Autonomous
Automated and
Connected Vehicles

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California Legislation – Senate Bill 1298

As soon as practicable, but no later than Jan. 1, 2015, DMV must adopt regulations setting forth requirements for:

• Manufacturers’ **testing** of autonomous vehicles on public roadways

• **Operation** of autonomous vehicles on public roadways
Global Perspective and Consensus Building
NHTSA defines 4 levels of autonomous vehicles

- Level 0 – No automation
- Level 1 – Function specific automation
  (ADAS – Advanced Driver Automation Systems)
- Level 2 – Combined function automation
- Level 3 – Limited self-driving automation
- Level 4 – Full self-driving automation

Society of Automotive Engineers (SAE) has similar definitions, although 5 levels
# Summary of SAE International’s Draft Levels of Automation for On-Road Vehicles (July 2013)

SAE’s draft levels of automation are descriptive rather than normative and technical rather than legal. Elements indicate minimum rather than maximum capabilities for each level. “System” refers to the driver assistance system, combination of driver assistance systems, or automated driving system, as appropriate. NHTSA’s levels of automation are provided to indicate approximate correspondence.

<table>
<thead>
<tr>
<th>NHTSA level</th>
<th>SAE level</th>
<th>SAE name</th>
<th>SAE narrative definition</th>
<th>Execution of steering and acceleration/deceleration</th>
<th>Monitoring of driving environment</th>
<th>Backup performance of dynamic driving task</th>
<th>System capability (driving modes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td><strong>Non-Automated</strong></td>
<td>the full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Human driver</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td><strong>Assisted</strong></td>
<td>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</td>
<td>Human driver and system</td>
<td>Human driver</td>
<td>Human driver</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2</td>
<td><strong>Partial Automation</strong></td>
<td>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</td>
<td>System</td>
<td>Human driver</td>
<td>Human driver</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3</td>
<td><strong>Conditional Automation</strong></td>
<td>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</td>
<td>System</td>
<td>System</td>
<td>Human driver</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4</td>
<td><strong>High Automation</strong></td>
<td>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</td>
<td>System</td>
<td>System</td>
<td>System</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>5</td>
<td><strong>Full Automation</strong></td>
<td>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</td>
<td>System</td>
<td>System</td>
<td>System</td>
</tr>
</tbody>
</table>
# Example Systems at each SAE Automation Level

<table>
<thead>
<tr>
<th>Level</th>
<th>Example Systems</th>
<th>Driver Roles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Adaptive Cruise Control, OR Lane Keeping Assistance</td>
<td>Must control other function, and still continuously monitor driving environment</td>
</tr>
<tr>
<td>2</td>
<td>Adaptive Cruise Control AND Lane Keeping Assistance</td>
<td>Must still continuously monitor the driving environment (system nags driver to ensure they are paying attention)</td>
</tr>
<tr>
<td>3</td>
<td>Stop-and-go driving assistance (low speed); Automated Parking</td>
<td>May read a book, text, watch a movie, but must still be prepared to intervene when needed</td>
</tr>
<tr>
<td>4</td>
<td>Highway driving pilot; Closed campus driverless shuttle; Valet parking in garage</td>
<td>May sleep, and system can revert to minimum risk condition, if needed</td>
</tr>
<tr>
<td>5</td>
<td>Automated taxi (even for children); Car-share repositioning system</td>
<td>No driver needed</td>
</tr>
</tbody>
</table>
• NHTSA Level 2 autonomous vehicles available now
  – 2014 Mercedes S class
  – 2014 BMW i3, 5-Series

• NHTSA Level 3 autonomous vehicles being tested now
  – Private test tracks
  – California public roadways
  – Human reaction testing
  – Situational awareness

• No industry agreement on NHTSA Level 4 timetable
  – Dependence on DSRC?
Technology in Self Driving Cars

- Adaptive Cruise Control

- Lane Departure Warning and Lane Keeping Assistance

- Forward Collision Warning and Collision Avoidance Braking

- Parking Assistance Systems
• Philosophical differences
  • Driver is essential to vehicle operations
    • Design systems to maintain situational awareness
    • Adequate notification time
    • Human is the backup system
  • Vehicle operations fully autonomous
    • No need for steering or braking controls
    • Redundancy and fail-safe built into system

• Technological differences
  – Self-contained processing
  – Map dependency and cloud computing
  – Vehicle to vehicle communication (v2v)
    • NHTSA decision on DSRC capability
  – Vehicle to infrastructure communication (v2i)

• Other considerations
  • Commercial vehicles
  • Self-parking
Connected Vehicles set the stage for Vehicle Automation

**Vehicle Data**
- latitude, longitude, time, heading angle, speed, lateral acceleration,
- longitudinal acceleration, yaw rate, throttle position, brake status,
- steering angle, headlight status, wiper status, external temperature,
- turn signal status, vehicle length, vehicle width, vehicle mass,
- bumper height

**Infrastructure Messages**
- Signal Phase and Timing,
- Fog Ahead
- Train Coming
- Drive 35 mph
- 50 Parking Spaces Available
Bosch Automated Driving Video

https://www.youtube.com/watch?v=0D0ZN2tPihQ
Google Self-Driving Car Project: A First Drive

https://www.youtube.com/watch?v=CqSDWoAhvLU
• Volvo
  No fatalities in a Volvo vehicle by the year 2020
  – Collision avoidance systems
  – Commercial trucking industry
  – Road train or platooning
  – Gothenburg, Sweden

• Nissan
  • Autonomous car will be available for sale before 2020
  • Price will be $1,000 - $2,000 above current prices

• Audi A-7 demo at the 2013 CES
Volvo System CW-EB - Collision Warning with Emergency Brake

https://www.youtube.com/watch?v=_6FckHjQyX8
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• **Audi A-7 demo at the 2013 CES**
Audi Piloted Driving at CES 2013

https://www.youtube.com/watch?v=rgN8MOrss40
Challenges

- Business model
- Safety
- Liability
- Privacy
- Security
- Licensing
- Reliability
- Infrastructure

- Usage
- Vehicle Code
- Visibility
- Standardization
- Insurance
- Technical constraints
- Messaging
- Public perception
Questions

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