Partial Automation for Truck Platooning

Background Information for Discussion About Testing at Gaps Shorter than 100 ft.

July 6, 2016
PATP Project Background

- Funded under FHWA Exploratory Advanced Research Program (EARP) competitive solicitation (proposal in March 2013)
- Cooperative Agreement from FHWA to Caltrans, then contract from Caltrans to UCB-PATH (and subcontract to Volvo)
  - 20% cost share requirement met by combination of Caltrans, LA Metro and Volvo
- Work started August 2014, planned to end June 2017
- About $1.64 M federal, $490 K cost share
PATP Project Goals

- Identify near-term opportunities for CACC to improve heavy truck operations
  - Energy savings from drag reductions
  - Traffic flow (stability and density increases)
  - Maintain safety
- Assess acceptance of moderately short CACC gaps by truck drivers
- Measure energy savings at gaps chosen by drivers
- Provide data and demos to show benefits to industry and public stakeholders
Three Trucks Equipped for CACC

- Dual DSRC Antennas
- Supplementary display
- Video camera (production)
- 5 Hz GPS
- ACC radar (Production)
- PC-104 computer
- Emergency disengage button by driver
Development/Testing Stages (1/2)

1. Modeling and simulating vehicle dynamic responses to acceleration and brake commands
2. Open-loop tests to measure truck responses to acceleration and braking commands
3. Calibrating vehicle dynamic models based on open-loop test data
4. Closed-loop tests of CACC control at low speed on closed track, 2 trucks and then 3 trucks
5. Driving simulator tests to assess driver reactions to supplementary information display design and content
Development/Testing Stages (2/2)

6. Closed-loop tests of CACC control on highway, 2 trucks and then 3 trucks
   - Large gaps, and then smaller gaps
   - Tuning to maximize string stability
   - Comparing performance with different V2V message content, for input to messaging standards

7. Human factors experiment with typical truck drivers on public roads to determine their preferences for CACC following time gap settings

8. Energy efficiency tests for range of time gaps chosen by drivers, on closed track with truck loading variations
   - Experimental controls for variations in grade and wind direction
Testing on Closed Track, Low Speed

- Initial testing of basic functionality after any modification to hardware or software
- Convenient to research team, no cost, no delay
- Minimize safety risks with low speeds and closed track
- Limitations: Short length of each run and very different truck performance compared to highway speeds
Testing on Public Roads, up to 55 mph

- Necessary to show performance under a wide range of road and traffic conditions
- Necessary for human factors experiments, to experience realistic traffic conditions
- Necessary for realistic demonstrations to stakeholders and media
- Need to be extra safety-conscious, especially with any new functionality
- Governed by SB719 in California
California SB719 – Reasons for this meeting

• Authorizes Caltrans to test vehicles at shorter gaps than the 100 ft. minimum specified for caravans or motorcades (to enable passing and overtaking)
  – “…in coordination with the Department of the California Highway Patrol…”
  – Report findings to Legislature by 7/1/17

• “The department may only use motor vehicles and streets and highways in testing … that the Department of the California Highway Patrol authorizes for these uses.”
Example Results from Recent Tests

- Testing of three trucks at gaps of at least 100 ft.
- Most testing on I-580 adjacent to U.C. Berkeley Richmond Field Station/Global Campus (between Buchanan St., Albany and Canal Blvd., Richmond)
General Testing Conditions for Review

- Identical Volvo VN-series Class-8 tractors, marked with PATH logos
- Voice contact among drivers (or experimenters) using walkie-talkies with headsets
- Development testing (immediate need) planned at gaps from 0.6 – 1.2 s along I-580 in Richmond – Albany (or I-680 in Dublin – Walnut Creek), plus some limited testing on steeper grades along I-80 from Richmond to Hercules
  - Left exit at Buchanan requires lane changes to the left on I-580
- Driver acceptance testing in autumn planned for two possible routes (selection TBD)
Development Testing Scenarios

- University employee drivers, doing all steering control and safety monitoring, but activating CACC speed control under suitable conditions:
  - Between 25 and 55 mph, after entering freeway
  - Up to moderate traffic density
  - Moderate weather conditions (no strong winds or heavy rain or fog)

- Deactivations of CACC based on any safety concerns by any driver by:
  - Braking, or
  - Toggling ACC button on steering wheel, or
  - Red emergency shutoff button.
Steady-State Vehicle Following Tests

- First truck driven manually or using conventional ACC speed control
- One or two followers using CACC speed control under these approximate conditions:

<table>
<thead>
<tr>
<th>Time Gap Setting</th>
<th>Clearance Gap at 55 mph (ft)</th>
<th>Clearance Gap at 30 mph (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6 s</td>
<td>48</td>
<td>40 (min.)</td>
</tr>
<tr>
<td>0.8 s</td>
<td>65</td>
<td>40 (min.)</td>
</tr>
<tr>
<td>1.0 s</td>
<td>81</td>
<td>44</td>
</tr>
<tr>
<td>1.2 s</td>
<td>96</td>
<td>52</td>
</tr>
<tr>
<td>1.5 s</td>
<td>120</td>
<td>65</td>
</tr>
</tbody>
</table>
CACC Join and Split Maneuvers

• **Join:**
  – Joining truck approaches from behind at a slightly higher speed than predecessor and CACC adjusts speed to match at the desired gap

• **Split:**
  – Departing truck driver changes to an adjacent lane
  – If departing truck is in the middle, last truck follows up with CACC join behind predecessor
Cut-in and Cut-out Maneuvers

- Some occurring as a natural outcome of local driving, others staged deliberately with a confederate driver of a passenger car

- Cut-in:
  - Forward sensor detects cut-in vehicle and commands gap increase to at least basic ACC following distance, changing to ACC control strategy.

- Cut-out:
  - Intervening vehicle changes lanes to leave
  - Truck switches back to CACC and adjusts gap to shorter CACC distance
Manual Braking by Leader

- If driver of lead truck perceives a forward hazard, he brakes manually.
- Manual braking message is communicated to followers (within 0.1 s), which automatically brake in response, to aid in hazard avoidance.
Future Driver Acceptance Testing

• Seeking to learn about driver preferences among clearance gap settings
• Planned for October – November
• 24 drivers to be recruited from local truck fleets (half for daytime, half night-time tests)
  – Our driver drives lead truck
  – Test subjects drive in trucks 2 and 3, switching positions at midpoint of test.
  – Our experimenters accompany them in passenger seat to record real-time observations and provide backup.
On-Road Testing Procedure

1. Paperwork at Richmond Field Station
2. Familiarization with ACC on outbound drive (half hour) at least at 1.5 s gap, before reaching lower density locations
3. CACC driving with gaps between 0.6 s and 1.5 s (3/4 hour) in first position
4. CACC driving with gaps between 0.6 s and 1.5 s (3/4 hour) in second position
5. ACC for return drive (half hour), at least 1.5 s
6. Debriefing, questionnaire to fill out
Potential Test Route 1

CACC usage from I-580 Castro Valley to I-5 Manteca area
Potential Test Route 2

CACC usage between Carquinez Bridge or Cordelia Junction and I-5/I-505 junction
Future Truck Demonstrations

• Southern California (for LA Metro)
  – LA Metro assessing sites: El Monte busway or Terminal Island Freeway
  – December 2016 or later

• Central Valley – Fresno area, specifics TBD