



CALIFORNIA – CENTRIC TRENDS

IMPLICATIONS & EV OPPORTUNITIES

TOM WEST, BOB MEADE

Transportation

Agenda

- **Introductions**
 - ▣ Institute of Transportation Studies
- **Connectivity for & Automation of Traffic Control**
- **California PATH Program**
- **California Trends – Implications & Opportunities for EV**

University of California

The University of California opened its doors in 1869 with just 10 faculty members and 38 students; Now:

- ❑ 10 campuses
- ❑ 5 medical centers
- ❑ 3 national laboratories
- ❑ 150 academic disciplines
- ❑ 600 graduate degree programs
- ❑ 233,000 students
- ❑ 190,000 employees
- ❑ 1.7 million living alumni
- ❑ 60 Nobel laureates



Organization of ITS' centers

Active centers at ITS (Dec. 2015)

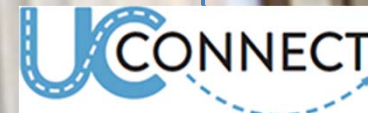


UCTC

SafeTREC



UCPRC

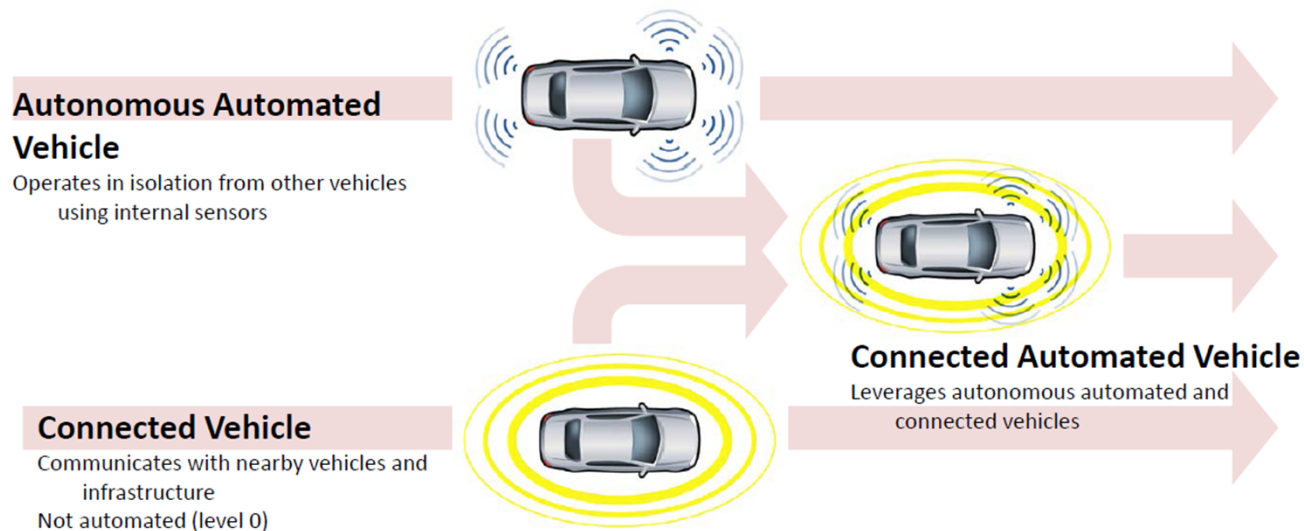


Autonomous, Connected, Connected Automated

5

Safe and Connected Automation

- Safe
 - Meets requirements for functional safety, cybersecurity, and system performance
- Connectivity
 - Includes all types of communication with vehicles and infrastructure (Wi-Fi, DSRC, Cellular, etc.)



Connectivity

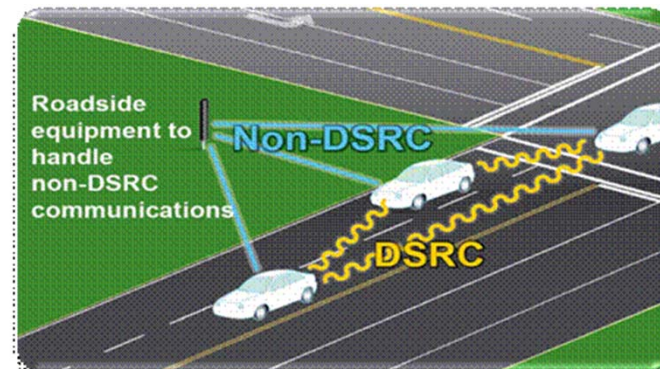
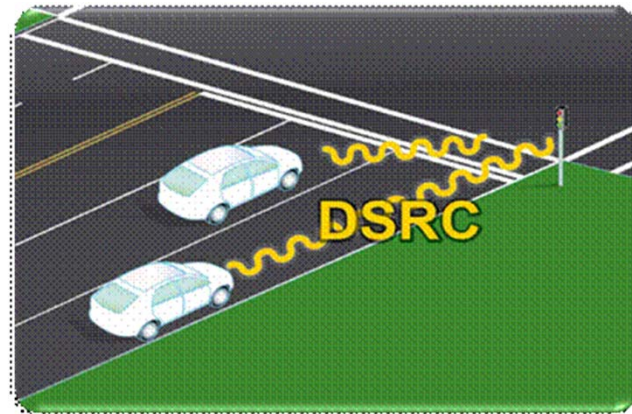
6

What is DSRC

- Basic safety messages sent out every 1/10 seconds.
- All messages carry a standard glob: values for pre-defined vehicle trajectory and operational data.
- Cars process data and warn driver.
- Equipment integrated into vehicle



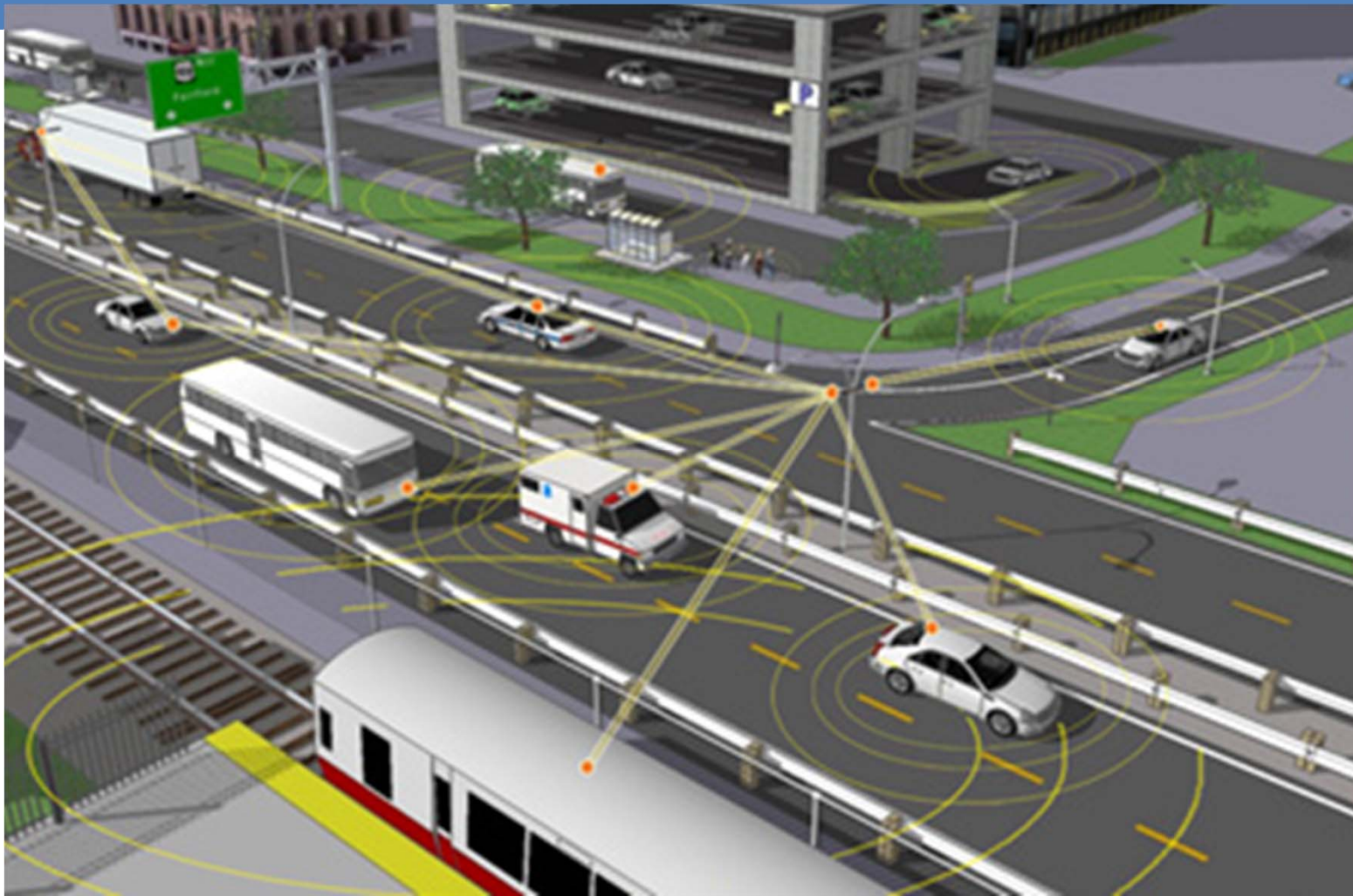
Photo Credit: US Dept. of Transportation



Connectivity

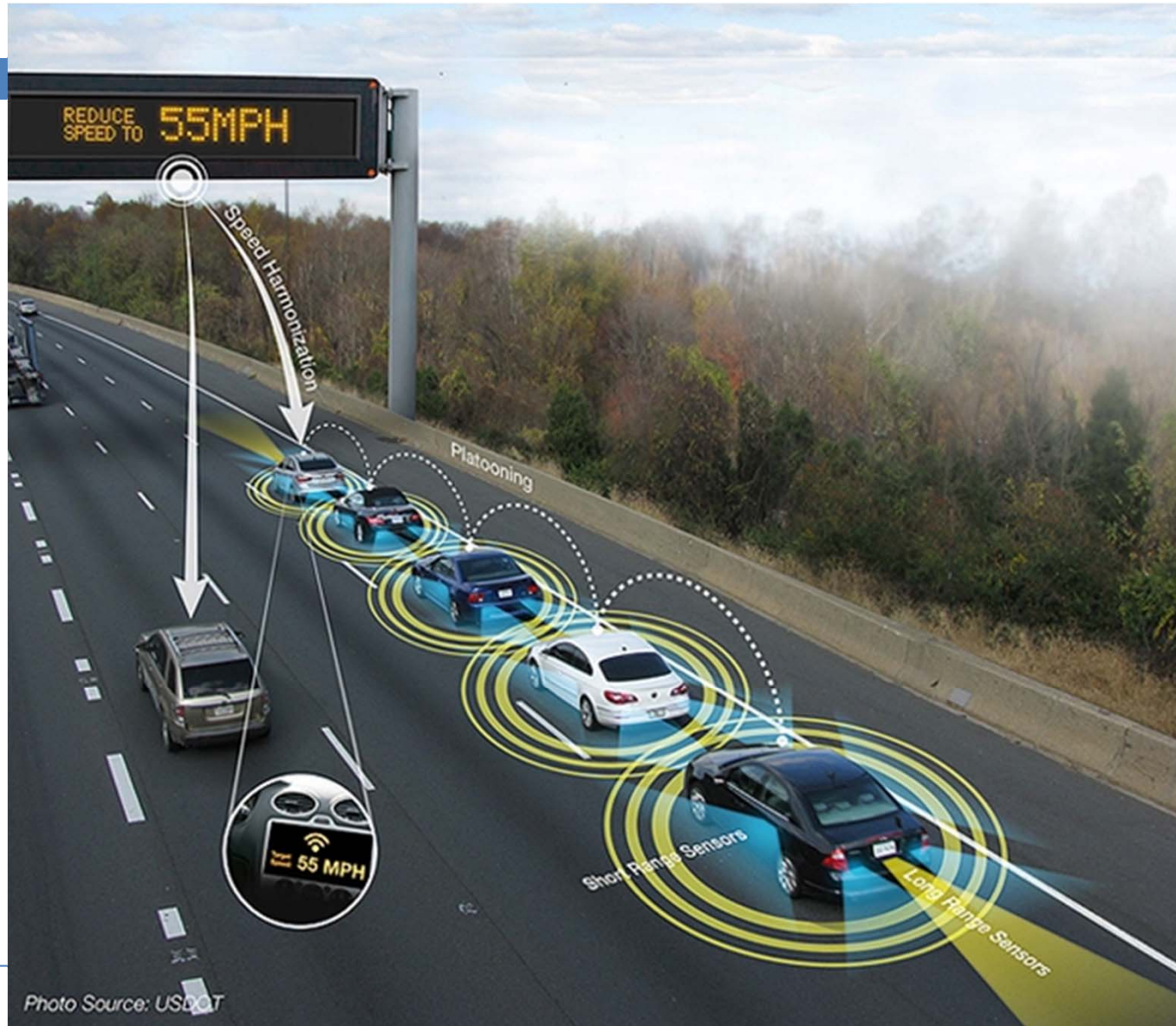
7

- **Vehicle to Vehicle and Vehicle to Infrastructure Connectivity (DSRC & Mobile Phone Network) will enable messaging directly to a vehicle**
 - ▣ Improve Safety
 - Pedestrian
 - Vehicle
 - ▣ Enable advanced ICM
 - Dynamic Highway Management Control
 - Urban and Arterial Traffic management
 - Incident Management
 - ▣ Improved Productivity for Freight and Transit
 - ▣ Reduced vehicle energy consumption and emissions.



V2I & V2V

9





California PATH



- **Strong emphasis on Automation and Connected Vehicles for 25+ years → over 600 labor years of PATH effort**
 - Experimental verification on full-scale vehicles (20+ passenger cars, 7 heavy trucks, 6 transit buses, 1 snowblower)
- **First V2V cooperative collision warning experiments in 2004-5**
- **First public DSRC installations in U.S. in 2005**
- **Full-Scale DSRC test facility on El Camino Real since 2006**
- **Consistent work on DSRC standards development**
- **Strong media attention on a variety of projects**
 - 200 media appearances, many interviews, and 3 press conferences associated with Mobile Millennium and Mobile Century
 - One media interview of staff per week on ITS efforts
- **Leading the largest national ICM effort**

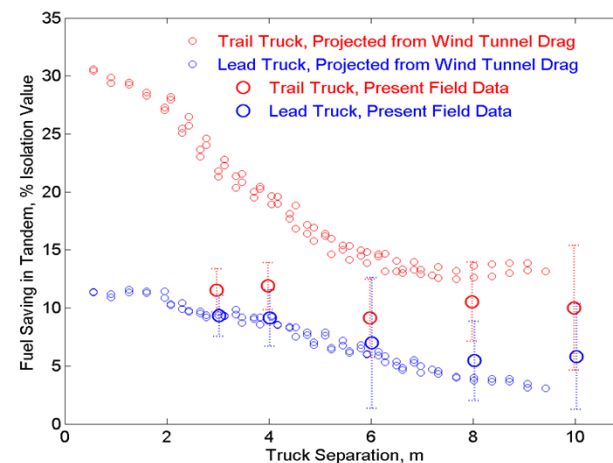
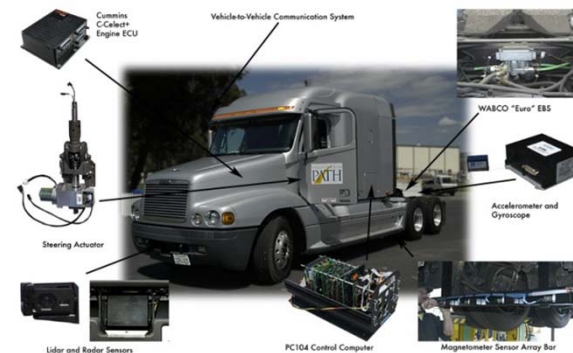
NAHSC Automated Platoon Demo

- ❑ PATH led complex system development and integration activity, with industrial partners
- ❑ Landmark event in 1997, raising awareness of automation potential
- ❑ Demo rides for ~1000 visitors, overwhelmingly positive responses
- ❑ Showed technological and user acceptance potential



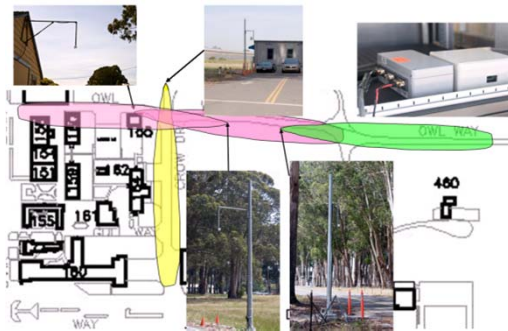
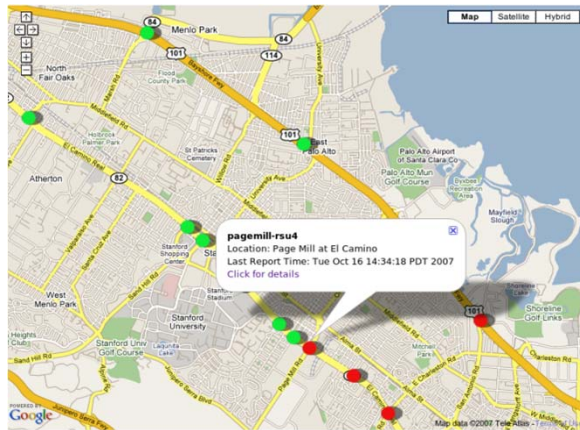
Automated Truck Platooning: 2003 -2011

- Developed and tested 2- and 3-truck platoons under automatic spacing control at gaps from 3 m to 10 m
- All hardware and software implementation by PATH, without industry help
- Fuel savings of 10 -15% measured



California Connected Vehicle Test Sites

- First field installations of DSRC wireless in the U.S. (2005)
- Test site for transportation researchers and automotive industry labs – developed, maintained, and managed by PATH
- Upgraded as part of national test bed network – 11 consecutive signalized intersections on SR 82, fully instrumented facility at BGC



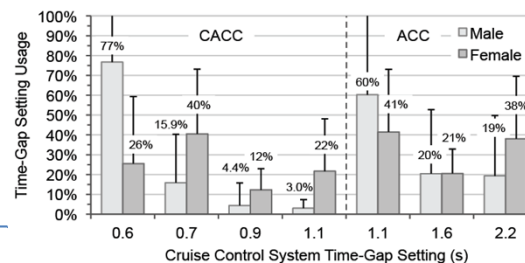
VAA Project at UCB-PATH

- **LTD, Eugene Oregon**
 - ▣ 2.5 miles of single/double dedicated ROW
 - ▣ One 60ft New Flyer BRT bus
 - ▣ Functions to be tested:
 - Lane guidance for on dedicated BRT lane
 - Precision docking
- **Full range of VAA applications for BRT**
 - ▣ Highway and urban BRT applications
 - ▣ Precision docking and guidance
 - ▣ Very low to highway speed (65 mph)



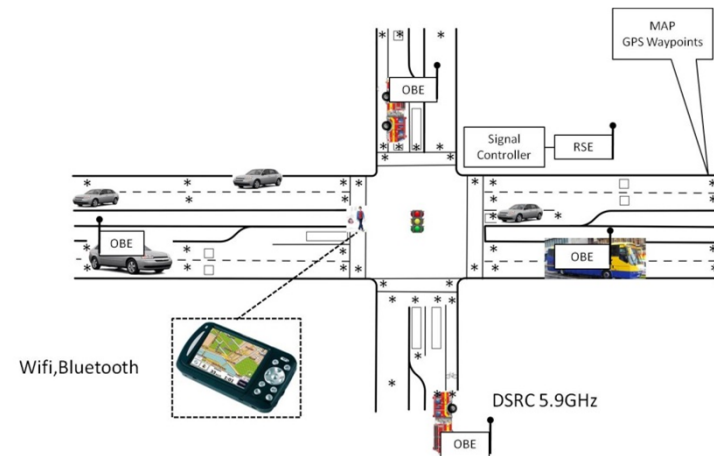
Cooperative Adaptive Cruise Control (CACC) (Since 2002)

- 3 generations of design, sponsored by Caltrans, FHWA and Nissan
- First-generation system showed driver acceptance of short gap following (0.6 s)
- Second generation showed string stability
- Traffic simulations showed lane capacity doubling potential
- Third generation for STOL Laboratory - 2015
- Current EAR project on CACC string strategies



Multi-Modal Intelligent Traffic Signal Systems (MMITSS)

- ❑ **MMITSS is the next generation of traffic signal systems**
- ❑ **Partners include: U of Arizona, California PATH, Savari Networks, Econolite, Volvo Technology**
- ❑ **Sponsors through Pooled Fund**
 - ▣ Virginia DOT, California DOT, Maricopa County DOT, Florida DOT, Michigan DOT
- ❑ **Suite of five CV Applications**
 - ▣ Intelligent Traffic Signal Systems (ISIG)
 - ▣ Transit Signal Priority (TSP)
 - ▣ Mobile Accessible Pedestrian Signal System (PED-SIG)
 - ▣ Emergency Vehicle Preemption (PREEMPT)
 - ▣ Freight Signal Priority (FSP)

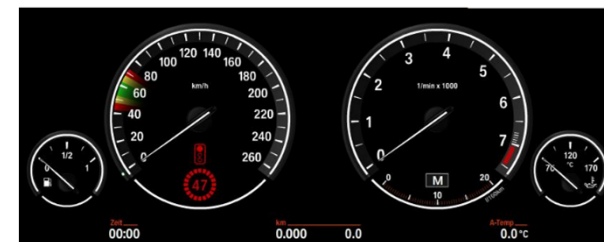


USDOT/FHWA Exploratory Advanced Research

- **ECO signal operations with BMW, UCI**
 - ▣ In-vehicle driver speed advisory for minimum fuel consumption
 - ▣ Integration of adaptive signal priority with driver advisory

- **Field testing at RFS**
 - ▣ Use SAE J2735 over cellular (4G/LTE)
 - ▣ Speed recommendation is calculated based on SPaT
 - ▣ Tested with 4 scenarios
 - Uninformed driver
 - Informed driver
 - Uninformed driver with signal priority
 - Informed driver with signal priority

- **Field Testing at California testbed**
 - ▣ Ongoing
 - ▣ Interaction with the leading vehicle
 - ▣ Uncertainties in phase time remaining
 - ▣ Queue discharging time



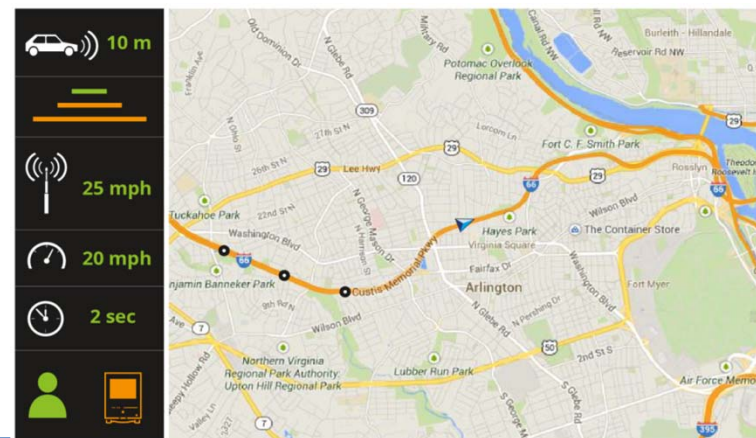
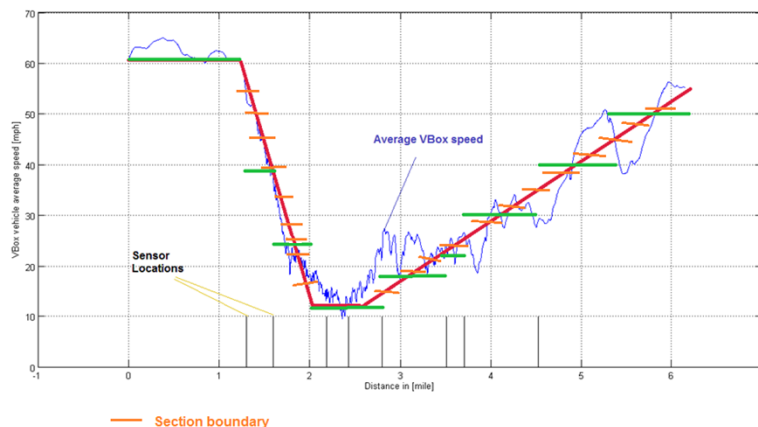
Hyundai Smart Eco-Driving

- **Smart Eco-Driving in collaboration with Hyundai**
 - ▣ Incorporating:
 - Traffic speed, signal timing, and roadway gradient (preview)
 - Smart cruise control (feedback regulation)
 - Powertrain characteristics (optimization)
 - ▣ Driver Assistance (manual control) or semi-automated (assisted control)



Vehicle Speed Limits (VSL)/Speed Harmonization

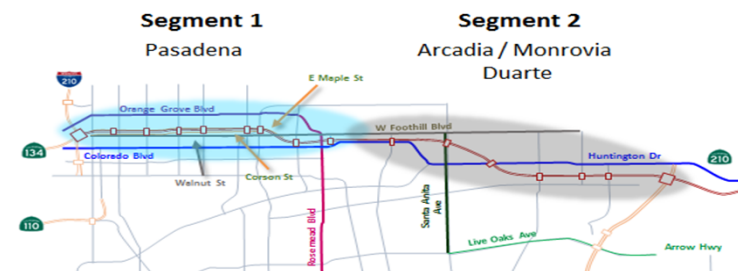
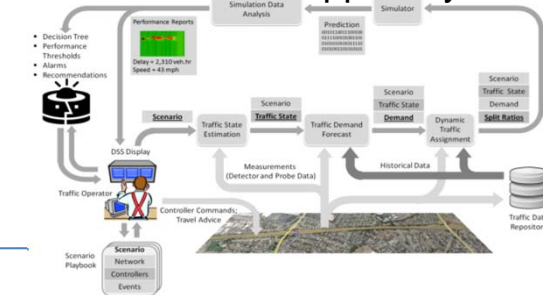
- ❑ Selecting highway speed to maximize throughput at bottleneck
- ❑ V2I probe vehicle data collection
- ❑ I2V target speed selection – as ACC set speed
- ❑ Simulations of traffic impacts, then field tested near Washington DC – FHWA STOL Laboratory, under Leidos



Connected Corridors

-  Vehicles
-  Infrastructure
-  People

- # Traffic Decision Support System

The logo for California PATH, featuring the word "CALIFORNIA" in a small, blue, sans-serif font above the word "PATH" in a large, blue, serif font. A yellow diagonal swoosh is positioned behind the letters "P" and "A". To the right of "PATH" is a horizontal line, and below it, the word "CALIFORNIA" is written in a small, blue, sans-serif font, followed by "PATH" in a large, blue, serif font, with a yellow diagonal swoosh behind the letters "P" and "A".

California Trends

22

- ❑ **Population Growth – 33% over the next 30 years**
- ❑ **Economic growth – 115% over the next 30 years**
- ❑ **Increased Goods Movement – 45% over the next 30 years**
- ❑ **Greenhouse Gas Reduction (40% by 2030, 80% by 2050)**
- ❑ **Combat (arrest, reverse) Urban Sprawl (also known as SCS)**

Public Policy Goals

23

- ❑ **Reduction in Criteria Pollutants - Ground Level Ozone Reduction 2015 (Federal CAA) (NO_x reduction 2023) & Reduction in PM_{2.5} (24-hr Std. 35 mg/CM)**
- ❑ **GHG Reduction {40%, 80%} (AB32, EO S-3-05, EO B-30-15, SB350, SB391, SB375, SB743)**
- ❑ **Sustainable Communities {80% CO₂ reduction} (SB375, SB743)**
- ❑ **Increase in Mass Transit Use (SB9, SB375, SB743)**
- ❑ **Transportation & CEQA (impact can not include Congestion SB743)**
- ❑ **Sustainable Freight (EO B-32-15)**
- ❑ **Transportation Electrification (AB32, SB1275 [Charge Ahead CA], SB350)**
- ❑ **Renewable Energy Mandates {20%, 50%} (AB32, SB350)**

Brave New World is Upon us

□ **Caltrans and California MPOs are facing their biggest mission challenge since the 1950s.**

- ▣ Growth in population, the economy and goods movement will continue to undermine safety, mobility and environmental goals
- ▣ California Public policy has set aggressive goals for emissions reduction (criteria pollutants and greenhouse gases)
- ▣ Metropolitan planning organizations have been placed at the nexus of transportation, land use and emission reduction goals
- ▣ HOWEVER, communication, connectivity, data analytics, vehicle automation, Traffic Control and EVs will bring new efficiencies to the transportation system and enable State DOTs to unlock the potential of their System to address challenges

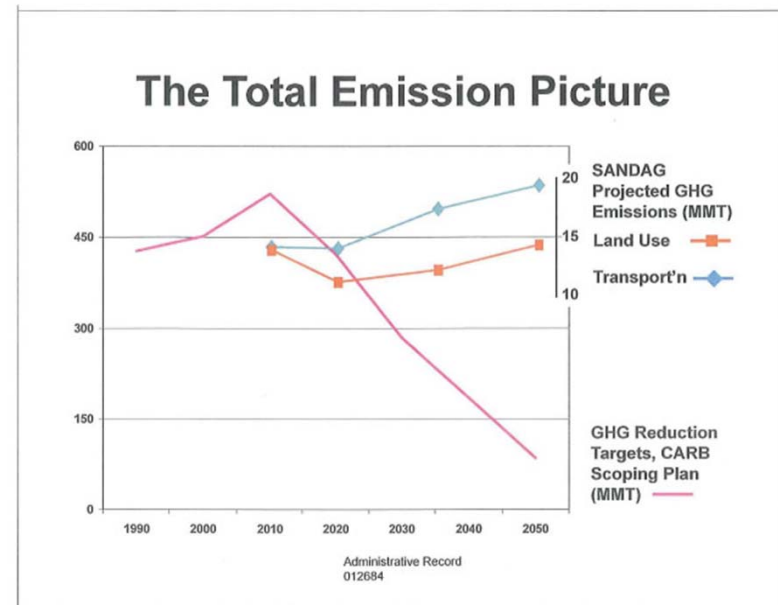
Metropolitan Planning Organizations (MPOs) and Regional Transportation Planning Agencies (RTPAs)



Long Range Transportation Plan

26

- SanDAG Transportation Plan
<http://www.sandag.org/index.asp?projectid=349&fuseaction=projects.deta>
- MTC The Plan:
<http://mtc.ca.gov/our-work/plans-projects/plan-bay-area-2040/transportation-2035>



10-28-11 SANDAG Meeting Materials: Slideshow Presentation on Large Majority of Californians Support Implementation of Climate Change Laws (AR 185:12684)

- www.transitsandiego.org

California's GHG-related Public Policy

SB375: Targets for 2020 and 2035

- In 2010, ARB established these targets for 2020 and 2035 for each region covered by one of the State's metropolitan planning organizations (MPO).

Approved Regional Greenhouse Gas Emission Reduction Targets

MPO Region	Targets *	
	2020	2035
SCAG	-8	-13
MTC	-7	-15
SANDAG	-7	-13
SACOG	-7	-16
8 San Joaquin Valley MPOs	-5	-10
6 Other MPOs		
Tahoe	-7	-5
Shasta	0	0
Butte	+1	+1
San Luis Obispo	-8	-8
Santa Barbara	0	0
Monterey Bay	0	-5

* Targets are expressed as percent change in per capita greenhouse gas emissions relative to 2005.

Emissions –Fleet, SR60, Normalized

28

Barth/Boriboonsomsin

19

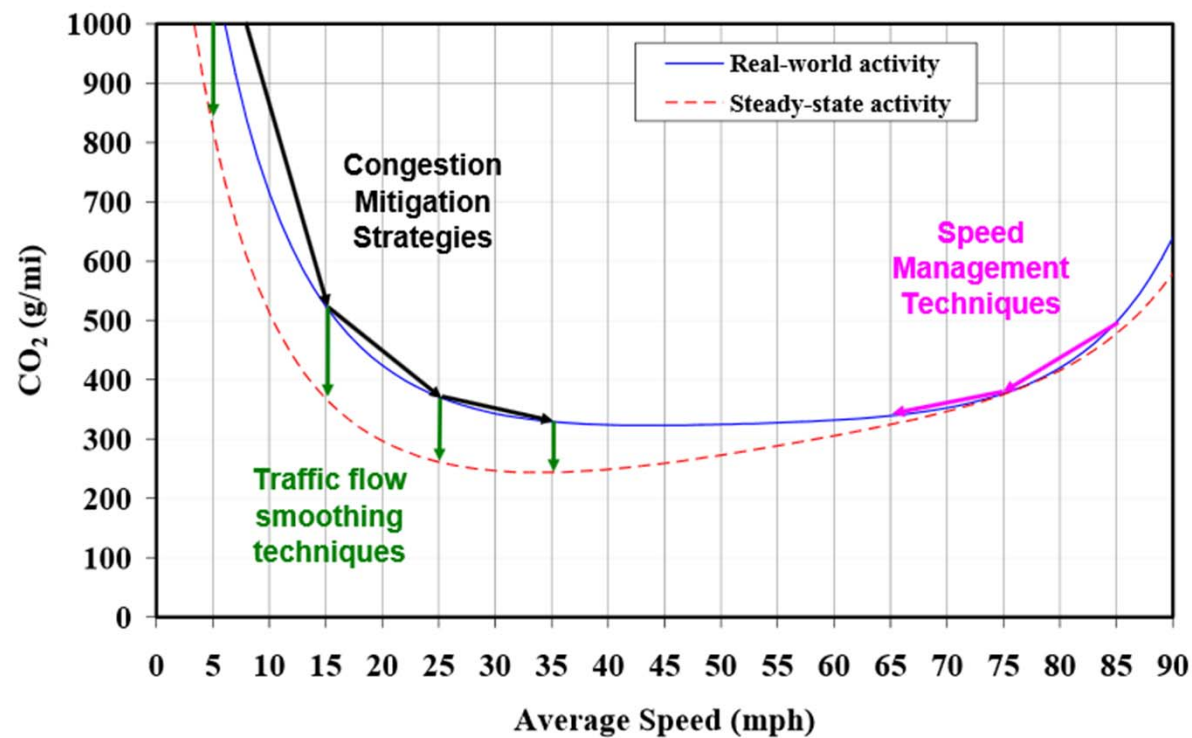


Figure 4. Possible use of traffic operation strategies in reducing on-road CO₂ emission

Approaches to Minimizing Energy & Emissions

29

- ❑ **More efficient vehicles**
- ❑ **Alternative fuels**
- ❑ **Decrease total amount of Driving**
- ❑ **Improve Transportation Efficiency**
 - ▣ **Intelligent Transportation Systems**
 - Advanced Vehicle Control & Safety Systems (eliminate accidents, smooth traffic flow)
 - Advanced Transportation systems (promote efficient operation, eliminate congestion)
 - Advanced Transportation Information Systems (reduce driving, promote efficiency and manage demand)

AERIS Operational Scenarios



ECO-SIGNAL OPERATIONS

Uses connected vehicle technologies to decrease fuel consumption and decrease GHG and criteria air pollutant emissions by reducing idling, the number of stops, unnecessary accelerations and decelerations as well as improving traffic flow at signalized intersections.



ECO-LANES

Dedicated freeway lanes – similar to HOV lanes – optimized for the environment that encourage use from vehicles operating in eco-friendly ways. The lanes may support variable speed limits, eco-cooperative adaptive cruise control (ECACC) and vehicle platooning applications, and wireless inductive/resonance charging infrastructure embedded in the roadway.



LOW EMISSIONS ZONES

Geographically defined areas that seek to incentivize “green transportation choices” or restrict specific categories of high-polluting vehicles from entering the zone to improve the air quality within the geographic area. Geo-fencing the boundaries allows the possibility for these areas to be responsive to real-time traffic and environmental conditions.



ECO-TRAVELER INFORMATION

Applications that enable development of new, advanced traveler information applications through integrated, multisource, multimodal data. An open data/open source approach is intended to spur innovation and environmental traveler information applications. Eco-Traveler Information applications include applications that assist users with finding charging stations for alternative fuel vehicles, parking applications, and eco-routing applications.

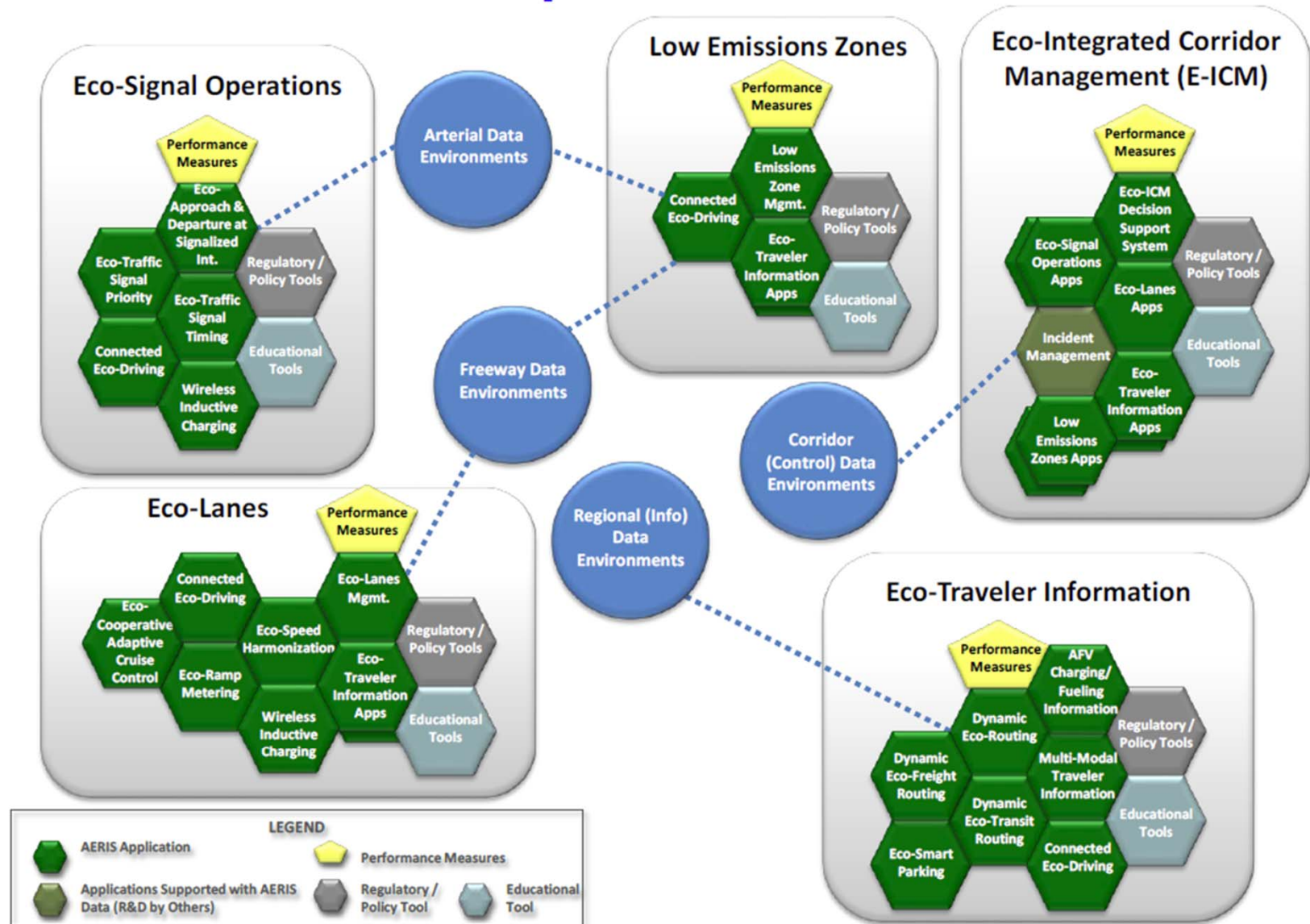


ECO-INTEGRATED CORRIDOR MANAGEMENT

Considers partnering among operators of various surface transportation agencies to treat travel corridors as an integrated asset, coordinating their operations simultaneously with a focus on decreasing fuel consumption and emissions.



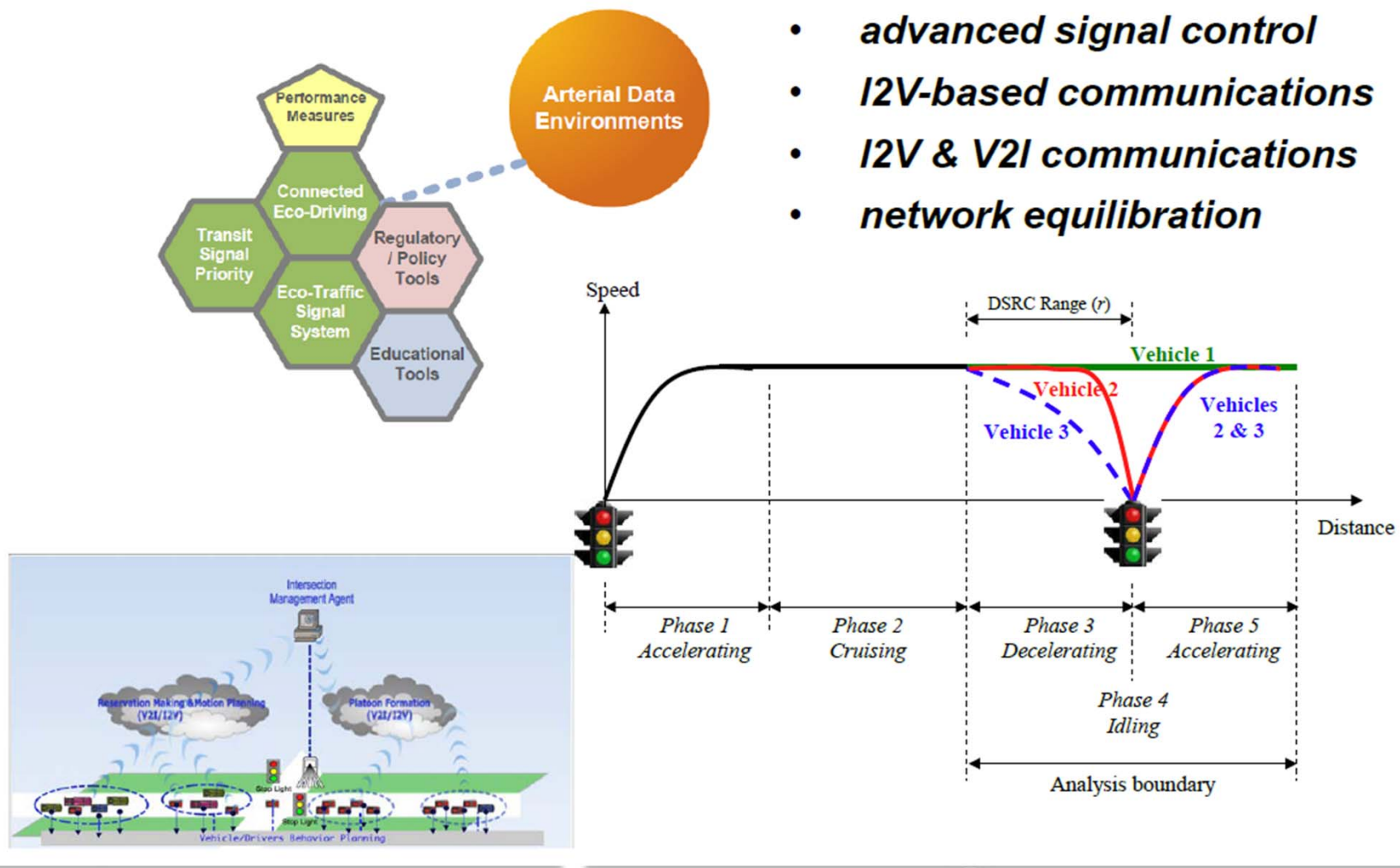
AERIS Operational Scenarios





Eco-Signal Operations

TRANSFORMATIVE CONCEPT | Eco-Signal Operations



- *advanced signal control*
- *I2V-based communications*
- *I2V & V2I communications*
- *network equilibration*

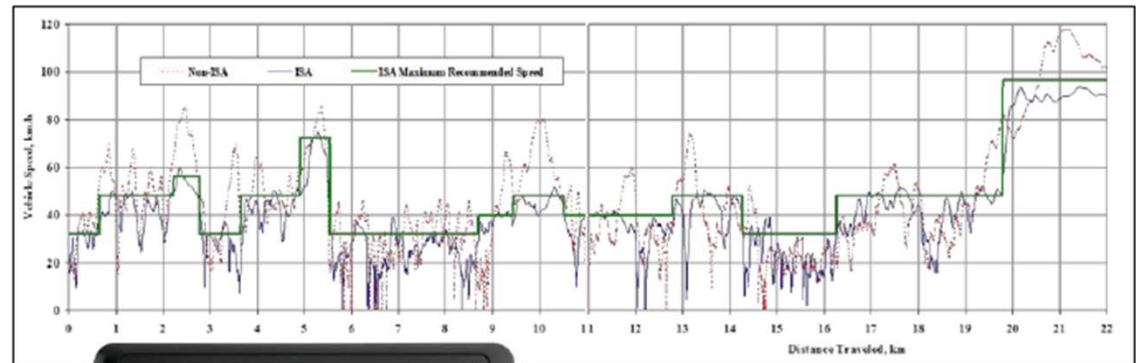
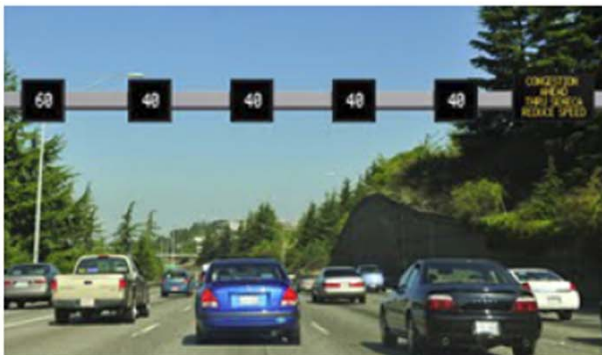




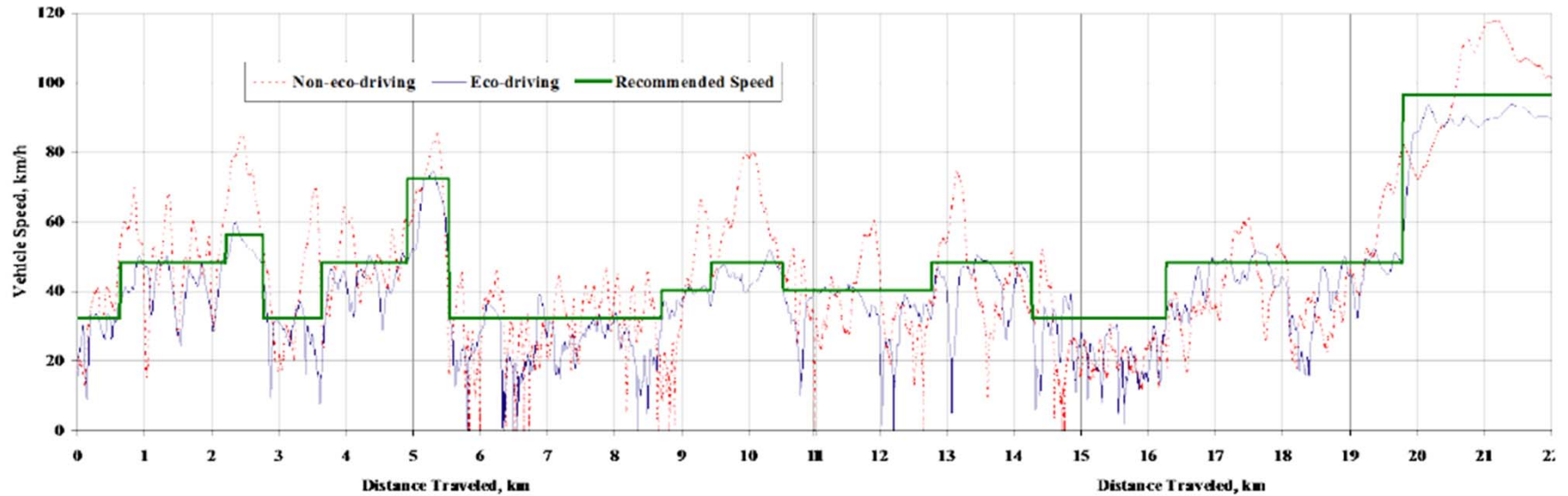
TRANSFORMATIVE CONCEPT | Eco-Lanes



- *intelligent speed adaptation*
- *speed harmonization*
- *variable Speed Limits*
- *dynamic eco-driving*
- *platooning*
- *cooperative cruise control*



Connected Eco-Driving Experiment



Energy/Emissions	Non Eco-Driving	Eco-Driving	Difference
Fuel (g)	1766	1534	-13%
CO ₂ (g)	5439	4781	-12%
CO (g)	97.01	50.47	-48%
HC (g)	3.20	1.90	-41%
NO _x (g)	6.28	3.97	-37%
Travel time (min)	38.9	41.2	+6%

Vehicle automation could provide even better results.

Source: Barth, M. and Boriboonsomsin, K. (2009). Energy and emissions impacts of a freeway-based dynamic eco-driving system. *Transportation Research Part D*, 14, 400-410.

Preliminary Results

35

- **ITS goals and strategies of improving safety and improving traffic performance often reduce energy consumption and CO₂ emissions**
 - ▣ Each Strategy potentially 5-15%, multiple strategies increase savings
 - ▣ Reduced benefits with increased congestion
 - ▣ Less benefit for corridor with existing coordinated timing
 - ▣ Benefits dependent on DSRC penetration rates
 - No benefit below 20% connected vehicle penetration levels
 - Increase significantly from 20% to 50% connected vehicle penetration levels
 - Remain consistent between 50% and 80% connected vehicle penetration levels
 - Increase significantly from 80% to 100% connected vehicle penetration levels

Transportation Electrification

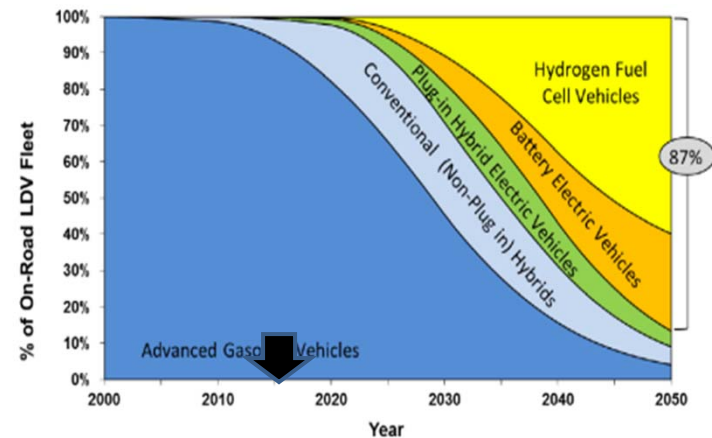
36

SB 350 740.12 (H) (1)

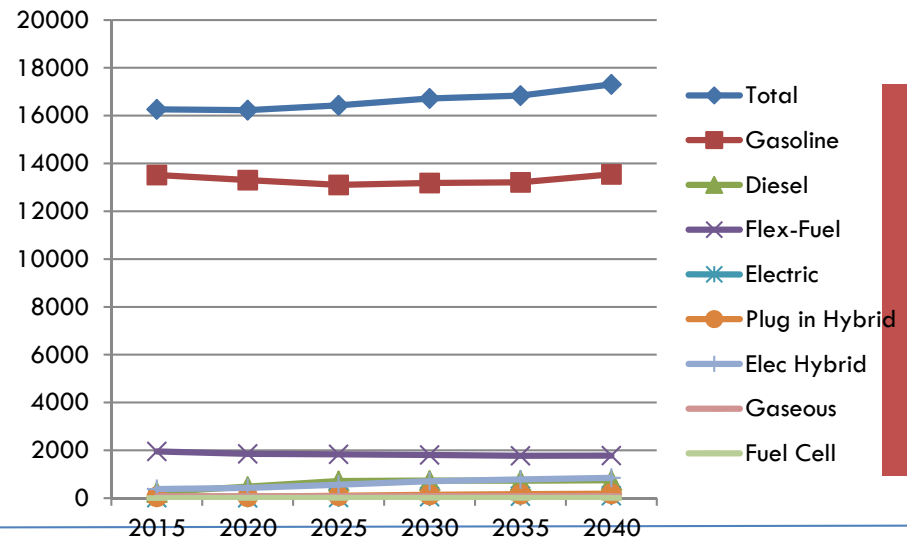
According to the State Alternative Fuels Plan analysis (by CEC, ARB) vehicle electrification results in approximately **70** percent fewer greenhouse gases emitted, over **85** percent fewer ozone-forming air pollutants emitted ... These reductions will become larger as renewable generation increases.

□ Potential Applications

- ▣ Eco Signals
- ▣ Eco Lanes
- ▣ Eco Low Emission Zones
- ▣ Eco ICM
- ▣ Transit Support



SB 32 Goals



DOE-EIA New LDV Car & Truck Sales Projections (2015)

Ground Level Ozone

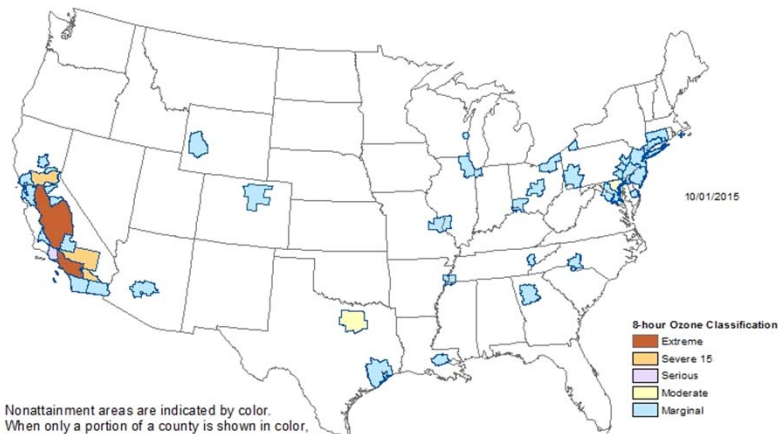
37

Challenge

- 2015 Standard is 70ppb, down from 75ppb (2008)

[View PDF map that ca](#)

8-Hour Ozone Nonattainment Areas (2008 Standard)



Nonattainment areas are indicated by color. When only a portion of a county is shown in color, it indicates that only that part of the county is within a nonattainment area boundary.

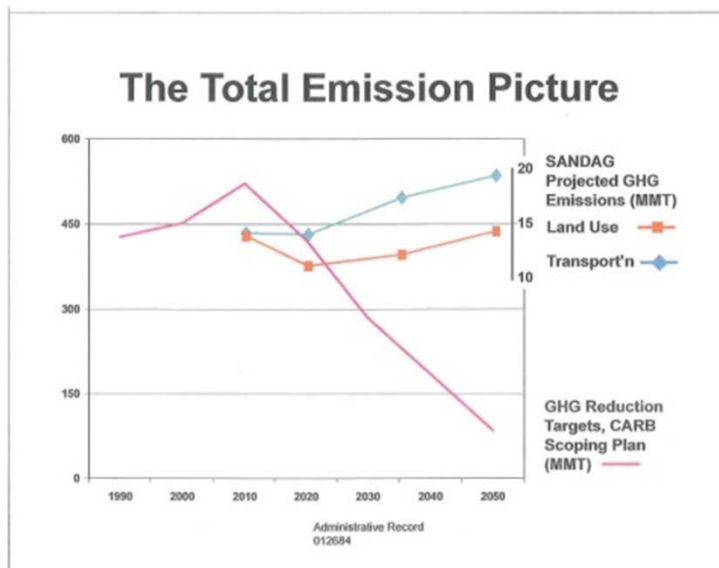
CV Tactics

- Traffic Smoothing Incident Management
- Advanced ICM
 - ▣ Eco Applications
- Transit
 - ▣ First/Last Mile Automated & Connected EV
- Sustainable Freight
- Transportation Electrification

GHG Reduction

38

Challenge



10-28-11 SANDAG Meeting Materials: Slideshow Presentation on Large Majority of Californians Support Implementation of Climate Change Laws (AR 185:12684)

Tactics

- Highway
 - Platooning
 - Speed / Access Control
 - Eco-ICM
- Arterial
 - Intelligent Signals
 - Priority & Eco Applications
- Transit with Automated Connected EV for first/last mile
- Transportation Electrification

Traffic Congestion

39

EV Opportunity

Annual California Impact

Barth/Boriboonsomsin

19

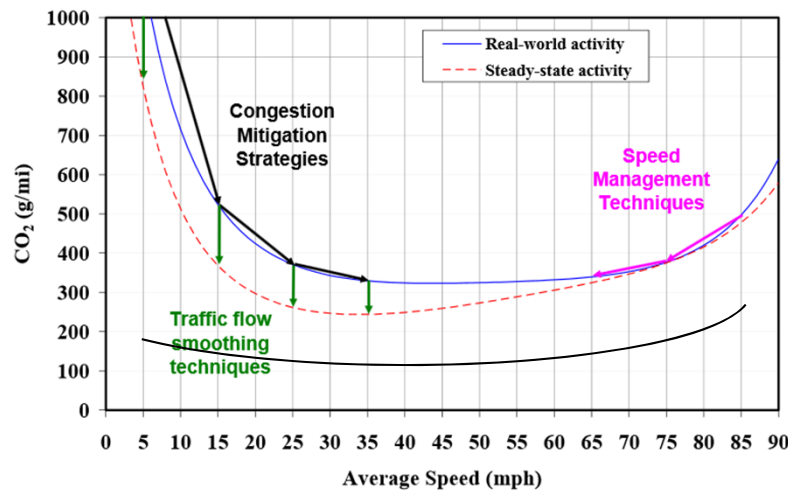


Figure 4. Possible use of traffic operation strategies in reducing on-road CO₂ emission

TTI:

- 437 Million gallons of fuel ... 8.5 Billion Pounds CO₂
- 1.2 Million Hours of delay
- \$27 Billion Cost
- 54% Highway; 46% Arterial

EV Opportunity



- ▣ Near Term: Quantify the benefits of combining EV and ITS for SOV
 - Need: Corridor Level Benefits (ozone, GHG) Quantification
 - Need: Stakeholder Collaboration
- ▣ Near to Mid Term: extend ITS Eco-applications to include EV
- ▣ Mid Term: Demonstrate EV ITS Eco-applications (ARB& CT 16/17)
- ▣ **Shared, Connected and Automated electric vehicles operating in our cities by 2030**
 - Displacing SOVs on our city streets and highways, Responsive to user demand (via traveler information), extending transit
 - Long Term Needs
 - ▣ concept development, benefits quantification for congestion and emissions reduction, demonstration and verification