



Caltrans Interests in Connected/Automated Vehicles

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- Today's Transportation Challenges
- Connected Vehicle Concepts and DSRC
- Connected Vehicle Applications
- Safety Pilot Model Deployment
- Affiliated Connected Vehicle Test Beds
- California Connected Vehicle Test Bed
- Automated Vehicle Levels and Definitions
- Caltrans/PATH History with Automated Vehicles
- Related Current Automated Vehicle Activities
- Operational Considerations

Today's Transportation Challenges

Safety

- 32,367 highway deaths in 2011
- 5.3 million crashes in 2011
- Leading cause of death for ages 4 - 27



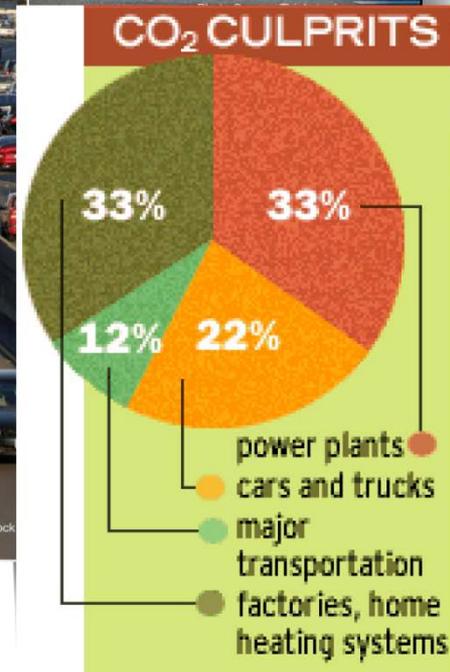
Mobility

- 4.8 billion hours of travel delay
- \$101 billion cost of urban congestion



Environment

- 1.9 billion gallons of wasted fuel



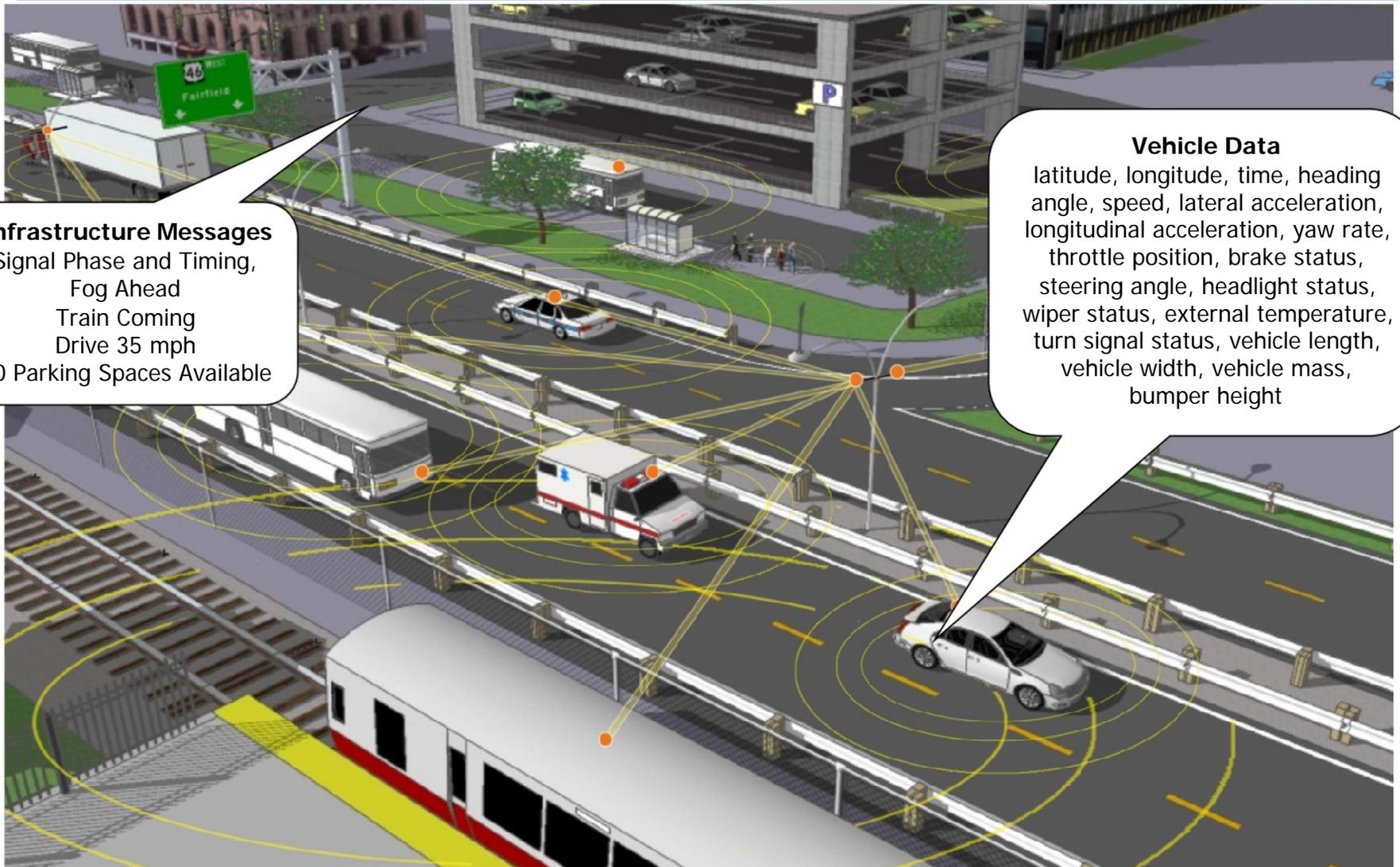
National Vision for Connected Vehicles

Infrastructure Messages

Signal Phase and Timing,
Fog Ahead
Train Coming
Drive 35 mph
50 Parking Spaces Available

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



Technology for Safety - 5.9 GHz DSRC

What is it?

- Wi-Fi radio technology adapted for the vehicle environment
- Low cost; easy to build in large quantity
- FCC originally allocated spectrum in 1999; revised in 2004 and 2006

How does it work?

- Messages transmitted 10 times/second (~300m range, restricted to line of sight)
- **Basic Safety Message (BSM)**: vehicle position, speed, heading, acceleration, size, brake system status, etc.
- Privacy **IS** protected (vehicle location is **NOT** recorded or tracked)

Benefits of DSRC technology compared to radar/laser technology:

- Reduced cost
- Improved reliability; fewer false alarms
- Increased performance; addresses more crash types

Drawbacks to using DSRC technology:

- Both vehicles need to be equipped in order to gain the benefit
- Requires back-office security infrastructure



Connected Vehicle Applications

SAFETY APPS (V2V)

- Forward Collision Warning (FCW)
- Emergency Electronic Brake Light (EEBL)
- Intersection Movement Assist (IMA)
- Blind Spot Warning (BSW)/ Lane Change Warning (LCW)
- Left Turn Across Path / Opposite Direction (LTAP)

SAFETY APPS (V2I)

- Red Light Violation Warning
- Curve Speed Warning
- Stop Sign Gap Assist
- Stop Sign Violation
- Railroad Crossing Violation Warning
- Spot Weather Impact Warning
- Oversize Vehicle Warning
- Reduced Speed/ Work Zone Warning
- Pedestrian Warning for Transit Vehicles
- Smart Roadside

MOBILITY APPS

- Integrated Dynamic Transit Operations (IDTO)
- Intelligent Network Flow Optimization (INFLO)
- Multi-Modal Intelligent Traffic Signal System (M-ISIG)
- Response, Emergency Staging and Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.)
- Enable Advanced Traveler Information System (EnableATIS)
- Freight Advanced Traveler Information System (FRATIS)

ENVIRONMENT APPS

AERIS

- Dynamic Low Emissions Zone
- Dynamic Eco-Lanes
- Eco-Traveler Information
- Eco-Signal Operations
- Eco-ICM
- Support AFV Operations

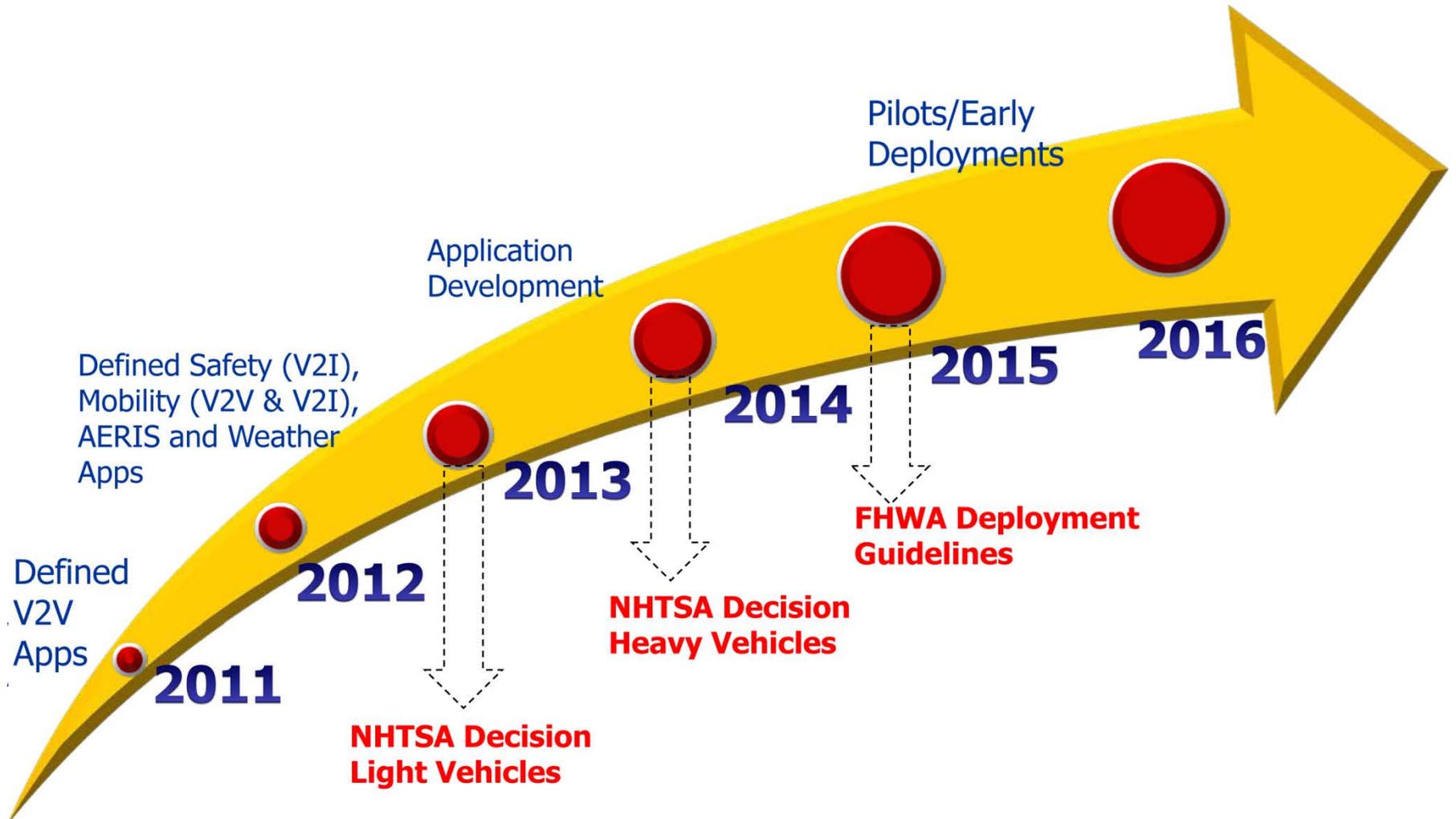
ENVIRONMENT APPS

Road Weather

- Enhanced Maintenance Decision Support System
- Information for Maintenance and Fleet Management Systems
- Variable Speed Limits for Weather-Responsive Traffic Management
- Motorist Advisories and Warnings
- Information for Freight Carriers
- Information and Routing Support for Emergency Responders



Moving towards Infrastructure Deployment



Connected Vehicle Safety

- **NHTSA Agency Decisions**

- 2013 NHTSA agency decision on V2V safety communications systems
- Similar milestone in 2014 for a decision regarding V2V safety technology on heavy vehicles
- Information to support the decisions will come from many sources, including the **Safety Pilot Model Deployment**

- **Policy Work (ongoing)**

- System Security
- Privacy
- Governance
- Business Models
- Legal Issues



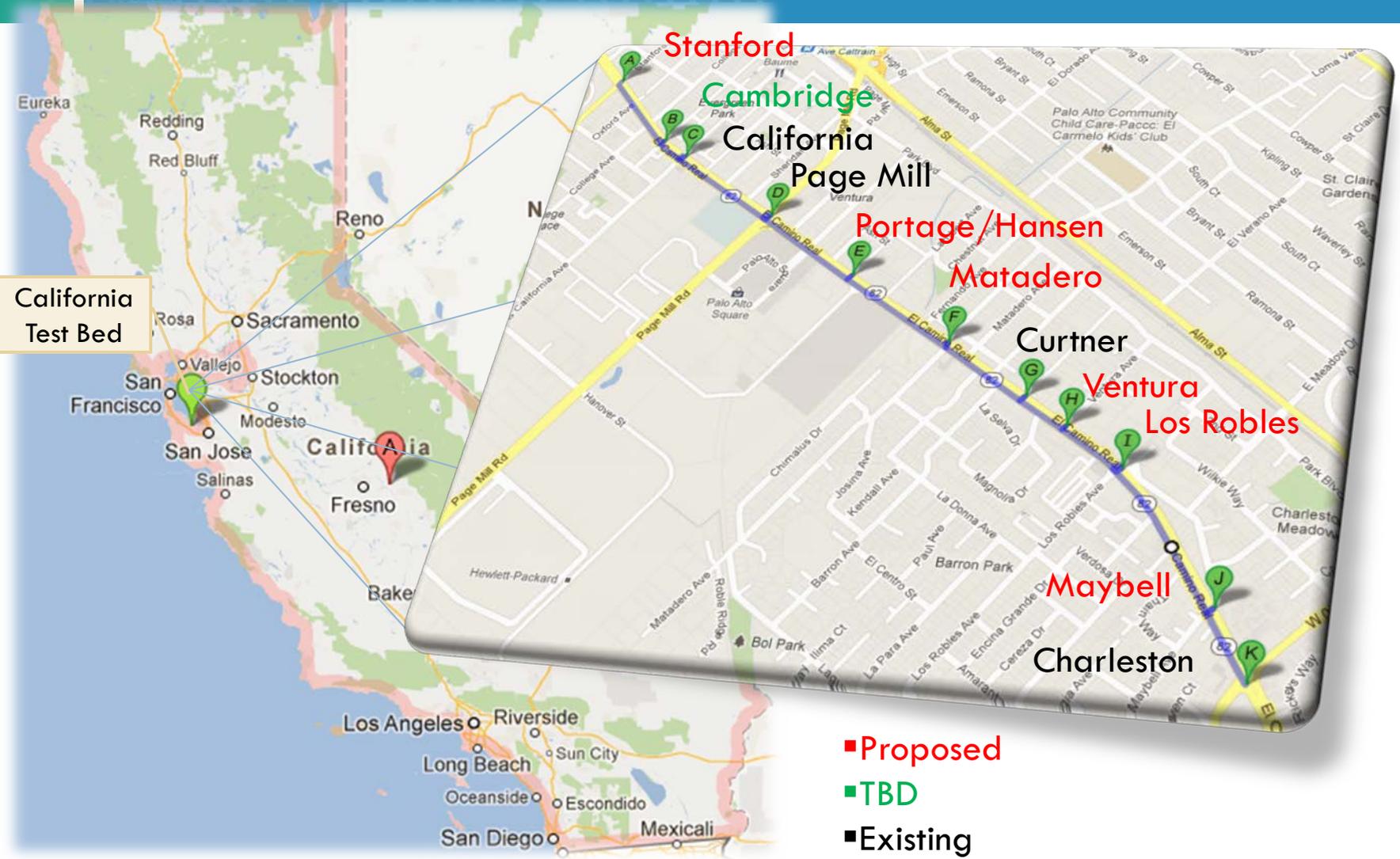
Affiliated Connected Vehicle Test Beds

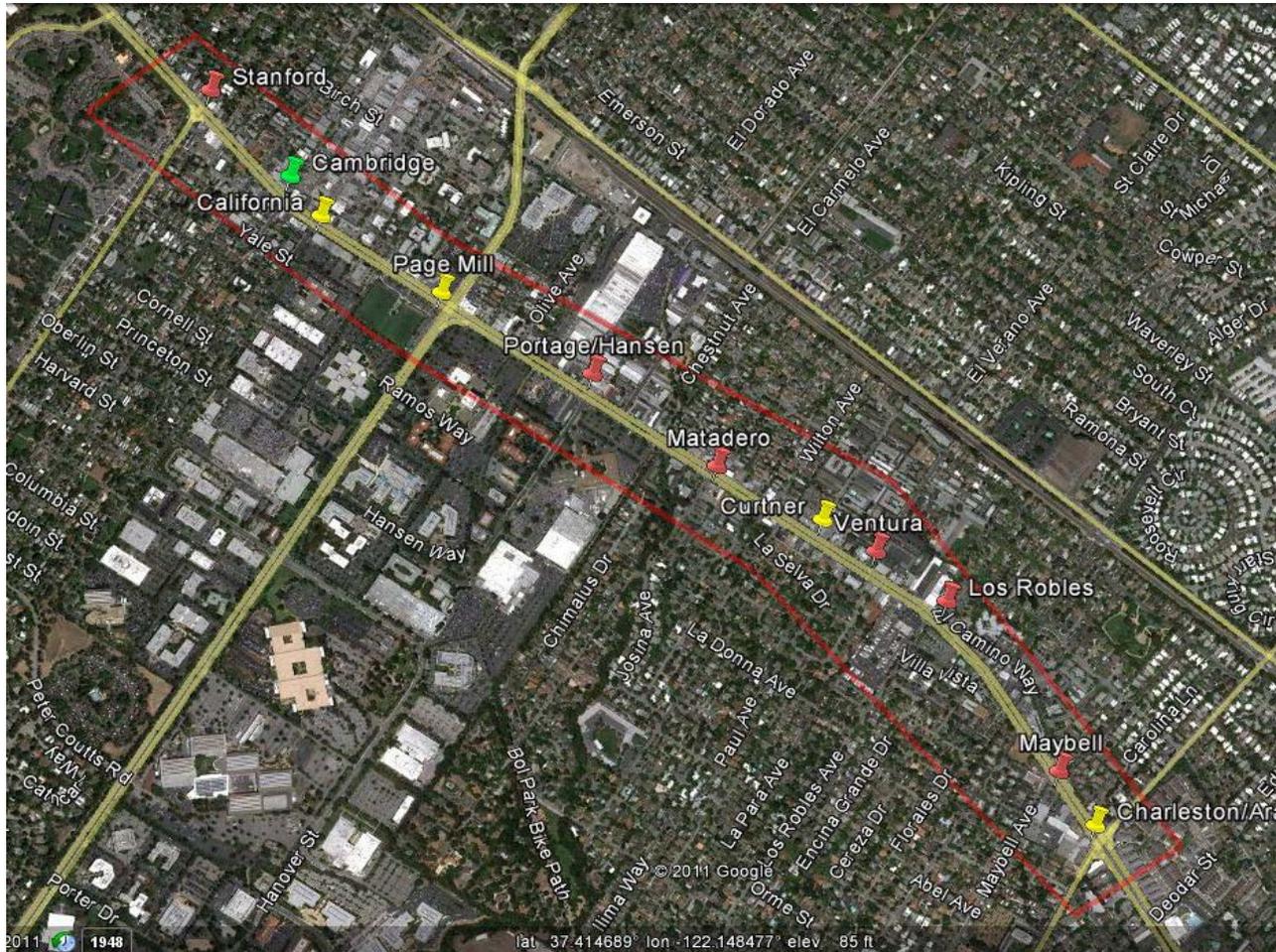


- Real-world, operational test beds that offer the supporting vehicles, infrastructure, and equipment to serve the needs of public and private sector testing and certifications activities
- Draft Memorandum of Agreement (MOA) – the purpose is to create an affiliation of 5.9 GHz DSRC roadside equipment makers, operators of V2I installations, and developers of applications that use V2I communications
 - Agreements will help to facilitate the sharing of tools and resources across all locations to bring about the future deployment of 5.9 GHz DSRC and other V2I communications technology
 - Based on feedback from the draft version, a second version is now being circulated for consideration by stakeholders
- **The finalized MOA is expected to be ready by March 2014**



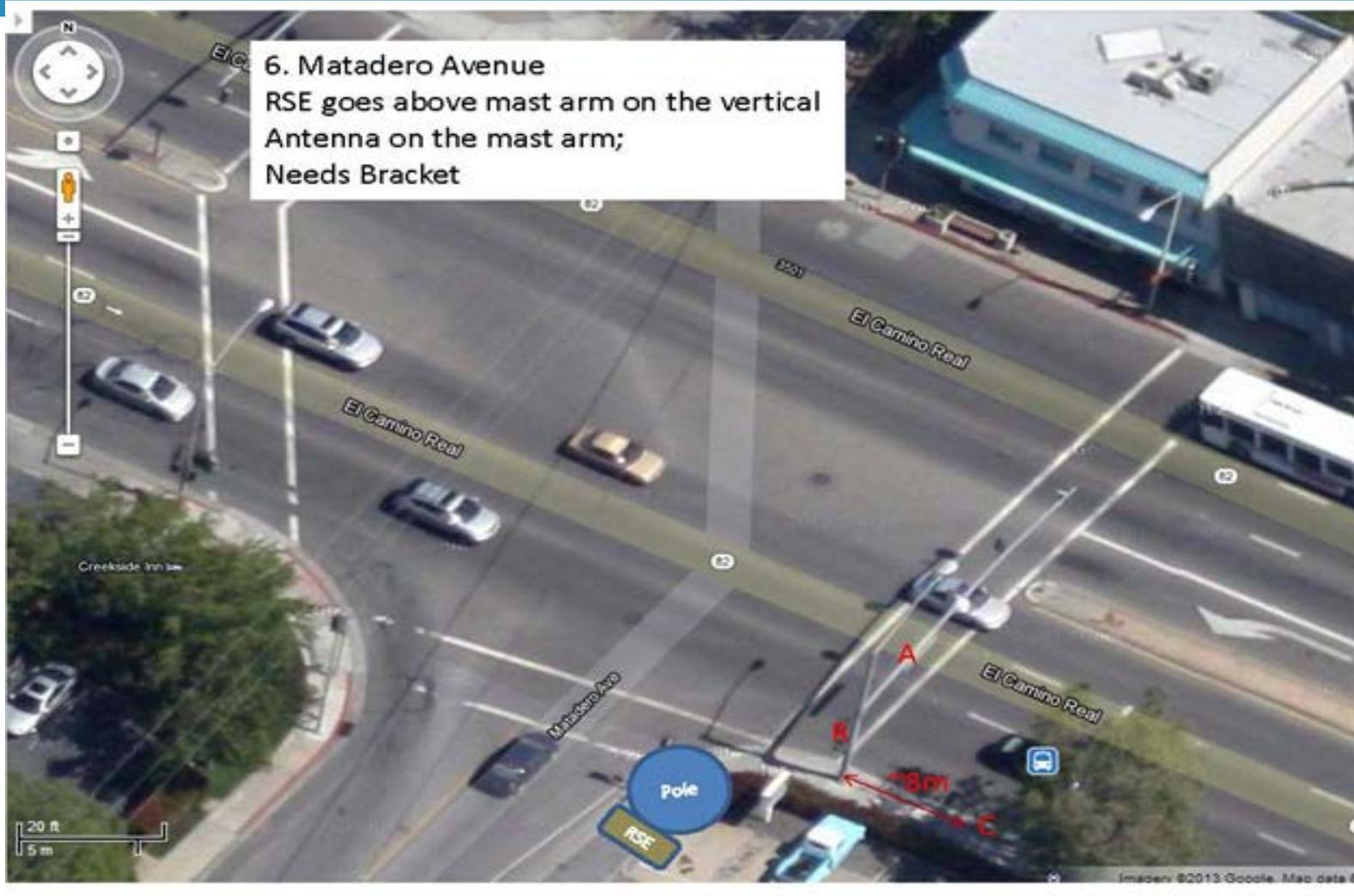
- **Michigan:**
 - 2008 Proof of Concept Test Bed in Oakland County (Detroit region)
 - Safety Pilot Model Deployment (Ann Arbor)
- **New York** (2008 ITS World Congress)
- **Florida** (Orlando; 2011 ITS World Congress)
- **Virginia** (under construction in Northern Virginia)
- **Arizona** (Maricopa County [Phoenix])
- **California** (installed 2005; currently being upgraded)





1. Stanford
2. Cambridge
3. California
4. Page Mill
5. Portage/Hansen
6. Matadero
7. Curtner
8. Ventura
9. Los Robles
10. Maybell
11. Charleston

Example Installation



Actual Installation (Page Mill Road and El Camino Real)



- Applications developed, under development, and planned
 - Traveler Information (collect vehicle probe data; process it into traffic information and send it back to the driver)
 - Electronic Payment and Toll Collection
 - Ramp Metering
 - Cooperative Intersection Collision Avoidance Systems (CICAS)
 - Curve Over-Speed Warning
 - Auto Industry Applications, such as Customer Relations and Vehicle Diagnostics

 - Multi-Modal Intelligent Traffic Signal Systems (Pooled Fund Study project)
 - Intelligent Traffic Signal System (ISIG)
 - Transit Signal Priority (TSP)
 - Mobile Accessible Pedestrian Signal System (PED-SIG)
 - Emergency Vehicle Preemption (PREEMPT)
 - Freight Signal Priority (FSP)

 - Nissan/PATH Cooperative “Green Wave”
 - BMW/PATH Cooperative “Green Wave”
 - At-Grade Light Rail Crossing Safety Research
 - ITSIS (Intelligent Transit Stop Information System)

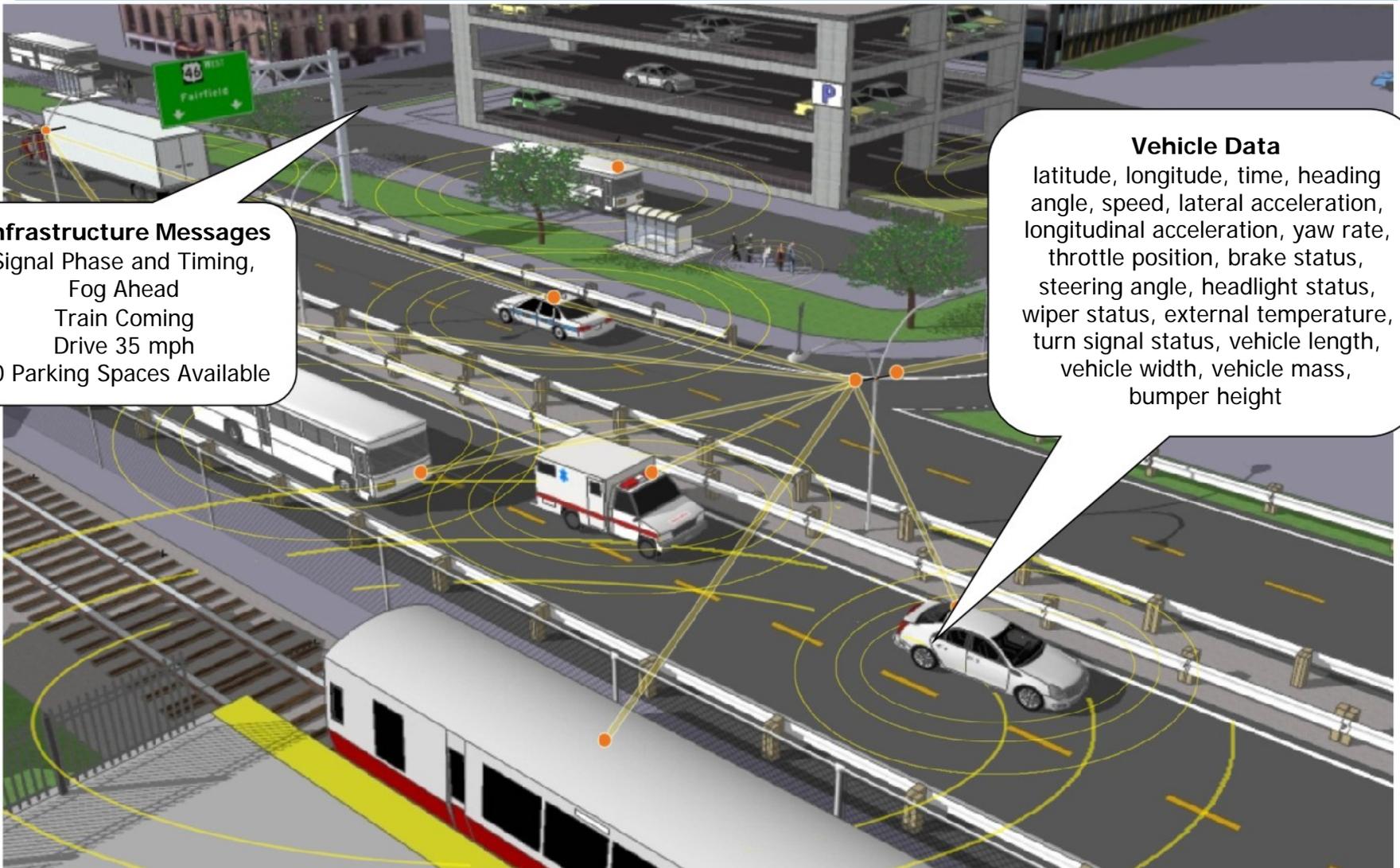
Connected Vehicles set the stage for Vehicle Automation!

Infrastructure Messages

Signal Phase and Timing,
Fog Ahead
Train Coming
Drive 35 mph
50 Parking Spaces Available

Vehicle Data

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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.

NHTSA level	SAE level	SAE name	SAE narrative definition	Execution of steering and acceleration/ deceleration	Monitoring of driving environment	Backup performance of dynamic driving task	System capability (driving modes)
Human driver monitors the driving environment				Human driver	Human driver	Human driver	n/a
0	0	Non-Automated	the full-time performance by the <i>human driver</i> of all aspects of the <i>dynamic driving task</i> , even when enhanced by warning or intervention systems				
1	1	Assisted	the <i>driving mode</i> -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 <i>human driver</i> perform all remaining aspects of the <i>dynamic driving task</i>				
2	2	Partial Automation	the <i>driving mode</i> -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 <i>human driver</i> perform all remaining aspects of the <i>dynamic driving task</i>	System	Human driver	Human driver	Some driving modes
Automated driving system ("system") monitors the driving environment							
3	3	Conditional Automation	the <i>driving mode</i> -specific performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> with the expectation that the <i>human driver</i> will respond appropriately to a <i>request to intervene</i>	System	System	Human driver	Some driving modes
4	4	High Automation	the <i>driving mode</i> -specific performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> , even if a <i>human driver</i> does not respond appropriately to a <i>request to intervene</i>	System	System	System	Some driving modes
	5	Full Automation	the full-time performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> under all roadway and environmental conditions that can be managed by a <i>human driver</i>	System	System	System	All driving modes



Example Systems at each Automation Level



Level	Example Systems	Driver Roles
1	Adaptive Cruise Control, <u>OR</u> Lane Keeping Assistance	Must control <u>other</u> function, and still continuously monitor driving environment
2	Adaptive Cruise Control <u>AND</u> Lane Keeping Assistance; “Traffic Jam Assist” (Mercedes)	Must still continuously monitor the driving environment (system nags driver to ensure they are paying attention)
3	“Traffic Jam Pilot” (Volvo); Automated Parking	May read a book, text, or web surf, but must still be prepared to intervene when needed
4	Highway driving pilot; Closed campus driverless shuttle; Valet parking in garage	May sleep, and system can still revert to minimum risk condition, if needed
5	Automated taxi (even for children); Car-share repositioning system	No driver needed

- Core Member, along with PATH, of the National Automated Highway System Consortium (NAHSC)
- Highlight was the 1997 Demo on I-15 in San Diego
- Passenger car automation demonstrated
- NAHSC ended its work in 1998



- Caltrans and PATH continued automated vehicle research after the end of the NAHSC
- Changed focus to heavy vehicles: buses and trucks
- Hosted a national workshop on Bus Automation in 2003, also on I-15 in San Diego
- Light Rail alternative?



- Caltrans and PATH tested automated truck platoons on a closed track in 2003
 - Significant fuel savings measured (12-18%)
- Real-world testing by PATH in Nevada in 2009 confirmed the fuel savings benefits



- Steering automation only on narrow right-of-way: circulator system in Eugene, OR; San Mateo Bridge Toll Plaza
- Oregon system operated in revenue service



- Caltrans and PATH have partnered with LA Metro and Gateway Cities to win FHWA EAR grant funding
- Efficient movement of trucks travelling in and out of the Ports of LA and Long Beach
- Builds on prior truck development work from 2003 and 2009 projects
- Pilot Test



- PATH continues working with Nissan to develop CACC for passenger cars
- Potential to safely reduce headways, which should increase throughput on existing roadways
- Travel speed could also be commanded by the roadway operator as a strategy for speed harmonization (VSL)
- Might be effective on Managed Lanes



- Intelligence balance between vehicles and infrastructure
- Emphasize heavy vehicle applications; early adopters?
 - Professional drivers; well-maintained vehicles; open standards for equipment; fleets sensitive to business costs
- Mixed or Segregated Operation?
 - Mixed will offer safety improvements, but may not increase throughput (could decrease?)
 - Segregated should provide both safety and mobility benefits, in greater amounts, with complications
- Active Traffic Management (VSL?)



Questions and Discussion



For more information, please visit:

www.dot.ca.gov/research

Caltrans Improves Mobility Across California

BSM also Effective for Mobility, Weather, and Environment Apps

- Connected V2V safety applications are built around the SAE J2735 Basic Safety Message, which has two parts:
 - BSM Part 1
 - Contains the core data elements (vehicle size, position, speed, heading acceleration, brake system status)
 - Transmitted approximately 10 times per second
 - BSM Part 2
 - Added to part 1, depending upon events (e.g., ABS activated)
 - Contains a variable set of data elements drawn from many optional data elements (availability varies by vehicle model)
 - Transmitted less frequently; triggered by an event
 - No on-vehicle BSM storage of BSM data
 - The BSM is transmitted using DSRC (range ~300 meters)
- **The BSM is tailored for low latency, localized broadcasts required by V2V safety applications, but is also effective for other apps**

Test Bed Objectives

□ Near Term Objectives

- Upgrade and rejuvenate the existing Test Bed
- Ensure compliance with national standards (RSE, Backhaul, and Back Office)
- Take current applications to operational status

□ Long Term Objectives

- Serve as a incubator and proving ground for Connected Vehicle technology and applications
- Build partnerships with a focus on current and future Connected Vehicle research
- Leverage the proximity to the Silicon Valley to take the Test Bed and associated research to the next generation

□ Users

- Automotive OEMs (BMW, VW/Audi, Mercedes, Toyota)
- DSRC Vendors (Arada, Savari, Denso?)
- Transit agencies (Santa Clara VTA, SamTrans)
- Potential Silicon Valley Partners