Automated Vehicle Safety Update for 2021

February 2021
Overview

- Where is the industry in general as of early 2021?

- Beyond the SAE Levels
  - Role of human vs. technology

- Industry trends for 2021
  - Role of standards
  - Technical challenges
  - Organizational challenges

https://on.gei.co/2r2rjzg
Low Speed Shuttles

- Low speed shuttles
  - Up to 15 passengers
  - Fixed route at perhaps 5-10 mph
  - Demonstrations in cities worldwide

- Safety approach
  - Slow speed limits kinetic energy
  - Often a non-driver safety conductor

- Example Mishaps
  - Shuttle hit by backing truck (Las Vegas, 2017)
  - False alarm emergency stop with passenger injury (Ohio 2020)
Parcel Delivery

- Parcels to stores, houses
  - Short range delivery
  - Roads, bike lanes, sidewalks
  - Demonstrations in several cities

- Safety approach
  - Early: trailing vehicle
  - Later: remote human

- Example Incidents
  - Sidewalk bot blocks wheelchair ramp (Pittsburgh, 2019)
  - Tension over use of sidewalk space
Driver-Monitored Automation

- Automated driving of car or truck
  - Continuous driver supervision
  - OEMs in production already

- Safety approach
  - Human driver monitors automation
  - Human driver responsible for safety

- Example Mishaps
  - Multiple fatal Tesla crashes
    - Issue: driver complacency
    - Issue: under 10 seconds from OK to fatal crash
  - Tempe Arizona fatality in testing (Tempe, 2018)
Fully Autonomous Operation

- Fleet vehicles
  - Waymo robotaxis deployed on a limited scale
  - Middle-mile trucks gained interest in 2020
  - Many players pushing hard in this area

- Safety approach
  - Early: Human safety driver
  - Later: Human on-call if car asks for help

- Example incidents
  - California reports indicate minor incidents in testing
Industry Trends

- Consolidation in the “race” to autonomy
  - It takes huge resources to succeed
  - Trend to OEM + ADS supplier teaming
  - Smaller players fail, team, or acquired over time

- Fully autonomous pivot toward freight
  - Low kinetic energy for last mile service
  - Middle mile highways less chaotic than urban

- Shift of “SAE Level 3” vehicles to L3+
  - Strict L3 means human driver supervision
  - OEMs shifting to L3+ with car safe stopping on its own
# A User-Centric Classification

<table>
<thead>
<tr>
<th>Operating Mode</th>
<th>Human Role</th>
<th>Driving</th>
<th>Driving Safety</th>
<th>Other Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ASSISTIVE</strong></td>
<td>Driving</td>
<td><img src="car.png" alt="Car" /></td>
<td><img src="person.png" alt="Person" /></td>
<td><img src="person.png" alt="Person" /></td>
</tr>
<tr>
<td><strong>SUPERVISED</strong></td>
<td>Eyes ON the road</td>
<td><img src="car.png" alt="Car" /></td>
<td><img src="person.png" alt="Person" /></td>
<td><img src="person.png" alt="Person" /></td>
</tr>
<tr>
<td><strong>AUTOMATED</strong></td>
<td>Eyes OFF the road</td>
<td><img src="car.png" alt="Car" /></td>
<td><img src="car.png" alt="Car" /></td>
<td><img src="person.png" alt="Person" /></td>
</tr>
<tr>
<td><strong>AUTONOMOUS</strong></td>
<td>No human driver</td>
<td><img src="car.png" alt="Car" /></td>
<td><img src="car.png" alt="Car" /></td>
<td><img src="car.png" alt="Car" /></td>
</tr>
</tbody>
</table>

**Driver Assistance**

**Automated Driving**

**Vehicle Automation Modes**
# Standards-Based Engineering Approach

<table>
<thead>
<tr>
<th>Component</th>
<th>Standard/Specification</th>
<th>Category</th>
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</thead>
<tbody>
<tr>
<td>SYSTEM SAFETY</td>
<td>UL 4600</td>
<td>Safety Beyond Dynamic Driving</td>
</tr>
<tr>
<td>DYNAMIC DRIVING FUNCTION</td>
<td>ISO/PAS 21448</td>
<td>Environment &amp; Edge Cases</td>
</tr>
<tr>
<td>FUNCTIONAL SAFETY</td>
<td>ISO 26262</td>
<td>Equipment Faults</td>
</tr>
<tr>
<td>CYBER-SECURITY</td>
<td>SAE J3061, SAE 21434</td>
<td>Computer Security</td>
</tr>
<tr>
<td>VEHICLE SAFETY</td>
<td>FMVSS, NCAP</td>
<td>Basic Vehicle Functions</td>
</tr>
</tbody>
</table>

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2021 Technical Safety Challenges

- Perception & prediction
  - Safety of machine learning-based functions
  - Need more than object motion tracking

- Safety of Intended Function (SOTIF)
  - Drive/Fix/Drive iteration with lots of testing
    - Waymo: 6M test miles; 65K deployed miles
  - How will safety be argued for larger fleets?
    - Likely will involve UL 4600 concepts and safety cases

- Getting from “works OK” to “safe”
  - You can brute force the first few “nines” ... but not all of them.
  - Field feedback into safety cases

https://bit.ly/3q7VCzv
Still an open world with unknowns & changes

- Want “Positive Risk Balance” (safer than human driver)
- But ... *no human driver responsible*

Use Positive Trust Balance

- Engineering rigor
- Practicable validation
- Strong safety culture
  .... and ...
- Field feedback
to handle surprises

UL 4600 ties feedback to Safety Case
Safety Arguments (Safety Case)

- **Claim** – a property of the system
  - “System avoids pedestrians”

- **Argument** – why this is true
  - “Detect & maneuver to avoid”

- **Evidence** – supports argument
  - Tests, analysis, simulations, ...

- **Sub-claims/arguments address complexity**
  - “Detects pedestrians” // evidence
  - “Maneuvers around detected pedestrians” // evidence
  - “Stops if can’t maneuver” // evidence
Safety Performance Indicators (SPIs)

SPIs monitor the validity of safety case claims (UL 4600)

- Leading Metrics
  - Sensors Effective
  - Data Fusion Effective
  - Sensor Cleaning
  - SW Quality
  - Test Coverage

- Lagging Metrics
  - Avoids Crashes
  - Detects Objects
  - Vehicle is Safe

CLAIMS-ONLY VIEW OF SAFETY CASE
Examples of SPIs

- “Acts dangerously” is only one dimension of SPIs
  - Violation rate of pedestrian buffer zones
  - Time spent too close per following distance math

- Components meet safety related requirements
  - False negative/positive detection rates
  - Correlated multi-sensor failure rates

- Design & Lifecycle considerations
  - Design process quality defect rates
  - Maintenance & inspection defect rates

- Is it relevant to safety? ➔ Safety Case ➔ SPIs
2021 Safety Themes

- **Positive Trust Balance:**
  - Engineering Rigor, Validation, Feedback, Safety Culture
  - Standards-driven safety
  - Transparency

- **Safety Performance Indicators (SPIs):**
  - Continual improvement & updates
  - Field feedback: development; deployed

- **Scalability past pilot vehicles**
  - Accurate perception/prediction is still work in progress
  - Transition from brute force data to safety case approach
2021 Organizational Safety Challenges

- Significant pressure to deploy
  - Flurry of empty driver seat demos in late 2020
  - Can teams take the time needed for safety?

- Industry transparency needed
  - Safety collaboration rather than competition
  - Public trust in face of an adverse news event

- Ensuring robust safety cultures
  - Silicon Valley culture + automotive culture + no human driver
  - We need to get this right to succeed!

https://youtu.be/nhqyrze30bk
Yandex demo video, Ann Arbor MI, Aug 2020