

# **Development of California Regulations to Govern the Testing and Operation of Automated Driving Systems (ADS)**

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# Fundamental Regulatory Challenges

- **Automation blurs the traditional regulatory boundaries**
  - NHTSA is responsible for new vehicle equipment & safety
  - States are responsible for vehicle operation (driver licensing)
  - State laws regarding ADS are preceding federal regulations
- **Need to balance:**
  - Public Safety while unproven systems are being tested & deployed
  - Encouraging Technological Innovation promising improved safety
  - Handle the wide range of different ADS concepts being proposed
- **Lack of technical standards to provide baseline references for performance, safety, testing protocols, or validation/verification methods**
- **Cultural differences between different regulatory agencies, the automotive industry, and the IT industry**
- **Differing models, concepts, and definitions of certification across government agencies, industries, and countries**

# SAE J3016 Taxonomy of Driving Automation System Levels

Level	Name	Dynamic Driving Steering/Speed	Roadway Monitoring	Fallback Steering/Speed	System Capability
<b>Human Driver Monitors the Driving Environment</b>					
1	Driver Assistance	Driver + System	Driver	Driver	Limitations
2	Partial Automation	System	Driver	Driver	Limitations
<b>ADS Monitors the Driving Environment</b>					
3	Conditional Automation	System	System	Driver	Limitations
4	High Automation	System	System	System	Limitations
5	Full Automation	System	System	System	Everywhere

# Driving Automation System Examples

Level	System Description	Examples
<b>Human Driver Monitors the Driving Environment</b>		
<b>1</b>	<u>Driver Assistance</u> <ul style="list-style-type: none"> <li>• ACC <u>OR</u> Lane Centering</li> </ul>	Honda, Audi, Chrysler, Ford, GM, Hyundai, Mercedes, Nissan, Tesla, Toyota, Volvo
<b>2</b>	<u>Partial Automation</u> <ul style="list-style-type: none"> <li>• ACC <u>AND</u> Lane Centering</li> <li>• Traffic Jam Assist (Low Speed)</li> <li>• Highway Autopilot / Super Cruise</li> </ul>	Acura, Audi, Hyundai, Infiniti, Mercedes Mercedes (2014), BMW (2014), Audi (2016?) Tesla (2015), Audi (2016?), Cadillac (2017?)
<b>Automated Driving System (ADS) Monitors the Driving Environment</b>		
<b>3</b>	<u>Conditional Automation</u> <ul style="list-style-type: none"> <li>• All Test Vehicles / Pilot Deployments</li> <li>• Other Applications Unclear</li> </ul>	Volvo 100-Car Gothenburg Tests (2017?)
<b>4</b>	<u>High Automation</u> <ul style="list-style-type: none"> <li>• Driving Pilot (w. Limitations)</li> <li>• Driverless Taxi (w. Limitations)</li> <li>• Closed Campus Driverless Shuttle</li> <li>• Driverless Valet Garage Parking</li> </ul>	Long-Term Target for Most Manufacturers Geographic, weather, road type, etc. Google NEV CityMobil2 (Low Speed / Segregated Routes) Most Manufacturers Have Shown Prototypes
<b>5</b>	<u>Full Automation</u> <ul style="list-style-type: none"> <li>• Automated Driverless Taxi</li> </ul>	Anywhere, Anytime

## SAE Level 2 Driving Automation Systems

- Not currently covered by CA legislation
- Level 2 systems can be severely limited by factors not necessarily apparent to drivers
  - Lane marking quality, curve radius, deceleration rates, objects, etc.
  - Can't anticipate trouble (e.g., work zones)
- Drivers feel they can look away from the road
  - How long is too long?
  - Can drivers interact with a phone?
- Misuse (Unknowing)
  - Will the public understand that difference between SAE Level 2 vs. Level 4 System?
- Abuse (Intentional)
  - Leaving the driver's seat
  - Taping a soda can to the steering wheel



**2015 Infiniti Q50  
ACC+LKA/LC**



**2015 Mercedes S-Class  
ACC+LKA/LC**

# Guiding Principles For Public Roads Testing Regulations

- **Recognize that testing is iterative, changes are frequent, and faults/failures are to be expected**
  - Not a linear progression from test track to public roads to deployment
  - Minimum testing miles not an indication of readiness
- **Safety is achieved through the combination of design, testing policies & procedures, and the test driver training**
  - Test driver qualifications → Minimum equivalent to CDL
  - Demonstrate test driver training process (concept dependent)
  - Demonstrate safety management process (continual risk assessment)
  - Prohibiting testing locations or vehicle types is counterproductive
- **Allow / support different testing stages & goals**
  - Engineering / prototype testing
  - Validation testing
  - Naïve driver testing (usability, user experience)
  - Field operational testing (limited deployments)

# ADS Test Vehicle Marking

- **Should You Require AV Test Vehicles Markings?**
  - Static: Decal or License Plate
  - Dynamic: Light when AV System is Active
- **Pros & Cons**
  - Warns other in case test vehicle does something unexpected...
  - The test driver is responsible for preventing bad behavior
  - Some cars already easily identifiable...others are not
  - Other road users may treat AV differently (decreasing validity of testing)
  - Marking makes the vehicle a target for fraud or hackers
  - CHP – Not needed because test driver is ultimately responsible



## How do you evaluate a test permit program's safety?

- **Crashes**
  - ADSs & ADS testing programs will not be crashless
  - Looking for patterns of bad system or test driver behavior
  - Report all crashes (not just AV active or at fault)
  - Need to account for exposure & crash severity
- **EDR Data**
  - Each vehicle will have different sensors & data definitions
  - Focus on defining a MFG. crash report using EDR data
  - Timeline of speed, braking, lead vehicle, test driver intervention
  - Was vehicle and test driver behavior reasonable?
- **Surrogate Safety Metrics (Near Crashes)**
  - Most SSMs based on hard accelerations (braking, lateral)
  - No clear metrics in literature w/o video analysis (false alarms)
  - Many near misses never get captured (can't record what you didn't see)
  - Metrics must be related to safety (e.g., AV disengagements may not be)



- **Goal: Ensuring Safety Prior to Deployment**
  1. Behavioral Competency
  2. Functional Safety
  3. Models Certification
- **Additional Deployment Issues Worth Considering**
  - ADS Registration
  - External Marking
  - Driver Training & Licensing
  - ADS Driverless Operation Issues
- **Other Industry Activities**

## Ensuring Safety: Behavioral Competency

- **Behavioral Competency** describes how well the automation behaves when dealing with **external hazards** in the driving environment.
- Is **Behavioral Competency** just a **Driving Performance Exam?**
  - DPE looks at benign traffic conditions (sometimes only urban)
    - Basic vehicle control in benign conditions is easy
    - Safety is more related to behavior in abnormal conditions
  - DPE infers potential driving performance potential based on where the driver is looking, sequences of maneuvers, etc.
    - AV sensors always looking everywhere
    - How do you infer what the system does with that data?
  - Multiple AV concepts with different operating scenarios
    - Not all tests will apply to all ADS concepts
    - ADS can add transitions to driver control



# Behavioral Competency Performance Standards & Testing

1. **Define ADS Operating Scenarios (from various mfg. concepts)**
  - Freeway Pilot
  - Rural Highway Pilot
  - City Street Pilot
  - Valet Parking
  - Low-Speed Shuttles
1. **Define High-Level Minimum Competencies (Critical Maneuvers)**
  - Could be defined by DMV, NHTSA, SAE, ISO, MFG
  - Minimum competency varies by operating scenario & ADS level
  - Minimum competency may simply be driver takeover
  - Generally assuming 3-5 s for driver takeover
2. **Define Test Conditions & Pass/Fail for Each Competency**
  - Could be defined by DMV, NHTSA, SAE, ISO, MFG, 3rd Party
  - NHTSA NCAP FCW Confirmation Test (34 Pages)
3. **Conduct Tests**
  - Could be DMV, NHTSA, MFG, 3rd Party

Minimum Competencies / Critical Driving Maneuvers	Freeway	Rural Highway	City Streets	Valet Parking	Low-Speed Shuttles
Detect Operating Envelope & System Malfunctions	✓	✓	✓	✓	✓
Detect & Respond to Speed Limit Changes (Including Advisories)	✓+	✓+	✓+		✓
Detect Passing and No Passing Zones / Perform Passing Maneuver		opt	opt		
Detect & Respond Work Zones, Temporary Lanes, and Safety Officials	✓+	✓+	✓+		*
Detect & Respond to Traffic Control Devices	✓+	✓	✓		
Detect & Respond to Access Restrictions (One-Way, No Turn,...)		*	✓	✓	✓
Perform High Speed Merge (e.g., Freeway)	opt	opt			
Perform a Lane Change or Lower Speed Merge	*	*	✓		
Park on the Shoulder (e.g., Minimal Risk State)	*	*	*		*
Navigate Intersections & Perform Turns		*	✓		✓
Navigate a Parking Lot & Locate Open Spaces			opt	✓	
Perform Car Following (Including Stop & Go)	✓	✓	✓	✓	✓
Detect & Respond to Stopped Vehicles	✓	✓	✓	✓	✓
Detect & Respond to Intended Lane Changes / Cut-Ins	✓	✓	✓		opt
Detect & Respond to Encroaching Oncoming Vehicles	*	✓	✓	✓	
Detect & Respond to Static Obstacles in Roadway	✓+	✓+	✓+	✓	✓
Detect & Respond to Bikes, Peds, Animals, or Moving Objects	*	✓+	✓+	✓	✓
Detect & Respond to Emergency Vehicles	✓+	✓+	✓+		*

# High-Level Minimum Competency Example

## Detect & Respond to Work Zones & Temporary Lane Shifts

- Illustrates potentially different requirements by ADS Level
- Illustrates potentially different requirements by ADS Functionality
- Note: defined minimums for SAE Level 3 ADS, but should we allow it?

SAE Level & ADS Functionality	Detection	ADS Response	Fallback
Level 3	Req'd	Alert Driver (~5 s)	Driver (by definition)
Level 4+ w. Driver	Req'd	Alert Driver <u>Optional Functionality:</u> <ul style="list-style-type: none"> <li>• Navigate temp. lanes</li> <li>• Respond to temp. TCDs</li> <li>• Lane changes if needed</li> <li>• Respond to safety officials</li> </ul>	ADS Safe Stop
Level 4+ w/o Driver	Req'd	<ul style="list-style-type: none"> <li>• Navigate temp. lanes</li> <li>• Respond to temp. TCDs</li> <li>• Lane changes if needed</li> <li>• Respond to safety officials</li> </ul>	ADS Safe Stop? Alert Remote Operator?

- **Functional Safety** refers to the ability of the automated driving system to accommodate **internal hazards & failures**, which could be electrical, mechanical, or software.
  - Cannot be evaluated through comprehensive testing
  - Achieved during the design and development using methodologies such as those described in ISO 26262
- **ISO 26262** currently relies on the driver as a backup
  - Driver intervention not required in Levels 4+ ADS
  - Also not entirely considered are interactions between the ADS and driver: **Errors, Misuse, and Abuse**
  - Efforts to modify ISO 26262 for ADS will take time
- **Few avenues to define sensible functional safety regulations, especially in the short term**

# Ensuring Safety: Certification Models

- **Self-Certification** used in the US for compliance with FMVSS
  - NHTSA spends about \$11 M / year on compliance testing
  - NHTSA → Broad investigation, recall, & punitive powers
  - NHTSA can investigate/recall any safety defect
  - Manufacturers still responsible for thorough internal testing
- **Type Approvals** used outside the US for ADAS & in US by EPA
  - Requires testable standards (e.g., ISO)
  - Requires an approval body with approval authority
- **Third-Party Testing** NHTSA NCAP (5-Star Crash Rating) & IIHS
  - NHTSA: \$17.4 M / yr in testing and \$16.6 M / yr in development
  - More appropriate for behavioral competency than functional safety
- **Third-Party Safety Concept Certification** used by EU manufacturers
  - Safety management process during prototype development & testing
- **Third-Party Functional Safety Certification** gaining popularity in EU
  - Manufacturer correctly following ISO 26262 methodology

- **What is being certified?**
  - Behavioral Competency
  - Functional Safety
- **Who is doing the certification?**
  - MFG. Self-Certification, Approval Agency, Independent 3rd Party
- **What is the depth of the certification?**
  - Benign Driving Conditions DPE
  - Review of MFG. Tests & Data
  - Behavioral Competency Testing (Hazards, Abnormal Conditions)
  - MFG. Functional Safety Process Review (Following ISO 26262)
  - Functional Safety “Hazard Analysis” by Behavioral Competency
  - Embedded 3rd Party Documentation (Aviation/Rail)
  - Full Code Review (Aviation)



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- **AV Registration and External Marking**
  - Key Registration Issue: Understanding ADS capabilities (resale, CHP)
  - External Marking: Currently more cons than benefits
  - May need to distinguish L2 from L3+ or driverless operation capability
- **Driver Training and Licensing**
  - License endorsements proposed in NV, NJ, others
    - Is the ADS driver training universal or vehicle-specific?
    - What special knowledge (written test) must be demonstrated?
    - What special skills (driving test) must be demonstrated?
    - Not recommended
  - How do drivers get trained?
    - Manufacturers / Dealers / In-Vehicle Tutorials
    - Current ADAS owners often unaware of vehicle features
    - New Vehicles vs. Used Vehicles vs. Borrowed/Rented Vehicles
    - PSA Campaigns?
  - General license testing should exclude ADS usage

- **Driverless operation is a feature of SAE Level 4+ ADS**
  - Valet Parking, Low Speed Shuttles, NEV Taxi, Automated Taxi
  - Some may or may not allow manual driving
  - Different behavioral competency requirements
- **Clear marking such as a special license plate?**
  - CA CHP wanted some way to quickly identify an unmanned or driverless ADS vs. runaway vehicle
- **Emergency stop (request) for occupants?**
- **Communication to owner/operator for passengers, maintenance, failures, crashes, stuck vehicle, etc.**
- **Owner/operator information exchange post-incident**
- **Restrictions on who can activate or use (children)**



# What's Next?

- **Industry standards development proceeding slowly**
  - ISO revisiting 26262 for ADS
  - SAE ORAV (J3016, J3018, V&V TF), S&HF ADS Task Force
  - NHTSA/NCHRP have funded a variety of research projects
  - European Commission funded project on ADS standards & certifications needs prior to deployment
- **Long-term adapting or re-interpreting existing codes**
  - Responding to police, crash monitoring, insurance exchange
  - Penalties for bad driving behavior
  - Restrictions on driver/passenger behaviors (DUI, open alcohol, cell phones, texting, distraction, recklessness...)
  - Protection of unattended children
- **Harmonizing diversity of state approaches → AAMVA**