection
2. Basic driver training
3. ADS-operation training
4. Initial driving on public roads
5. Periodic re-evaluation and training

2. References

2.1 Applicable Documents

The following publications were referenced during development of this document. Where appropriate, documents are cited.

2.1.1 SAE Publications

Unless otherwise indicated, the latest issue of SAE publications apply. Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J3016_201806	Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles
SAE J3018_201909	Safety-Relevant Guidance for On-Road Testing of SAE Level 3, 4, and 5 Prototype Automated Driving System (ADS)-Operated Vehicles

2.1.2 Other Documents

Automated Driving Systems: A vision for safety (AV2.0). National Highway Transportation Safety Administration (NHTSA), 2017.

Code of Practice: Automated vehicle trialling. Centre for Connected and Autonomous Vehicles, 2019.

Preparing for the Future of Transportation (AV3.0). NHTSA, 2018.

Technical Reference – Autonomous Vehicles – Part 2: Safety. Singapore Standards Council, 2019.

Testing of Autonomous Vehicles, California State Regulations, Title 13, Division 1, Chapter 1, Article 3.7, §227.50.

Deployment of Autonomous Vehicles, California State Regulations, Title 13, Division 1, Chapter 1, Article 3.8.

Testing Highly Automated Vehicles in Canada: Guidelines for trial organizations. Transport Canada, 2018.

3. Definitions

For clarity, relevant industry definitions for standard terms are reproduced here.

FALLBACK TEST DRIVER (SAE J3018_201909): A person specially trained and skilled in supervising the performance of prototype ADS-operated vehicles in on-road traffic for testing purposes.

NOTE: Unlike a “fallback-ready user,” which is a unique term defined in SAE J3016 for Level 3 features, a fallback test driver applies specifically to testing of prototype ADS-operated vehicles at Levels 3, 4, or 5.

IN-VEHICLE FALLBACK TEST DRIVER (IFTD) (SAE J3018_201909): A fallback test driver of a prototype ADS-operated vehicle who is capable of safely responding to unexpected ADS and vehicle behaviors in a variety of operating situations, including hazardous ones, by exercising in-vehicle braking, accelerating, steering, and transmission position selection input devices.

NOTE: An IFTD becomes a conventional (test) driver after s/he assumes performance of the complete DDT.

DYNAMIC DRIVING TASK (DDT) (SAE J3016_201806): All of the real-time operational and tactical functions required to operate a vehicle in on-road traffic, excluding

the strategic functions such as trip scheduling and selection of destinations and waypoints, and including, without limitation:

- Lateral vehicle motion control via steering (operational);
- Longitudinal vehicle motion control via acceleration and deceleration (operational);
- Monitoring the driving environment via object and event detection, recognition, classification, and response preparation (operational and tactical);
- Object and event response execution (operational and tactical);
- Maneuver planning (tactical); and
- Enhancing conspicuity via lighting, signaling, and gesturing, etc. (tactical).

DISENGAGEMENT: Testing of Autonomous Vehicles, CA, Title 13, Div 1, Chapter 1, Article 3.7, §227.50 defines *disengagement* as the "deactivation of the autonomous mode when a failure of the autonomous technology is detected or when the safe operation of the vehicle requires that the autonomous vehicle test driver disengage the autonomous mode and take immediate manual control of the vehicle…"

NOTE: The term "disengagement" is often used colloquially *any time* the automated system is turned off and the human takes over the DDT (having nothing to do with technology failure or safe operation might include the completion of a prescribed test, ODD transition, IFTD rest, etc.). Because of this, the AVSC does not utilize the term "disengagement" beyond this explanation.

OBJECT AND EVENT DETECTION AND RESPONSE (OEDR) (SAE J3016_201806): The subtasks of the DDT that include *monitoring and 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).

OPERATIONAL DESIGN DOMAIN (ODD) (SAE J3016_201806): Operating conditions under which a given *driving automation system* or feature thereof is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics.

NOTE: Readers are encouraged to read SAE J3016_201806 section 3.22 in its entirety for a thorough discussion of ODD including examples.

4. In-Vehicle Fallback Test Driver Characteristics and Training Framework

The sole responsibility of an IFTD is to ensure the safe operation of an ADS-operated vehicle under test whenever the ADS is responsible for the DDT. When not under control of the ADS, the IFTD becomes a "traditional" [test] driver. The selection and training of these human fallback systems is critical to avoid mishaps on public roadways. The duties of an IFTD include two high-level functions: (1) anticipating a failure condition; and (2) controlling a vehicle during a failure condition, should one occur. ADS Testing Organizations should thoroughly train IFTDs in how the ADS-enabled vehicle they are overseeing performs OEDR, planning, and executes the DDT. They should also be thoroughly familiar with the ODD in which the vehicle will be tested, maturity of the technology, and the mission or test parameters.

4.1 Driver Selection

Driving experience. ADS Testing Organizations should verify that IFTDs are licensed drivers with at least 3 years' experience and a valid, government-issued license for the class of vehicle under test.

Record checks. Companies conducting ADS-operated vehicle testing on public roadways should conduct checks of their drivers' records. Prior to being selected as an IFTD, the applicant must at least have no serious moving violations on their record during the three-year period prior to applying to become an IFTD. Serious violations may include excessive speeding, DUI, vehicular manslaughter, hit-and-run, street racing, etc.

Driving evaluation. A basic driving evaluation should be conducted in the early stages of the IFTD recruitment/

FIGURE 1 IFTD training framework consists of processes and types of training for ADS-operated vehicles.

selection process. Applicants must pass a basic driving skills assessment.

Mindset. In-vehicle fallback test driver candidates should be evaluated during the selection process through a series of interviews and questionnaires to ensure they have a safety mindset. Their demeanor, motivation, and communication skills are evaluated, as well as their affinity for technology. In-vehicle fallback test drivers should be interested in new technologies, but not naively confident of performance and reliability, especially during early-stage testing and development. Their role is especially challenged because, as technology improves and errors or failure states become rarer, test drivers must maintain their vigilance for more prolonged periods. Repeated success during test does not reduce the need for oversight vigilance. The mindset for an IFTD is one that should expect and anticipate failure during testing.

Drug screening. In-vehicle fallback test drivers should be subjected to a minimum five-panel drug test (opiates, cocaine, marijuana, phencyclidine or PCP, and amphetamines/methamphetamines) as soon as practicable by a third party during the selection process.

Criminal background check. A background check going back at least three years for safety-related violations, offenses, and felonies should be conducted for all applicants. Any felony during the reporting period is grounds for disqualification. Additional analysis and individualized assessments should be conducted for applicants in compliance with applicable state laws.

4.2 Basic Driver Training

ADS Testing Organizations should train IFTDs progressively, building on skills and introducing increasing levels of complexity. Hands-on training starts with basic driver training in controlled environments.

Controlled environment training. In-vehicle fallback test driver training begins in the classroom and progresses to closed course training for manual (traditional) driving before assuming responsibility for testing an ADS-operated vehicle on the public roads. Basic driver training should include general understanding of manual vehicle handling and dynamics using a combination of lessons and practical application in:

- State and local laws.
- Basic manual driving skills focused on understanding vehicle dynamics and control, such as stopping distances, smooth acceleration, and braking.
- Evasive maneuvers and maintaining control following an evasive maneuver.
- Defensive driving skills, such as sound decision making and judgement training; knowledge of the driving environment and human behavior to improve anticipatory skill; techniques to maintain focus and remain alert during driving and to recognize degraded states of attention; and additional fundamental driving skills, such as knowing how to safely and legally pass, make proper turns, etc.
- Familiarization with the base vehicle technology (e.g., AEB).

Interaction training. Driver interaction training introduces elements of the targeted operational design domain (ODD) in which the ADS will be tested. This includes manual operation of the vehicle in controlled conditions and in or around the intended ODD, including the infrastructure and other road users in representative scenarios. Some scenarios may include, but are not limited to, handling blind spots, negotiating intersections, navigating multiple lane traffic, managing merging traffic, and situations with other road users that may result in conflict or direct challenges to the ADS's performance of the DDT (perhaps by aggressive drivers or pedestrians). Interaction training includes ride-along and supervised driving on public roads.

Evaluation/assessment of skills. Upon completion of basic driver training, IFTDs must pass a written exam and demonstrate their driving skills on a closed course and/or on road with an experienced instructor. This is a stage-gate that must be met prior to progressing to more advanced training on the ADS technology and vehicle dynamics.

4.3 ADS Training

ADS in-classroom instruction. Classroom instruction is an introduction to the technology used in the ADS-equipped vehicle. It includes: ADS technology training, such as OEDR and the type of sensors used on the vehicle, their role in OEDR, and the relative strengths and weaknesses of each sensor modality. This type of training provides improved awareness and knowledge about the technologies used so the IFTD can properly calibrate their trust in the ADS as conditions change during and between trips. IFTDs should also be instructed in:

- Conducting pre-trip, in-trip, and post-trip protocols (specifically, the IFTD must gain an understanding of the intention of the protocol and what constitutes a successful completion of the protocol).
- Understanding the ADS human-machine interface (HMI):
  - Engaging/disengaging the ADS-function.
  - Recognizing when the ADS is/is not engaged to avoid confusion over responsibility of the DDT.

- Understanding ADS limitations including sensor limitations, control limitations, and behavior limitations. This type of training supports the ability to anticipate potential error states, recognize limitations or safety events, and take control *prior to* a potentially unsafe condition.
- Effective communication skills are essential for the safe oversight of ADS-operated vehicles. *During early-stage testing*[3], it is recommended that at least two humans are on board vehicles during test and development. Two-person crews allow the IFTD to focus on safety while ensuring all systems and environmental factors are monitored. The addition of a co-driver (also called assistant driver, technician, or engineer) necessitates the ability to communicate clearly and concisely without hesitation. A clear division of labor on-board the vehicle (who is specifically responsible for what) will facilitate communications and minimize the duplication of effort; however, either member of the team must be free to communicate *any* potential issue of concern. Communications may include topics such as:
  - Key items or events to be included in trip notes (note taking).
  - Communication between vehicle and control facilities.
  - Communication between IFTD and human co-driver to communicate important environmental situations, objects, and report important system statuses to ensure readiness and safe operation.

IFTDs (and all vehicle test personnel) should be trained to document ADS safety and performance concerns and be encouraged to openly share them.

Closed course (controlled environment) in-vehicle ADS operation. Closed course training and practical application with the ADS to be tested includes the following general elements:

a. Training to conduct walk around pre-trip/post-trip protocols. Pre-trip checks should include, at a minimum, visual inspection of sensors, checks of the base vehicle system (e.g., lights), and in-cabin system checks and ADS health reports.
b. Scenario-based exercises. This training involves the IFTD experiencing vehicle behaviors with physical actors performing scripted actions where the ADS outcomes are known. This type of training familiarizes the IFTD with baseline ADS behaviors and capabilities. Increasingly challenging scenarios and complicated environments are simulated during training.
c. Fault-injection training. This training introduces human response to system/component confusion or failure that might create an unsafe state. Following scenario-based exercises, situations beyond the capabilities of the ADS are introduced where IFTD intervention is required. At this stage, degraded system training is introduced. In-vehicle fallback test drivers go through scenarios with the ADS operating in a degraded state to understand and recognize performance impacts and be better prepared to assume control over the ADS-operated vehicle on public roads.
d. General awareness and response to external environmental hazards. Training includes exercises performing evasive maneuvers (such as avoiding negative obstacles like potholes or avoiding objects that suddenly appear).
e. Attention. Additional random, frequent training is provided to test IFTD responses and increase IFTD mindfulness so that, during tests and trips, they are more aware of their own attention (metacognition) and therefore prepared to refocus on the environment.
f. Concepts addressed in classroom training such as sensor limitation and in-vehicle communications are reinforced throughout each aspect of closed course training. The “hands-on” reinforcement of concepts will strengthen the retention and application of the concepts and provide additional context for the IFTD-in-training.

Use of driving simulators. Driving simulators may be used for training IFTDs in high-risk scenarios or fault-injection training. While simulators cannot replicate all conditions, especially those related to driving “feel” and kinesthetic sensations associated with the DDT, simulators may help IFTDs familiarize themselves with system capabilities, takeover procedures, and interfaces while training for scenarios that may cause injury or serious damage, especially in the earlier stages of training.

Evaluation/assessment of skills. Upon completion of basic driver training and ADS training, all IFTDs-in-training should be given a written test and assessed on a closed course. Personnel should not be allowed on public roads without passing these examinations.

4.4 Initial ADS Driving on Public Roads

Supervised operation. The final stage of *initial* training is supervised operation on public roads. Depending on the operating domain, supervised operation training may begin with the training as the co-driver or as a ride-along to observe IFTD actions and in-vehicle communication with the co-driver. In-vehicle fallback test driver operational skills should be verified by experienced personnel under increasingly complex driving environments. Fault-injection evaluations should *never* be conducted on public roads.

[3] This document uses the Defense Acquisition Guidebook (2010) definition of TRL 7 for “early stage” stage, which is system prototype demonstration in an operational environment.

4.5 Periodic Evaluations/ Re-Evaluation of Driving Skills and On-Going Training

Monitoring. In-vehicle fallback test drivers should be monitored across a number of categories that may impact their ability to perform safety-related functions. These include:

- Drug testing, randomly or any time an ADS Testing Organization has reasonable suspicion of use, consistent with applicable laws.
- ADS Testing Organizations should require IFTDs to self-report incidents which might impact their ability to legally operate a motor vehicle and any changes to their driving record (e.g., DUI, serious moving violation, medical condition).
- ADS Testing Organizations should monitor the driving record of all IFTDs. IFTDs should be registered with a Driving Record subscription service in states where available.

Evaluation/assessment of skills. In addition to regular shift updates (see section 5.2), IFTDs should be required to undergo re-evaluations. These include both written knowledge of the current configuration of the ADS (both hardware and software), as well as re-evaluation of basic and defensive driving skills. Proficiency should be demonstrated on either a closed course or public roads under supervision of an experienced trainer, depending on the complexity of the evaluation.

On-going training. A continuous improvement program for IFTD training should be established and feed periodic refresher training for IFTDs. In-vehicle fallback test drivers should be required to stay up-to-date with on-going training. Refresher training and remedial training are key elements of company on-going training program.

Remedial training. Companies should define remedial training requirements for IFTDs that support operational policies (such as an infraction or performance review, or if the IFTD is away from ADS and vehicle testing for extended periods of time). In-vehicle fallback test drivers that meet the remedial training requirements may result in full or partial re-training. Remedial training should not be interpreted as refresher training, but instead utilized when a degradation in skill is identified (systemic or individually) or other training opportunities to improve skill are identified through performance.

Refresher training. In-vehicle fallback test drivers should be required to continuously meet performance requirements and periodically undergo refresher training to reinforce skills learned in Basic Driving and ADS Training. In controlled settings, refresher training provides IFTDs the opportunity to practice skills that are rarely used in public road testing. For this reason, this training should include closed course programs such as defensive driving, fault injection, evasive maneuvers, and other relevant courses. In-vehicle fallback test driver refresher training can include written exams to monitor current knowledge of the ADS and supervised ride-alongs on public roads.

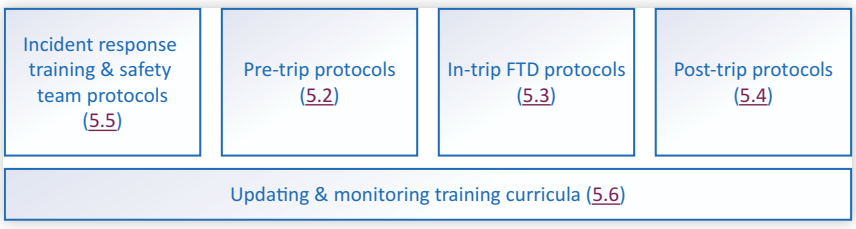
5. ADS-Operated Vehicle On-Road Testing Protocols

Protocols are the processes followed prior to, during, and after testing an ADS-equipped vehicle on public roadways. While details will vary per each organization that develops and tests ADS-operated vehicles on public roadways, it is recommended that procedures and policies in the following areas be established, documented, and communicated to personnel responsible for supervising the ADS. This best practice is intended to complement the recommended practices in SAE J3018.

5.1 Changes

Any changes to any element of the crew, vehicle, or trip should initiate (re-initiate) the pre-trip protocols. Trip is defined in SAE J3016 as “the traversal of an entire travel pathway by a vehicle from the point of origin to a destination.” Applied in a testing environment, “trip” can include a test route, even if the origin and destination are the same location.

FIGURE 2 ADS-operated vehicle on-road testing protocols.



5.2 Pre-Trip [or Pre-Mission] Protocol

Pre-trip or pre-mission protocols are intended to ensure current information is relayed to the in-vehicle team. A pre-trip protocol (also called a pre-mission protocol) should be implemented prior to the ADS-operated vehicle moving from point A to point B executing a prescribed test plan. Similarly, a pre-shift protocol should be implemented when new personnel arrive to execute a prescribed test plan. Multiple pre-trip protocols may be executed within a single pre-shift protocol, or, depending on the mission, may be one-to-one. Specific content of the protocols will vary between ADS, vehicle, operating design domain (ODD), and test plan.

Use of checklists. Checklists may be used to reduce the risk of omissions and mishaps. Daily checklists help ensure tasks such as the following are completed and provide traceability for process improvement. Detailed content for checklists will vary from company to company; however, some general categories are included in this section. This list is not meant to be all-inclusive.

a. Support team preparations list. The testing support team readies vehicles for testing operations. Daily checks should be executed by the testing support team which may or may not include the IFTD and co-driver (on-board personnel) depending on the size of the organization testing the ADS.
   - Documentation for system updates is consolidated (for review with IFTD and on-board test personnel).
   - Component, integration, and regression testing completed and passed (for software updates and new hardware integration).
   - Previous test mission logs consolidated (for use in pre-trip briefings for on-board personnel).
   - Test vehicles have proper paperwork and documentation.
   - New updates to driver procedures.
   - New advisories that should be considered during upcoming trip (e.g., construction on the planned route, recurring issues not accounted for with software updates).
   - Readiness check of IFTD and crew (e.g., rested, free from adverse influence of medications or other substances).

b. Known ADS limitations list. Known limitations and any significant changes or updates to software and hardware should be communicated to IFTDs prior to new testing missions. System updates and the meaning of test results should be discussed and agreed upon prior to designing the route or geographic area of the test and the likely scenarios the ADS will, or might, encounter on the public roads. A list of such significant changes and updates and the functional impact of the updates, as well as limitations of the ADS including the operational design domain, should be generated for the team. This list should be used during pre-trip/mission briefings.

c. Vehicle system check and walkaround list. At the beginning of a shift, on-board personnel should ensure the vehicle has proper documentation (e.g., license, registration, insurance) and emergency protocols and emergency contact information in the event of an incident. They should check the condition of the vehicle and ADS hardware by physically checking off important items such as:
   - Tire wear is acceptable.
   - Windshield is undamaged.
   - Lights function properly.
   - State of the batteries is acceptable.
   - Sensor systems are operational (e.g., scratch free, firmly mounted, clean).

Conduct pre-trip briefings. At least daily (prior to every trip depending on the frequency of ADS updates or new mission assignments), test control personnel or operations managers should review the following lists with on-board personnel:

- ADS updates *since the crew's last test*. This includes a review of new features and behaviors and any additional information that may impact current performance.
- Known ADS limitations.
- Trip test plan including the driving route or geographic area, current road conditions, description of the operational environment, and the weather forecast.
- Incident response protocols and emergency contact information.

5.3 In-Trip IFTD Protocols

As humans become fatigued, they lose focus and their reaction times slow. Fatigue can take the form of both physical fatigue (becoming tired from physical exertion) and mental fatigue (losing focus from concentrating or thinking too hard or for too long)[4]. ADS Testing Organizations should have a written policy on IFTD and co-driver working hours. This policy should, at a minimum, set the maximum hours worked in a 24-hour period supervising the vehicle in autonomous mode, driving the vehicle in manual mode, and working outside the vehicle, as well as mandatory breaks.

Mandatory breaks allow time for the IFTD (and co-driver, if used) to stay fresh and focused on the safe

[4] Marcora, S., Staiano, W., and Manning, V. (2009). Mental fatigue impairs physical performance in humans. Journal of Applied Physiology, Vol 106.

testing and operation of the ADS system. A baseline of 15-minute breaks every 2 hours of ADS operation is appropriate, with break duration and frequency adjusted depending on the complexity of the operating environment (ODD), the maturity of the Automated Driving System under test, and the amount of rest an IFTD has had since their last shift. The IFTD should feel empowered to take breaks as needed to maintain focus.

NOTE: U.S. law provides a helpful definition of rest[5]: 29 CFR §785.18 | Rest. Rest periods of short duration, running from 5 minutes to about 20 minutes, are common in industry. They promote the efficiency of the employee and are customarily paid for as working time. They must be counted as hours worked. Compensable time of rest periods may not be offset against other working time such as compensable waiting time or on-call time.

While there is not a definitive body of research around shift limits for IFTDs, there are established limits in other modes of transportation that should be considered. The Federal Aviation Administration limits flight time for pilots to eight or nine hours depending on the start time of the pilot's entire flight duty period. FAA also limits air traffic controllers to 10-hour shifts or 10 hours of work in a 24-hour period. The Federal Motor Carrier Safety Administration (FMCSA) limits drivers to 10 hours of driving if carrying passengers, and 11 hours of driving if carrying cargo. The Federal Railroad Administration (FRA) limits employees engaged with the movement of trains to no more than 12 hours in 24-hour period.

The maximum hours worked set forth in the written policy of companies testing ADS-operated vehicles should be adapted from and consistent with the most current, applicable federal regulations. It is left to the discretion of the organization to determine which set of federal regulations are most relevant; however, three examples are provided in this best practice (FAA, FMCSA, FRA). Furthermore, policies should take into account the complexity of the operating environment and maturity of the automated driving system since, as the maturity of the system improves and failures become more rare, drivers must maintain vigilance for longer periods of time.

Limiting IFTD distraction while the vehicle is in motion.

- Personal electronic devices cannot be used by the IFTD.
- Personal electronic devices cannot be used by the co-driver/co-operator when the ADS is operating the vehicle. (Nothing prohibits the co-driver from operating electronic equipment necessary to monitor and operate AV technology.)
- Communications should be limited to topics related to the safe operation of the vehicle.
- Eating and smoking/vaping are not permitted.
- Never operate or be present in the vehicle if under the influence of alcohol or any other substance, including prescription medicines that may impact an individual's ability to operate vehicles.
- Limit noise distraction (e.g., radio) and never allow radio to distract or drown acoustic HMI - the use of headphones or earbuds is prohibited.

Responsibilities in the vehicle under test. Companies should have clearly defined tasks for humans inside the cabin of the vehicle, if more than one person is present. This ensures all major responsibilities are covered, minimizes duplication of effort, and clarifies responsibilities in the event of an incident. Clearly defined roles and awareness of the total set of tasks also facilitates communication.

Driver state monitoring. Companies engaged in on-road ADS testing should include some type of driver state monitoring and recording for their IFTDs. Depending on the type of system under test, real-time warnings should be sounded for alertness, eyes on road/forward, head movement/position, and hands near (or on) the wheel. If the driver state monitoring system does not include real-time alerts/notifications, trip data should be periodically reviewed so that the IFTD's road-attention can be assessed. It is important to note that the driver state monitoring system should be mature technology and will have been tested to ensure the system effectiveness prior to use on public roads. In other words, the driver state monitoring system should not be the subject of the test while on public roads testing ADS. Driver state monitoring may become more important to the safe oversight of an ADS-operated vehicle as technology matures and the time between incidents increases (thus increasing the likelihood of an IFTD's attention wandering).

5.4 Post-Trip [Post-Shift or Post-Mission] Protocol

Conduct post-trip briefing. Following each trip (or shift or mission), on-board personnel should share and communicate their experiences with engineers and test personnel. Such communications should include review of the following (non-exhaustive) list:

- A report on operational outcomes – were the test objectives met?
- Ensuring that ADS issues are logged for investigation, re-test, further development, or promotion to the next version of the software. Behaviors and environmental issues should

[5] Ref: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=167842928accd251fbca30147f00a8cf&mc=true&r=PART&n=pt29.3.785#se29.3.785_118.

be noted, and limitations included in briefing lists for follow-on shifts.
- A review of system performance and anomalies.
- A report on environmental conditions and operational factors (e.g., traffic, Vulnerable Road Users (VRUs), infrastructure condition, construction, etc.).
- Discussion of any newly experienced events (e.g., edge and corner cases). A separate team should review new edge cases that are flagged during a trip.
- Ensure that any unplanned IFTD interventions and outcomes that occurred during the trip are documented.

5.5 Incident Response Training and Protocols for the Safety Team

Implement incident response protocols and training. Incidents involving other road users and emergency response are inevitable[6]. Protocols should be documented for reasonably foreseeable events such as crashes, collisions, or other events involving first responders. Incident response documentation should be on-board the vehicle in the event an incident occurs. Examples of documentation may include:

- Compliance plan to ensure reporting in accordance with applicable laws.
- Processes and technology in place to capture data required under applicable laws in the geographic operating area.
- Procedures for interacting with law enforcement.
- Procedures for interacting with other first responders (e.g., fire department).
- Procedures for communicating with internal company team members.

5.6 Updating and Monitoring Training Curricula

Change management. Companies should deploy a change management and communication strategy that ensures IFTD training remains representative of current ODD, company operational policies/procedures, and capabilities and behaviors of the ADS and ADS-operated vehicle. Safety training will improve by creating a standardized process where changes are communicated to IFTDs (training or otherwise), which allows for traceability through documentation and approval.

Internal program reviews. For continuous improvement, companies should conduct regular reviews of the training curriculum to ensure training continues to support IFTD scope and competencies. ADS Testing Organizations should evaluate not only the content of their programs, but the delivery of the content to improve aspects related to trainee reaction, learning, behavior, and outcomes[7]. This can be accomplished through the use of a variety of tools such as formal audits, IFTD trainee feedback, and performance reviews.

The evaluation process used to qualify IFTDs should also be examined regularly. It is important that exit criteria of a qualified trainee support the learning objectives of the training program and that the training program continues to support what is required to safely test the ADS on public roads. It is recommended that these reviews occur at least on an annual basis.

6. Summary

The IFTD's sole responsibility in an ADS-operated vehicle is to ensure its safe operation. Companies engaged in ADS-operated vehicle testing on public roads should follow a rigorous process to attract and train individuals with a technological focus and safety mindset. Thinking through and thoroughly documenting processes that reinforce a culture of safety and continuous improvement should be the cornerstones of any on-road testing program. Adhering to best practices like those outlined in this document can reduce risk and engender public trust in automated driving systems and the companies that develop and deploy them.

7. About Automated Vehicle Safety Consortium™

The objective of the Automated Vehicle Safety Consortium™ is to provide a safety framework around which autonomous vehicle technology can responsibly evolve in advance of the broad use of commercialized vehicles. The consortium will leverage the expertise of its members and engage government and industry groups to establish safety principles and best practices. These technology-neutral principles are key considerations for deploying SAE Level 4 and Level 5 automated vehicles on public roads.

AVSC Vision:
Public acceptance of SAE Level 4 and Level 5 automated driving systems as a safe and beneficial component of transportation through industry consensus.

[6] Interaction with first responders is another topic that warrants commonality and further discussion in a separate document.

[7] Kirkpatrick, D.L. and Kirkpatrick, J.D., 2006. *Evaluating Training Programs*. San Francisco, CA: Barrett-Koehler.

AVSC Mission:
The mission of the Automated Vehicle Safety Consortium™ (AVSC) is to quickly establish safety principles, common terminology, and best safety practices, leading to standards to engender public confidence in the safe operation of SAE Level 4 and Level 5 light-duty passenger and cargo on-road vehicles ahead of their widespread deployment.

The AVSC will:

- Develop and prioritize a roadmap of pre-competitive topics;
- Establish working groups to address each of the topics;
- Engage the expertise of external stakeholders;
- Share output/information with the global community;
- Initially focus on fleet service applications.

8. Contact Information

To learn more about the Automated Vehicle Safety Consortium™, please visit https://avsc.sae-itc.org.

Contact: AVSCinfo@sae-itc.org.

9. Acknowledgement

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Appendix A. AVSC Best Practice Quick Look

In-vehicle fallback test driver (safety operator) selection, training, and oversight procedures for automated vehicles under test

IN-VEHICLE FALLBACK TEST DRIVER SELECTION (4.1)

- **Driving experience.** (IFTDs are licensed drivers with at least 3 years' experience and a valid, government-issued license for the class of vehicle under test.)
- **Record checks.** (Check of drivers' record confirms no serious moving violations in at least the last three years.)
- **Driving evaluation.** (IFTDs pass a basic driving skills assessment.)
- **Mindset.** (IFTD candidates have a safety mindset with appropriate demeanor, motivation, communication skills, and affinity for technology.)
- **Drug screening.** (IFTDs pass a minimum five panel drug test (opiates, cocaine, marijuana, phencyclidine or PCP, and amphetamines/methamphetamines).)
- **Criminal background check.** (IFTDs pass criminal background check.)

BASIC DRIVER TRAINING (4.2)

- **Controlled environment training.** (Classroom and closed course training to understand fundamental vehicle handling and dynamics.)
- **Interaction training.** (Introduce elements of the operational design domain (ODD) in which the ADS will be tested.)
- **Evaluation/assessment of skills.** (IFTDs pass written exam and demonstrated driving skill on a closed course with experienced instructors.)

ADS TRAINING (4.3)

- **ADS in-classroom instruction.** (Classroom instruction with technology used in the ADS-equipped vehicle.)
- **Closed course (controlled environment) in-vehicle ADS operation.** (Closed course training and practical application with the ADS[8].)
- **Evaluation/assessment of skills.** (IFTDs pass written test and closed course assessment.)

INITIAL AV DRIVING ON PUBLIC ROADS (4.4)

- **Supervised operation.** (IFTDs complete supervised operation on public roads.)

PERIODIC EVALUATIONS/RE-EVALUATION OF DRIVING SKILLS AND ON-GOING TRAINING (4.5)

- **Monitoring.** (IFTDs monitored across categories that may impact their ability to perform safety-related functions.)
- **Evaluation/assessment of skills.** (IFTDs undergo re-evaluations and refresher training.)
- **Remedial training.** (Company policy to address full or partial re-training to improve an individual or systemic deficiency.)
- **Refresher training.** (Reinforces IFTD skills learned in basic driving training and ADS training.)

PRE-TRIP PROTOCOLS (5.2)

- **Conduct pre-trip briefings.** (ADS updates or new trip/mission assignments.)

[8] Driving simulators should be used for high-risk scenarios or fault-injection training that may cause injury or serious damage, especially in the earlier stages of training as FTDs are familiarizing themselves with system capabilities. The use of driving simulators, however, does not replace the need for physical experience in a vehicle on a controlled course.

IN-TRIP PROTOCOLS (5.3)

- **Mandatory breaks.** (IFTD allowed to refresh, refocus, and discuss in-trip issues with other in-vehicle personnel as needed.)
- **Limit IFTD distraction while the vehicle is in motion.**
- **Responsibilities in the vehicle under test.** (Companies have clearly defined tasks for humans inside the cabin of the vehicle.)
- **Driver state monitoring.** (Some type of driver monitoring and recording for their IFTDs.)

POST-TRIP PROTOCOLS (5.4)

- **Conduct post-trip briefing.** (Review system performance, anomalies, and any edge cases.)

INCIDENT RESPONSE TRAINING AND PROTOCOLS FOR THE SAFETY TEAM (5.5)

- **Implement incident response protocols and training.** (Companies should have established plans, procedures, and training to support incidents involving other road users and emergency response personnel.)

UPDATING AND MONITORING TRAINING CURRICULA (5.6)

- **Implement a change management program.** (Companies conducting testing should continue to improve safety training and document any changes for traceability.)
- **Conduct internal program reviews.** (Conduct audits to ensure training curriculum is current and relevant.)