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# Partial Automation for Truck Platooning

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

**July 6, 2016**

# PATP Project Background

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- **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**

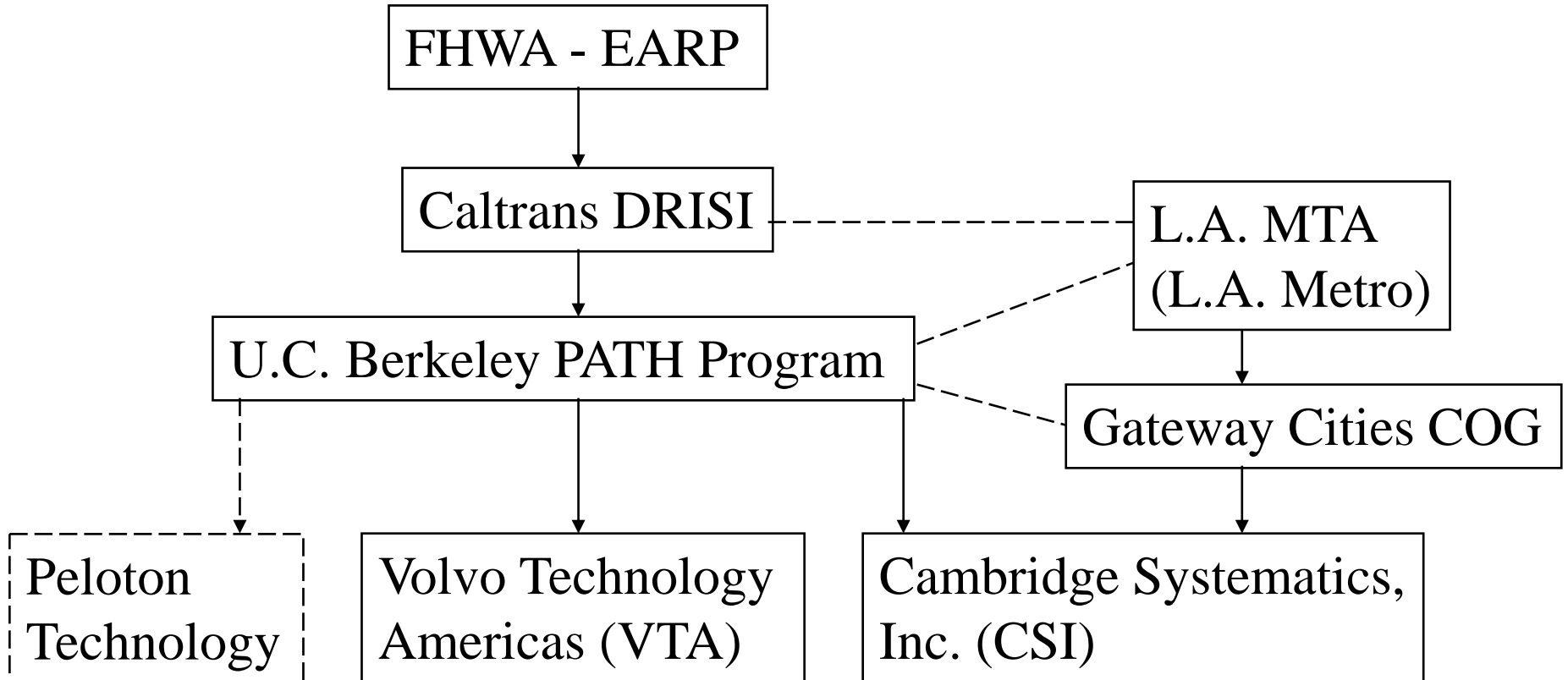
# PATP Project Goals

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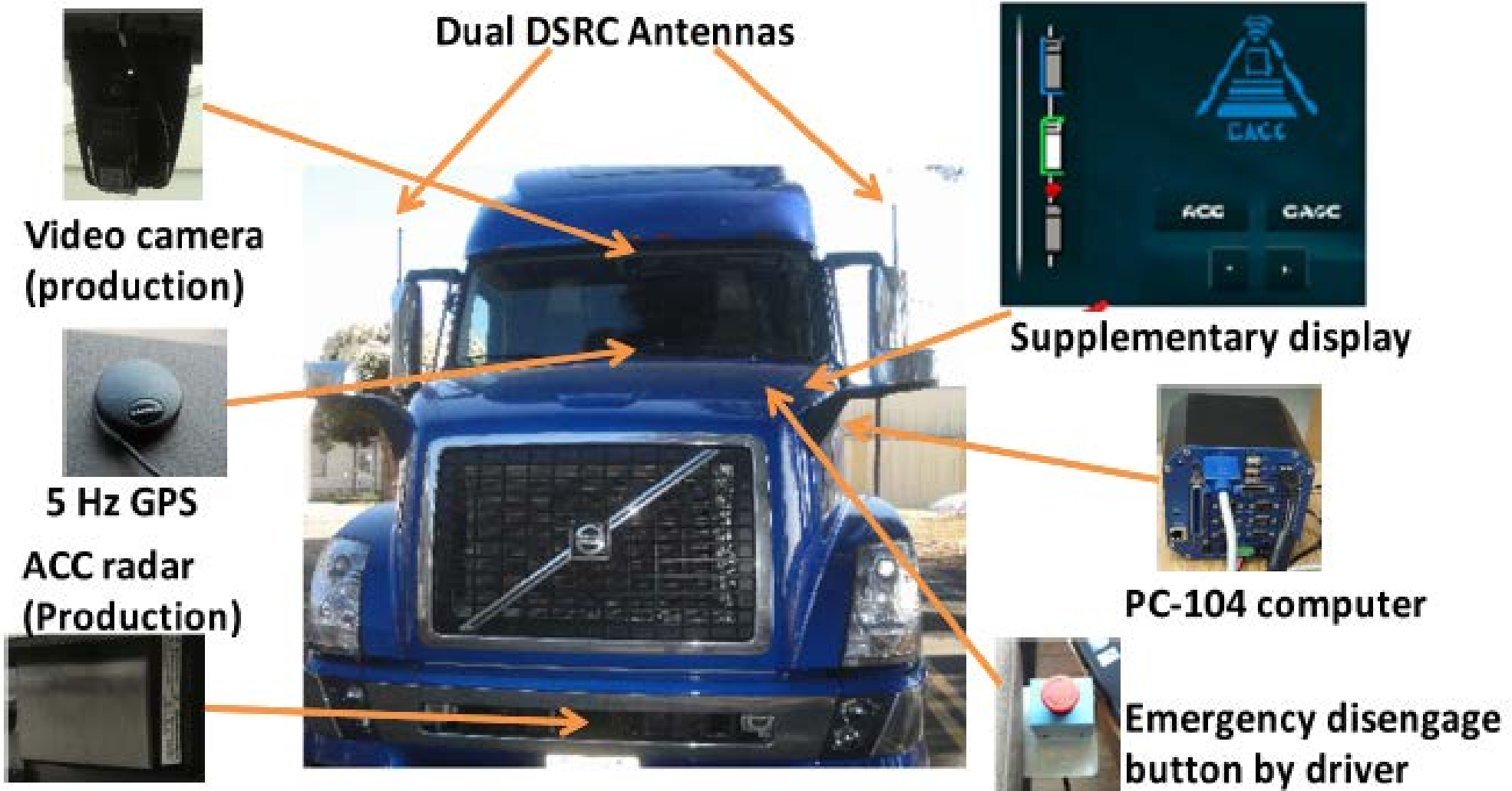
- **Identify near-term opportunities for CACC to improve heavy truck operations**
  - **Energy savings from drag reductions**
  - **Traffic flow (stability and density increases)**
  - **Maintain safety**
- **Assess acceptance of moderately short CACC gaps by truck drivers**
- **Measure energy savings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

# PATP Project Team

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# Three Trucks Equipped for CACC



# Development/Testing Stages (1/2)

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- 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)

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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

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- **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

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- **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

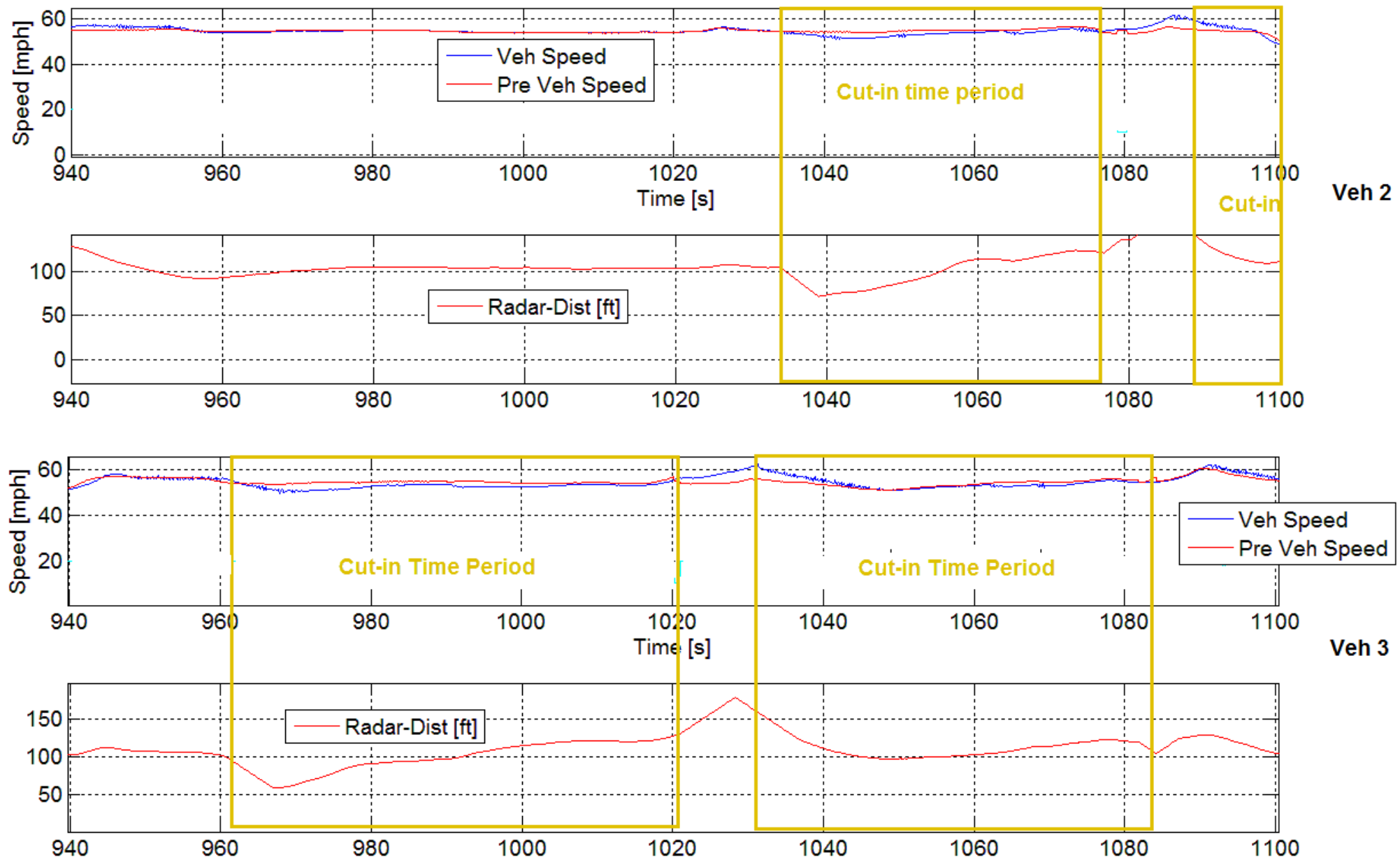
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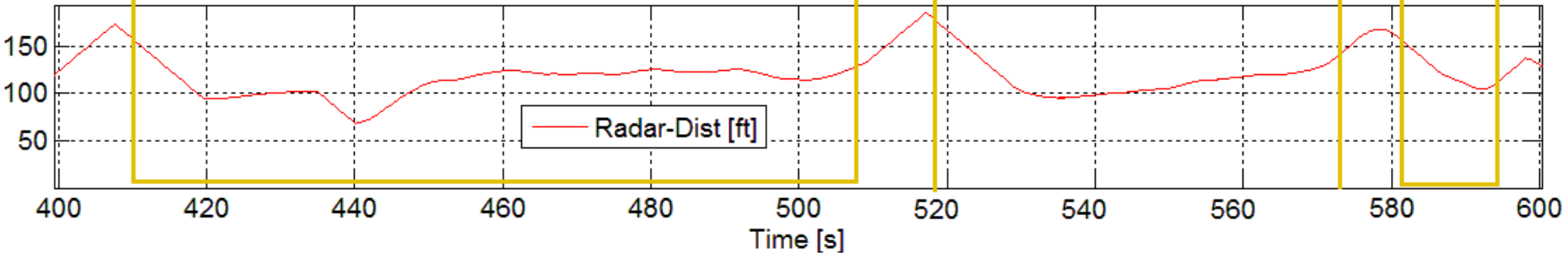
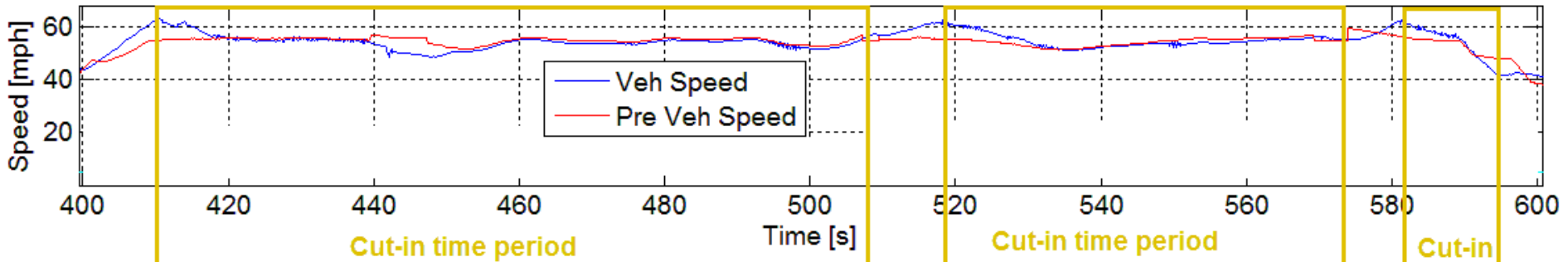
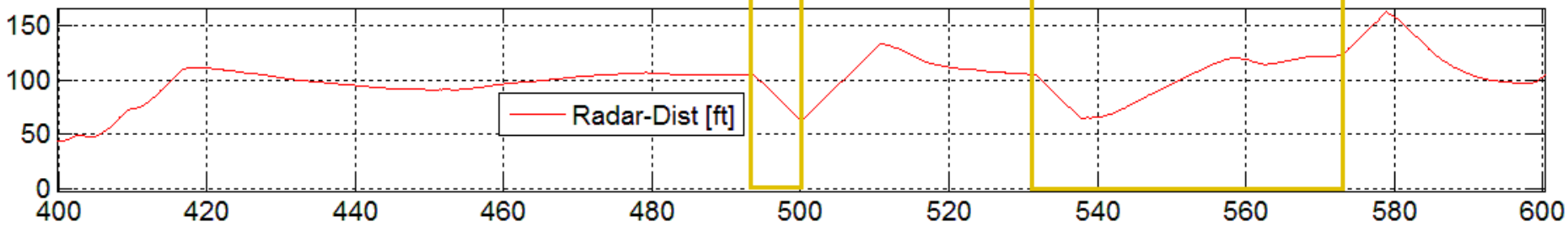
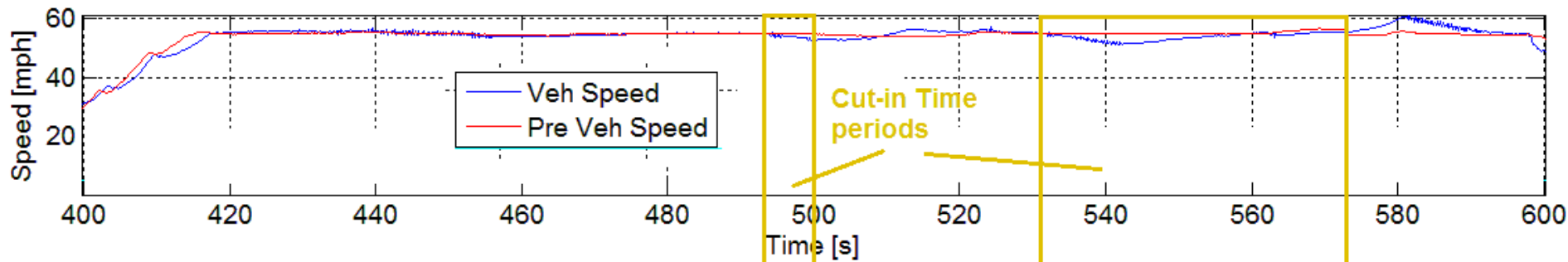
- **Authorizes Caltrans to test vehicles at shorter gaps than the 100 ft. minimum specified for caravans or motorcades (to enable passing and overtaking)**
  - **“...in coordination with the Department of the California Highway Patrol...”**
  - **Report findings to Legislature by 7/1/17**
- **“The department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

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- **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

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- **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

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- **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

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

<b>Time Gap Setting</b>	<b>Clearance Gap at 55 mph (ft)</b>	<b>Clearance Gap at 30 mph (ft)</b>
<b>0.6 s</b>	48	40 (min.)
<b>0.8 s</b>	65	40 (min.)
<b>1.0 s</b>	81	44
<b>1.2 s</b>	96	52
<b>1.5 s</b>	120	65



# CACC Join and Split Maneuvers

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- **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

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- **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

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- **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

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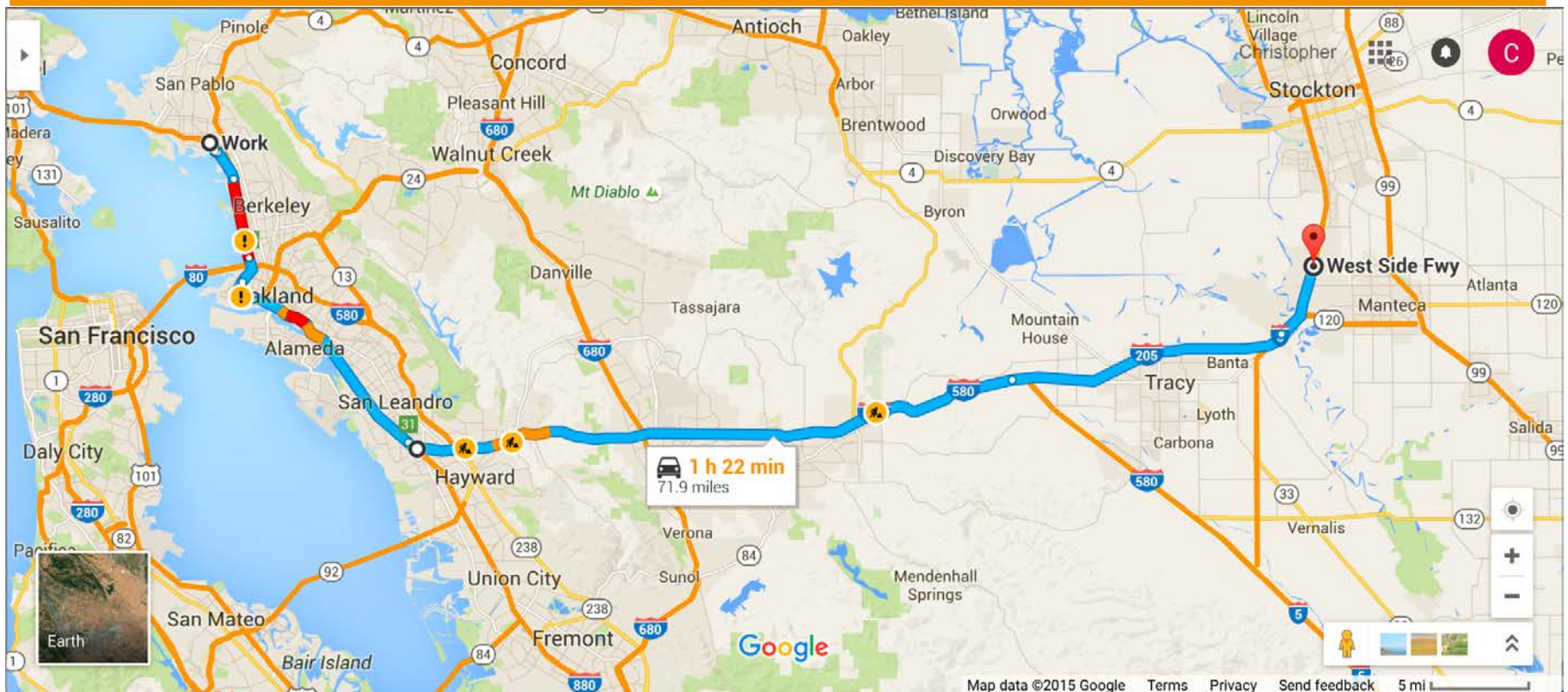
- **Seeking to learn about driver preferences among clearance gap settings**
- **Planned for October – November**
- **24 drivers to be recruited from local truck fleets (half for daytime, half night-time tests)**
  - **Our driver drives lead truck**
  - **Test subjects drive in trucks 2 and 3, switching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

# On-Road Testing Procedure

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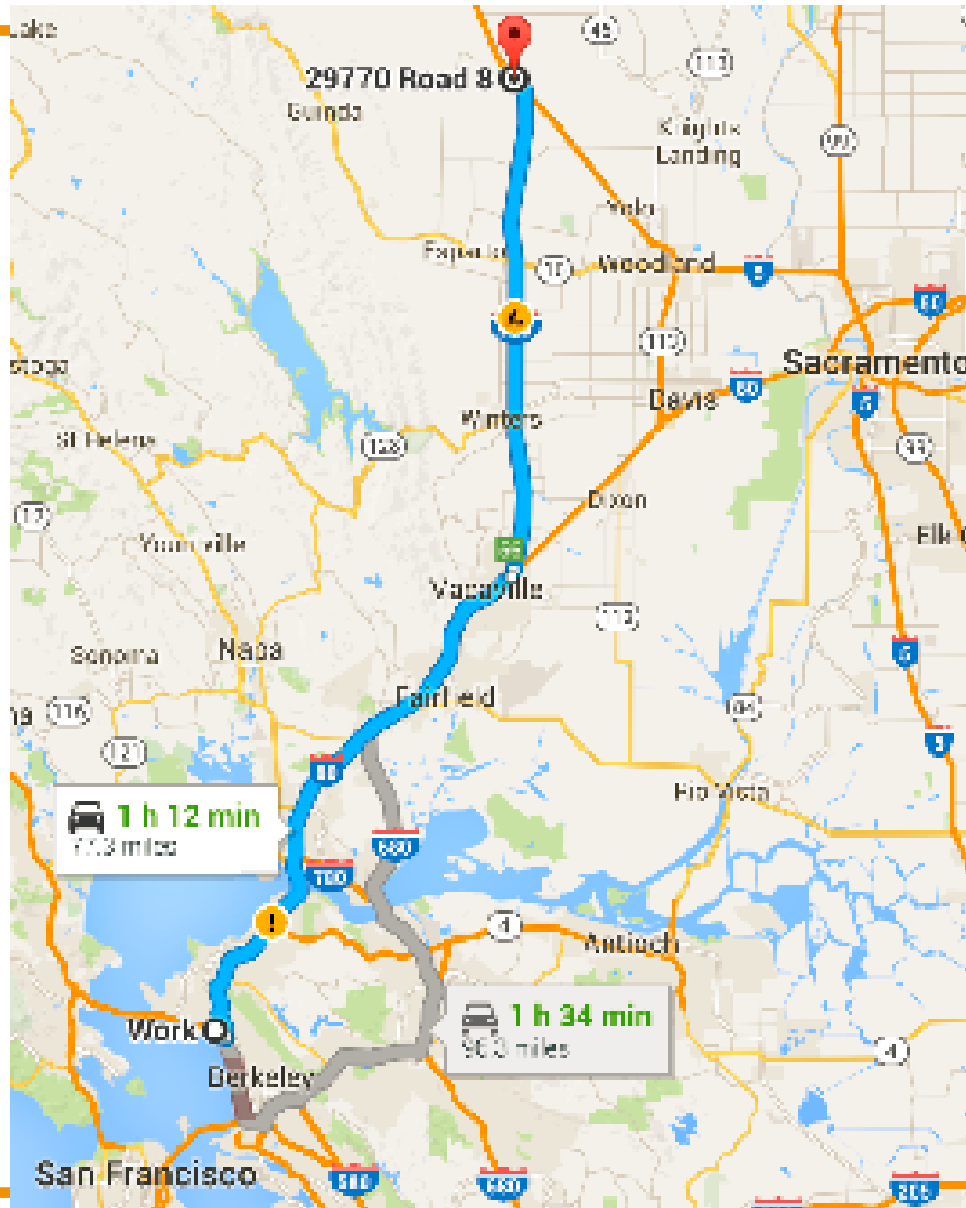
- 1. Paperwork at Richmond Field Station**
- 2. Familiarization with ACC on outbound drive (half hour) at least at 1.5 s gap, before reaching lower density locations**
- 3. CACC driving with gaps between 0.6 s and 1.5 s (3/4 hour) in first position**
- 4. CACC driving with gaps between 0.6 s and 1.5 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

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- **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**