
Connected Vehicle Deployment in a Live Environment in California

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Background

- PATH Program was jointly established by Caltrans and UC Berkeley in 1986
- PATH is a technical extension of the Caltrans Research Program, focused on Intelligent Transportation Systems (ITS)
 - Traffic Safety
 - Transportation Systems Management and Operations (TSMO)
 - Multi-modal and Public Transportation
 - Connected and Automated Vehicles
- PATH supports CV deployment in CA through 3 contracts
 - Connected Vehicle Test Bed Support and Maintenance
 - Connected Vehicle Deployment Support and Application Development
 - MMITSS Phase III (funded by FHWA and CV Pooled Fund Study)



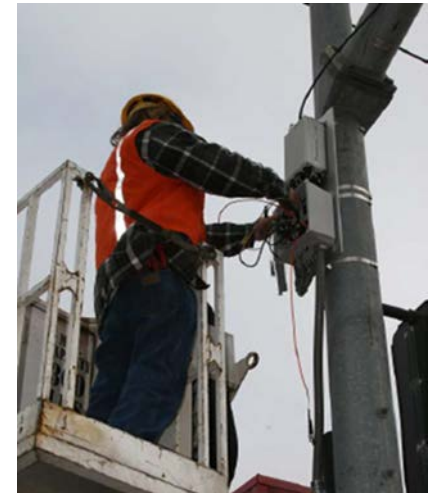
California Connected Vehicle Test Bed

- Established in 2005 by Caltrans, Metropolitan Transportation Commission and PATH in Palo Alto
- First-in-the-nation facility for testing CV applications using Dedicated Short Range Communications (DSRC) on public roads
- Located on El Camino Real (SR 82)
 - 2.1 miles long
 - 11 consecutive intersections
 - 6 more planned
 - AADT of 50K veh/day
 - Busy transit corridor

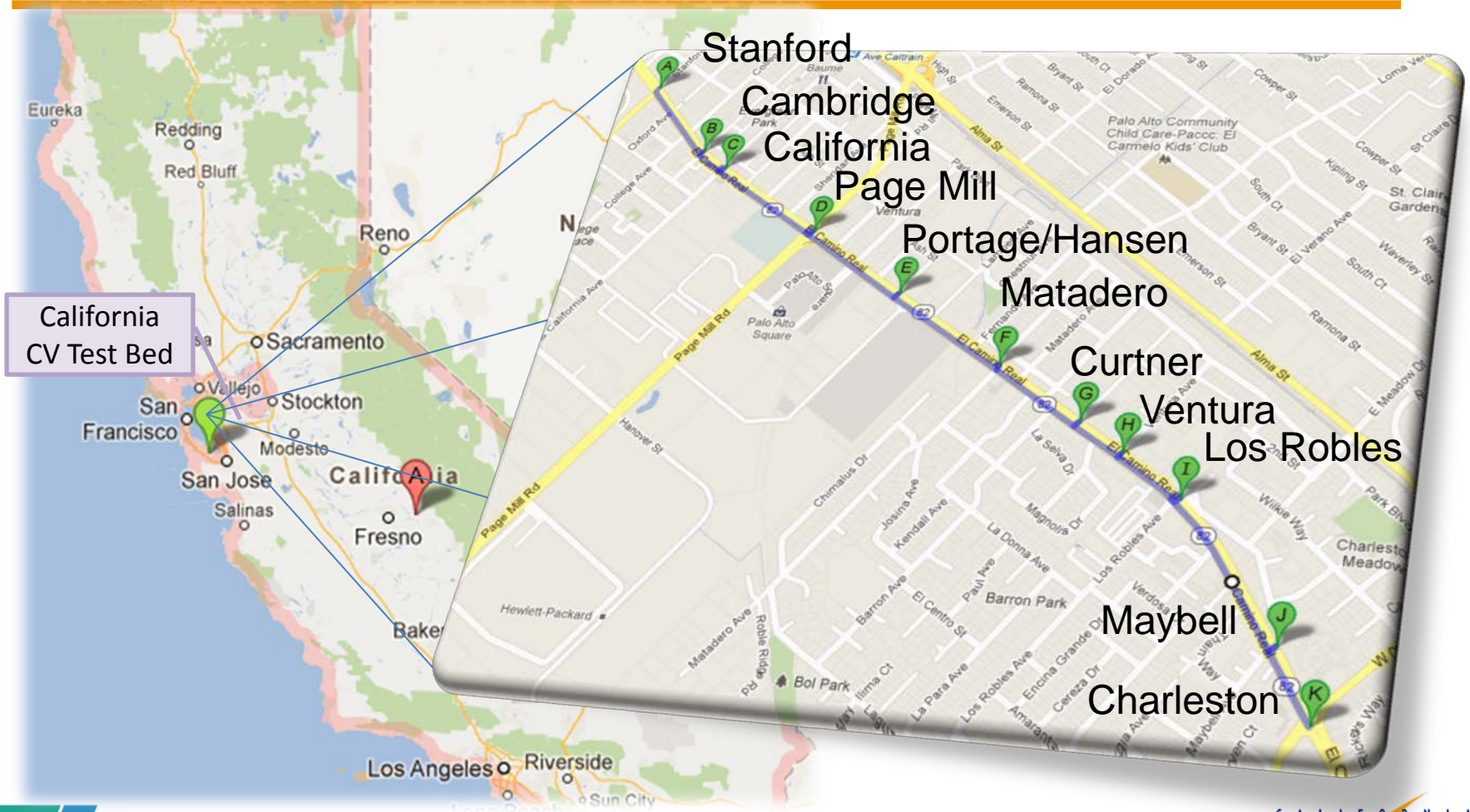


California Connected Vehicle Test Bed (cont.)

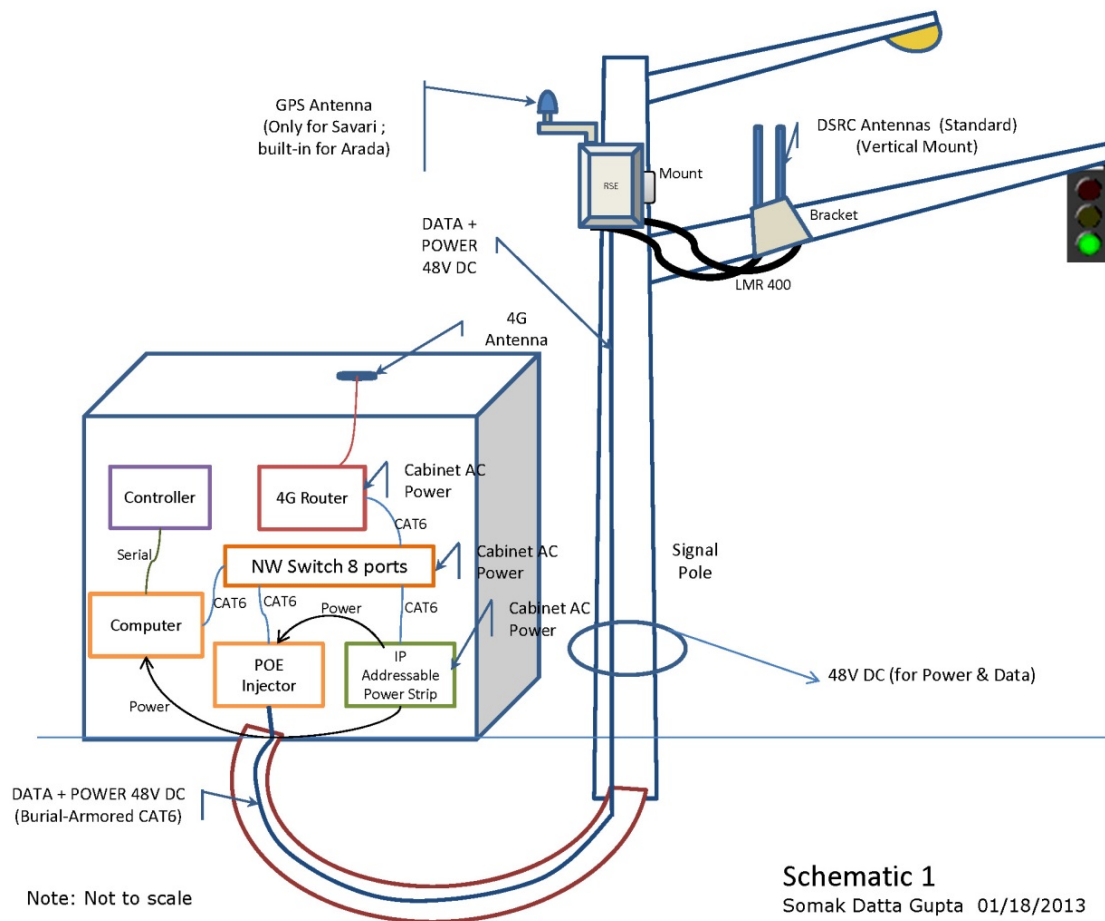
- Each intersection equipped with a DSRC roadside unit (RSU) broadcasting:
 - Signal Phase and Timing (SPaT)
 - Geometric Map (MAP)
 - Signal Status Message (SSM)
 - RTCM Corrections messages (planned)
- PATH serves as technical consultant
- Several companies have used the test bed for application development and testing
- Ready for new application development -
Open for Business!



California Connected Vehicle Test Bed (Map)



Example Layout Schematic (Roadside)



Intersection list:

Stanford
Cambridge
California
Page Mill
Portage /
Hansen
Matadero
Ventura
Los Robles

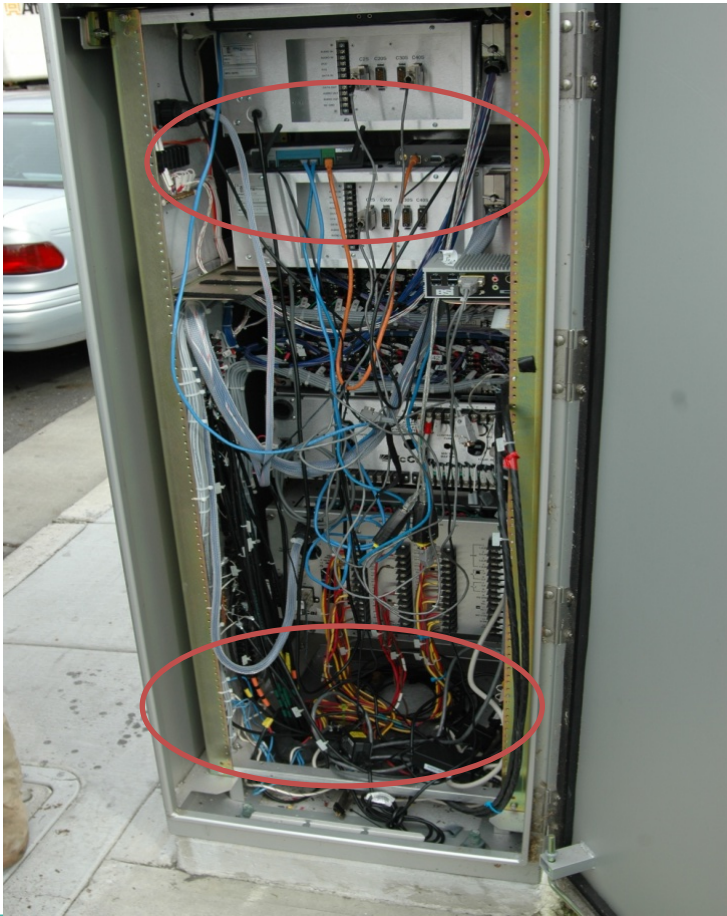
Actual Installation (RSU and Antenna)



Page Mill Road and El Camino Real



Actual Installation (Cabinet)



Back



Side Cabinet

California CV Test Bed

Current Status and Plan for Late 2017

| | Current | Plan for late 2017 |
|---|---|---|
| # of Intersections | 11 | 17 |
| Roadside Unit (RSU) | Version 3.1 | Version 4.1 with security chip |
| Linux computer | <ul style="list-style-type: none"> • Ubuntu 16.04.2 (latest) • Linux kernel 4.10.0 (latest) | |
| Backhaul | Router utilizes 3G | Replace router to utilize 4G LTE |
| Broadcast Messages | <ul style="list-style-type: none"> • MAP • SPaT • SSM | Add RTCM Corrections message |
| SAE J2735 Standard | Version 2016-03 (latest) | |
| Data feed to National CV Data Warehouse | | ✓ |
| Integration with National SCMS | | Work with RSU/OBU vendors and SCMS service provider |

CV Testbed Support and Maintenance

- Provided by PATH through multi-year Caltrans contract
 - Fix and replace any broken hardware and software
 - Keep up to date with the latest standards
 - Provide real-time data to National CV Data Warehouse
 - Develop web-based Test Bed “Health Monitoring” tool

<http://caconnectedvehicletestbed.org/>

- On-line “primer” on how to use the Test Bed
- Description of available services
- Frequency of broadcast messages (e.g. BSM, SPaT, SRM, etc.)
- Tool for users to report issues on using the test bed, and to request assistance

CV Deployment Support and Application Development

- Provided by PATH in partnership with UC Riverside
- Testbed expansion and enhancement
- CV application development and testing
 - Adaptive transit signal priority
 - Connected Eco-Approach/Departure application for transit and heavy vehicles (partnering with UC Riverside)
 - Partner with Santa Clara VTA for testing and evaluation of transit applications
- Technical assistance to Caltrans on CV deployment
 - Meetings and webinars
 - Demonstrations
 - Build partnerships



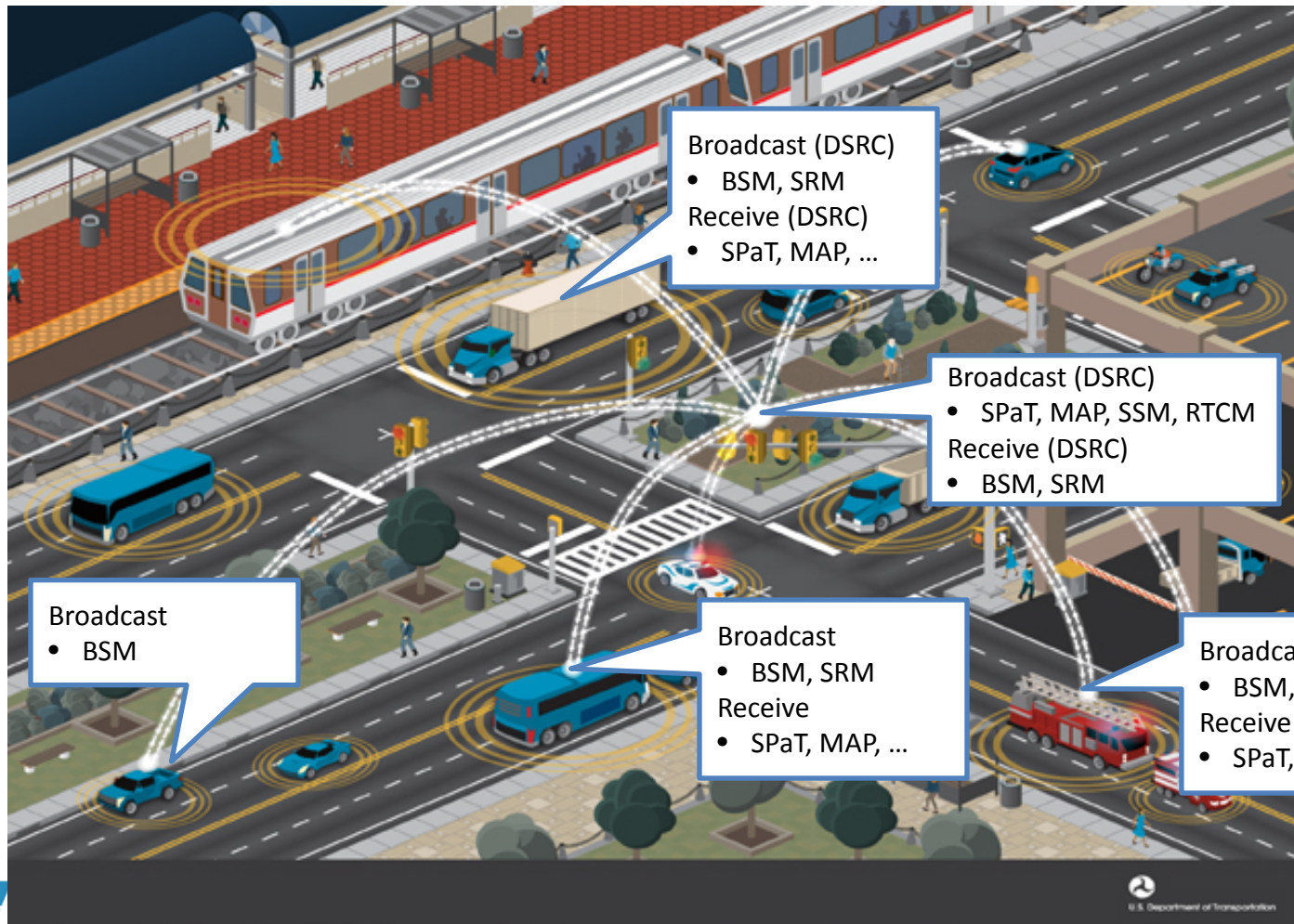
Multi-Modal Intelligent Traffic Signal System (MMITSS)

- Funded through the Connected Vehicle PFS, led by VDOT
- Additional funding from USDOT Dynamic Mobility Applications (DMA) program
- University of Arizona and California PATH Program
- MMITSS applications bundle
 - I-SIG: Intelligent Traffic Signal System
 - TSP: Transit Signal Priority
 - FSP: Freight Signal Priority
 - EVP: Emergency Vehicle Signal Preemption (AZ)
 - PED-SIG: Pedestrian Mobility

MMITSS Status

- Phase I: 2012 – 2013
 - ConOps, System Requirements, Preliminary Design
- Phase II: 2013 – 2016
 - Two MMITSS prototypes built
 - MMITSS-AZ: adaptive traffic signal and priority control, NTCIP-based
 - MMITSS-CA: semi-actuated coordinated signal and priority control, uses Caltrans protocol (AB3418)
 - MMITSS-CA demonstrated on CA Testbed in Nov. 2015
- Phase III: Sep. 2017- Feb. 2019
 - Enhanced applications, more testing, deployment-focused, NTCIP
- Documentation and source code available at CV PFS web site and on USDOT open-source portal

MMITSS-CA Operational Concept (Connected Vehicle Application)



MMITSS-CA Operational Concept (Cont'd)

Roadside (RSU, MRP, Controller, Signal)

- Broadcast SPaT (source: controller)
- Broadcast MAP (source: intersection geographic description file)
- Receive BSMs
 - Locate BSMs on MAP
 - Estimate expected-time-to-arrival (ETA)
 - Determine I-SIG strategy and command to traffic signal controller
 - Calculate performance measure
- Receive SRMs
 - Associate SRM with BSM
 - Determine signal priority strategy
 - Command to controller
- Broadcast signal status message (SSM)

Equipped Vehicle (OBU/ASD)

- Broadcast BSM
- Receive MAP(s) and SPaT(s)
 - Determine active MAP & SPaT
 - Locate vehicle on MAP
 - Estimate expected-time-to-arrival (ETA)
 - Determine the needs for priority
- Send signal request message (SRM)
- Receive SSM (confirmation for SRM)

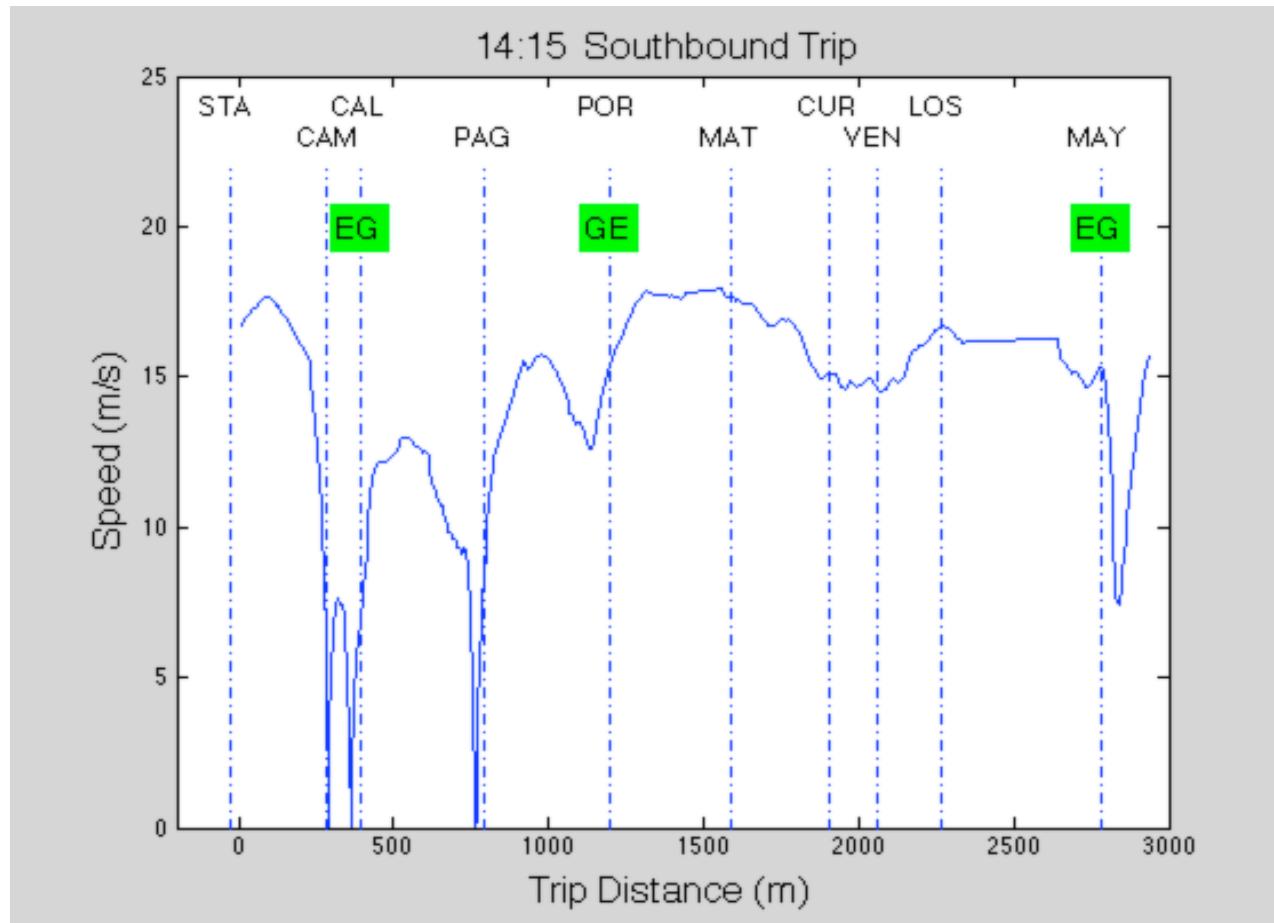


MMITSS-CA Field Tests (Phase II)

- 5 instrumented vehicles: 2 Savari and 3 Arada OBUs
- 'Before' scenario (without priority): Thursday November 5th, 2015
- 'After' scenario (with priority): Thursday November 12th, 2015
 - 2 'buses', 2 'trucks' and 1 passenger car

| | Without Priority | | | With Priority | | | Percentage Change |
|-------------------------|--------------------|----|-------|---------------------|----|-------|-------------------|
| | SB | NB | Total | SB | NB | Total | |
| Number of Trips | 33 | 36 | 69 | 35 | 36 | 71 | |
| Number of Stops | 3.9 ± 1.5 | | | 3.6 ± 1.4 | | | - 7.3% |
| Cumulative Time of Stop | $127.0s \pm 65.3s$ | | | $109.1 s \pm 53.2s$ | | | - 14.1% |
| Trip Travel Time | $386.4s \pm 82.1s$ | | | $358.1 s \pm 67.6s$ | | | - 7.4% |
| Delay due to Stops | $132.1s \pm 74.2s$ | | | $115.7 s \pm 54.5s$ | | | - 12.5% |

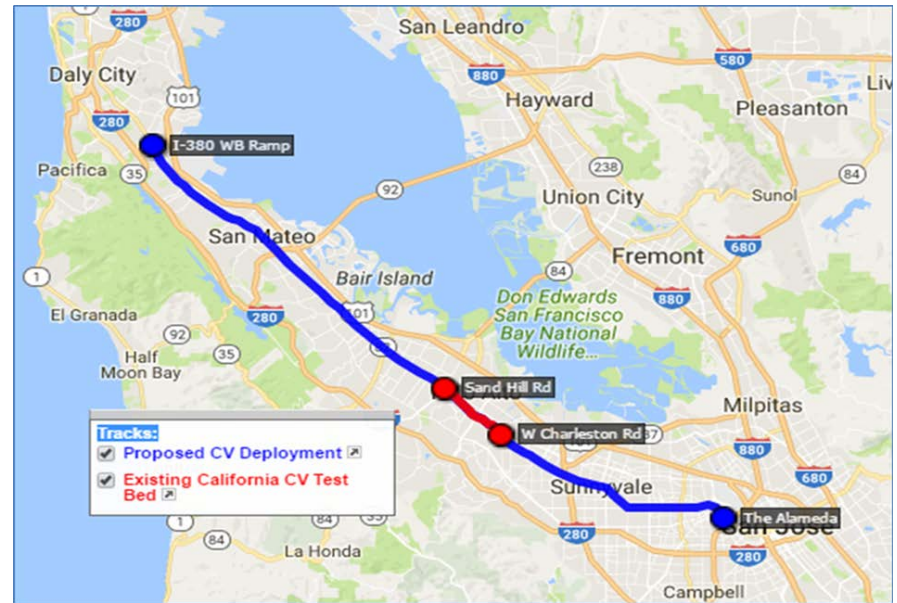
Example: Granted Priority Requests



EG = Early Green
GE = Green Extension

California CV Test Bed Future Plans

- Partnership with Prospect Silicon Valley to attract new users
- Considering support of new technologies such as AV and 5G
- “Ready-to-Go” proposal to equip the entire EL Camino Real corridor
 - 30 miles long with 139 additional intersections



Comments & Questions?

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or visit

<http://caconnectedvehicletestbed.org/>

Caltrans provides a safe, sustainable, integrated, and efficient transportation system to enhance California's economy and livability

