College of Engineering- Center for Environmental Research & Technology

Connected and Automated Vehicle Research at UCR

Ziran Wang 王子然

Research Assistant at CECERT, UCR

2018.1.31 @ UCR Extension

College of Engineering- Center for Environmental Research & Technology

University of California, Riverside
Bourns College of Engineering
Center for Environmental Research and Technology (CE-CERT)

加州大学河滨分校伯恩斯工程学院
环境技术与研究中心

www.cert.ucr.edu

CE-CERT SNAPSHOT:

- 27 interdisciplinary faculty
- 30 full-time staff (technical & administrative)
- 60 undergraduates
- 55 graduate students
- 100+ industry partners
- 12 major UCR partners
- 40 other academic partnerships

$18 million in ongoing projects

- 3 CE-CERT Specific Centers
- 4 Integrated UCR Centers

UCR | Bourns College of Engineering

UC RIVERSIDE University of California School of Public Policy

UCR | College of Engineering- Center for Environmental Research & Technology

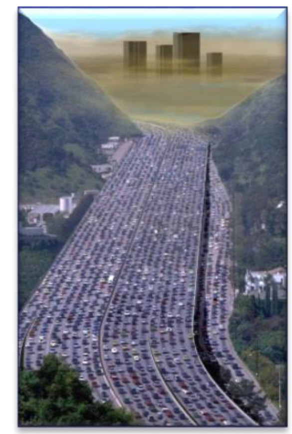
University of California, Riverside UCR School of Medicine Inaugural Class 2017

Balanced Focus as Trusted Agent

~100 Academic, Industry, Government Partners

CE-CERT Research Focus:
Air Quality, Transportation and Energy

Clean Air
Quantifying and Measuring Emissions
Toxic, Ozone and PM formation



Sustainable Transportation
Intelligent Transportation Systems
Connected and Automated Vehicles
Electric and Hybrid vehicle integration
Ecodriving, Shared Vehicle Systems

Renewable Fuels
Aqueous Processing of Biomass to Fuels
Thermochemical Processing of Biomass to Fuels

Renewable Electricity & Smart Grids
Advanced Solar Energy Production
Energy Storage
Energy Management

Climate Change Impacts
Impacts of our fuels
Cloud formation & impacts

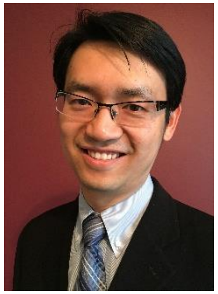
https://www.youtube.com/watch?v=5P_iiCKCcjU

- Vehicle Emissions Research Laboratory
- Heavy-Duty Chassis Dynamometer Laboratory
- Heavy-Duty Engine Dynamometer
- Portable Emissions Measurement Systems Laboratory
- Commercial Cooking Emissions Laboratory
- Transportation Management Research Laboratory
- Mobile Mapping Laboratory
- Transportation Electronics Laboratory
- Atmospheric Process Laboratory
- Aerosol-Cloud Interactions Laboratory
- Advanced Spectroscopic Laboratory
- Advanced Thermochemical Research Laboratory
- Aqueous Processing Fermentation and Robotics Laboratory
- Aqueous Biomass Pretreatment, Processing Analysis Laboratories
- SC-RISE: Southern California Research Initiative for Solar Energy
- Mobile Energy Storage, Inverter, Charger and Distribution Laboratories
- Energy Storage, Control, and Distribution Laboratories
- Power Quality & Harmonics Laboratory

CE-CERT Facilities

https://www.youtube.com/watch?v=04KHOfayQsk

Transportation System Research (TSR) Lab

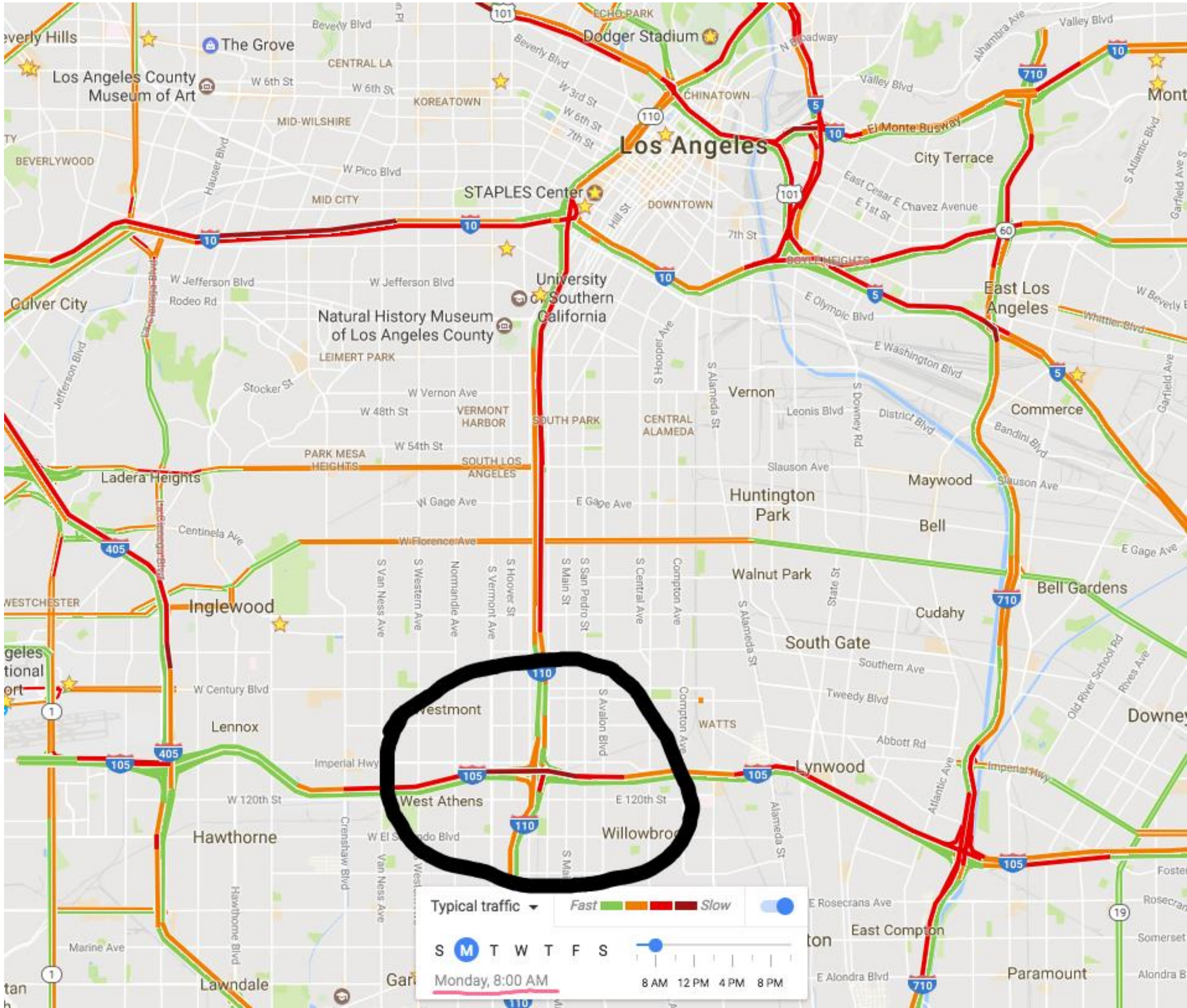


- Dr. Matthew Barth (ECE)
  - Intelligent transportation systems, advanced sensing and mapping, connected and automated vehicles
- Dr. Kanok Boriboonsomsin (CE)
  - Transportation modeling, traffic simulation, vehicle activity analysis, vehicle energy/emission modeling
- Dr. Guoyuan Wu (ME)
  - Control and automation, optimization of dynamic systems, advanced vehicle/powertrain technologies
- Dr. Peng Hao (CE)
  - Mobile sensor data, stochastic modeling, urban traffic control and operation, machine learning

Why to make transportation intelligent?

105/110 freeway interchange

(Source: Google Map)



105/110 freeway interchange

(Source: Google Map)

Wasted Fuel and Wasted Time

- In 2016, Los Angeles tops the global ranking with 104 hour/commuter spent in traffic congestion
- In 2014, 3.1 billion gallons of energy were wasted worldwide due to traffic congestion
- In 2013, fuel waste and time lost in traffic congestion cost $124 billion in the U.S.

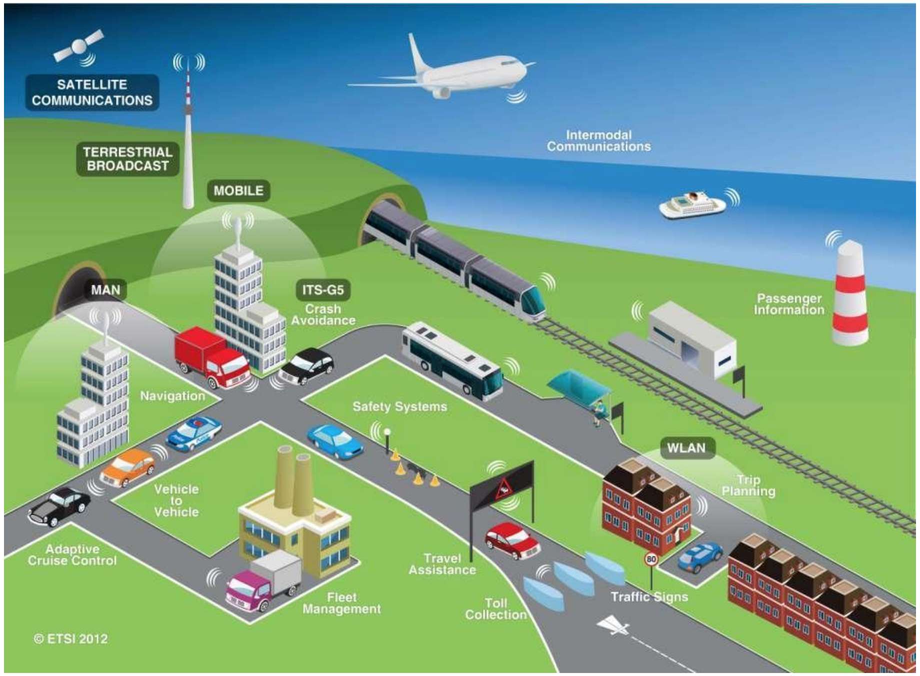
(Source: La La Land)

Motivation of the Research

- Expand existing transportation infrastructure: costly, and raise negative social and environmental effects

- Develop Intelligent Transportation Systems:

- Improve traffic safety
- Improve traffic mobility
- Improve traffic reliability

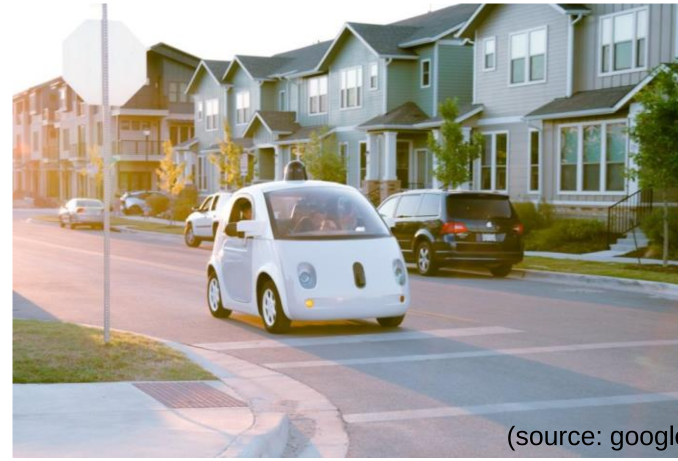


(source: ETSI)

Automated Vehicle Technology

- Definition of automated vehicles

At least some aspects of a safety-critical control function (e.g. , steering, acceleration, or braking) occur without direct driver input



(source: google)

- Sensing techniques

Radar, Lidar, GPS, odometry, computer vision, etc.

(source: google)

- **Level of automation by SAE**

- Level 0: No Automation
- Level 1: Driver Assistance
- Level 2: Partial Automation
- Level 3: Conditional Automation
- Level 4: High Automation
- Level 5: Full Automation

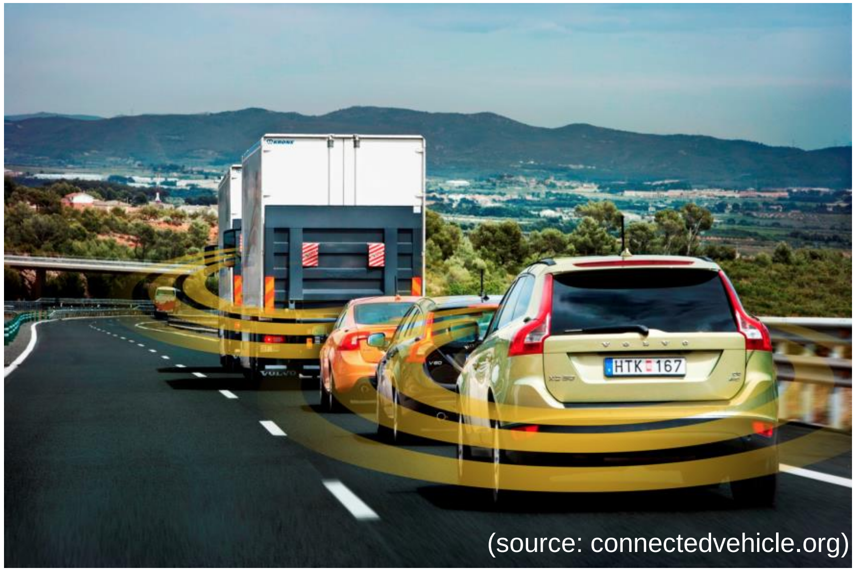
Connected Vehicle Technology

- Definition of connected vehicles

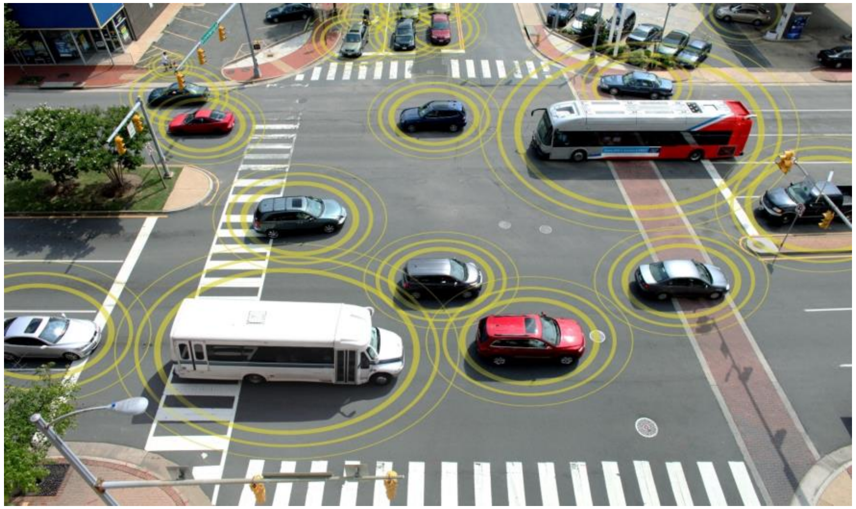
Vehicles that are equipped with Internet access, and usually also with a wireless local area network

- Communication flow

- Based primarily on dedicated short-range communications (DSRC)
- Between vehicles (V2V)
- Between vehicles and infrastructure (V2I/I2V)



(source: connectedvehicle.org)



(source: USDOT)

Merging of Connectivity and Automation

- **Automated Vehicles**

  - **Pros**: In general, partial or full vehicle automation can help **safety**
  - **Cons**: **Mobility and environmental impacts** may remain the same or could even get worse, e.g., adaptive cruise control (ACC) has been shown to have negative traffic mobility impacts

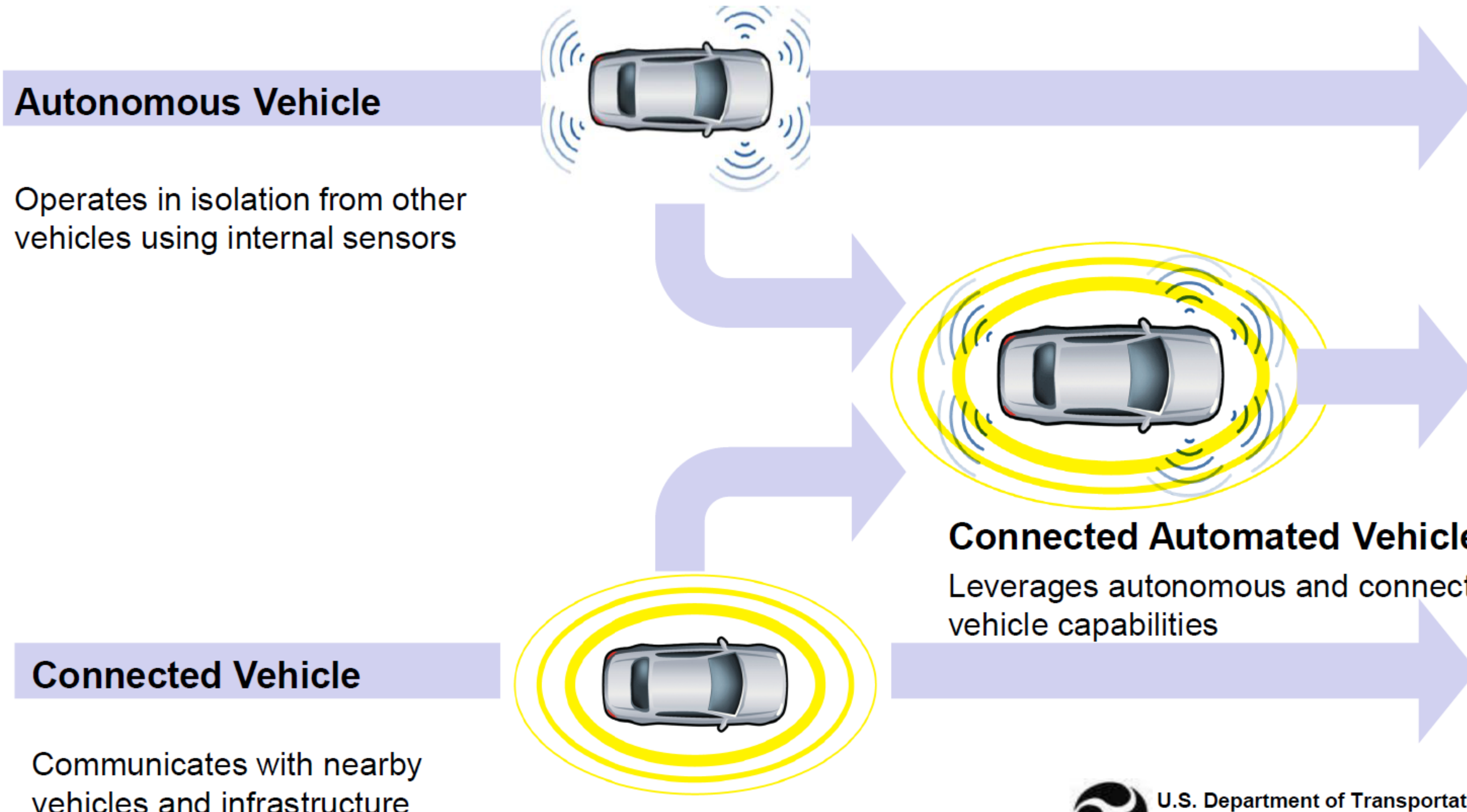
- **Connected Vehicles**

  - **Pros**: Introduction of a significant amount of **information** to support decision making
  - **Cons**: Increase in the driver's cognitive load, thus causing extra **distraction** and system disturbance

- **Therefore, a potentially better solution:**

Connected + Automated

Merging of Connectivity and Automation



U.S. Department of Transportation
ITS Joint Program Office

Convergence

Electrification

Mobile Technologies

SECA

T. Papandreou, 2016

Shared Mobility

Automation

FAVES

(fleets of automated vehicles that are shared & electric)

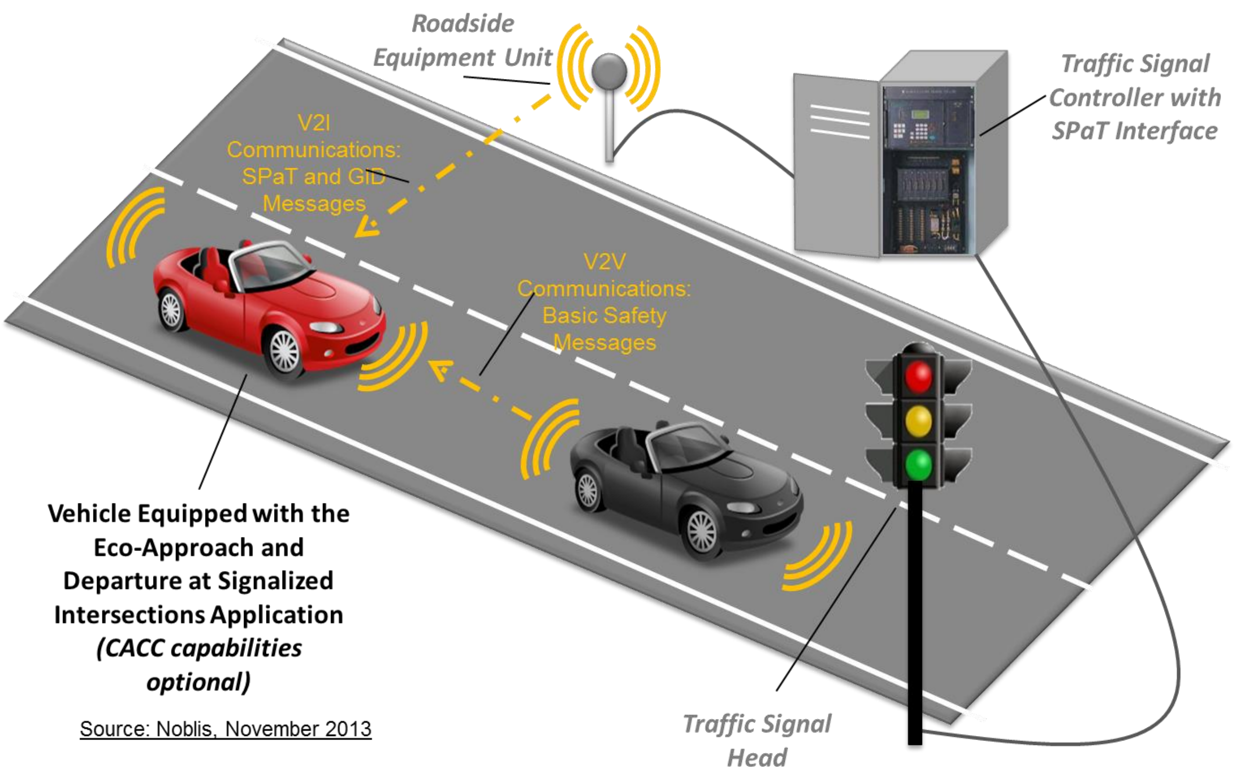
TSR Facilities

- Driving simulators (light-duty and heavy-duty)
- Mobile mapping and positioning system
- Portable traffic signal system (traffic light and signal controller)
- Connected testbed vehicles
- Traffic simulation suites (VISSIM, Paramics, TransModelers, SUMO)

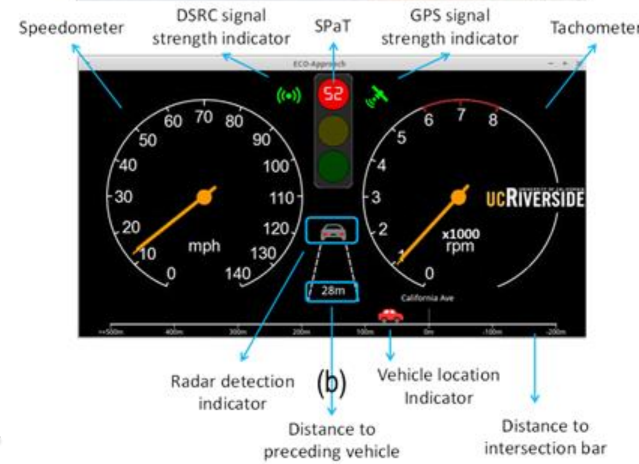
Eco-Driving Technology

Eco-Approach and Departure

- Utilizes traffic signal phase and timing (SPaT) data to provide driver recommendations that encourage “green” approaches to signalized intersections

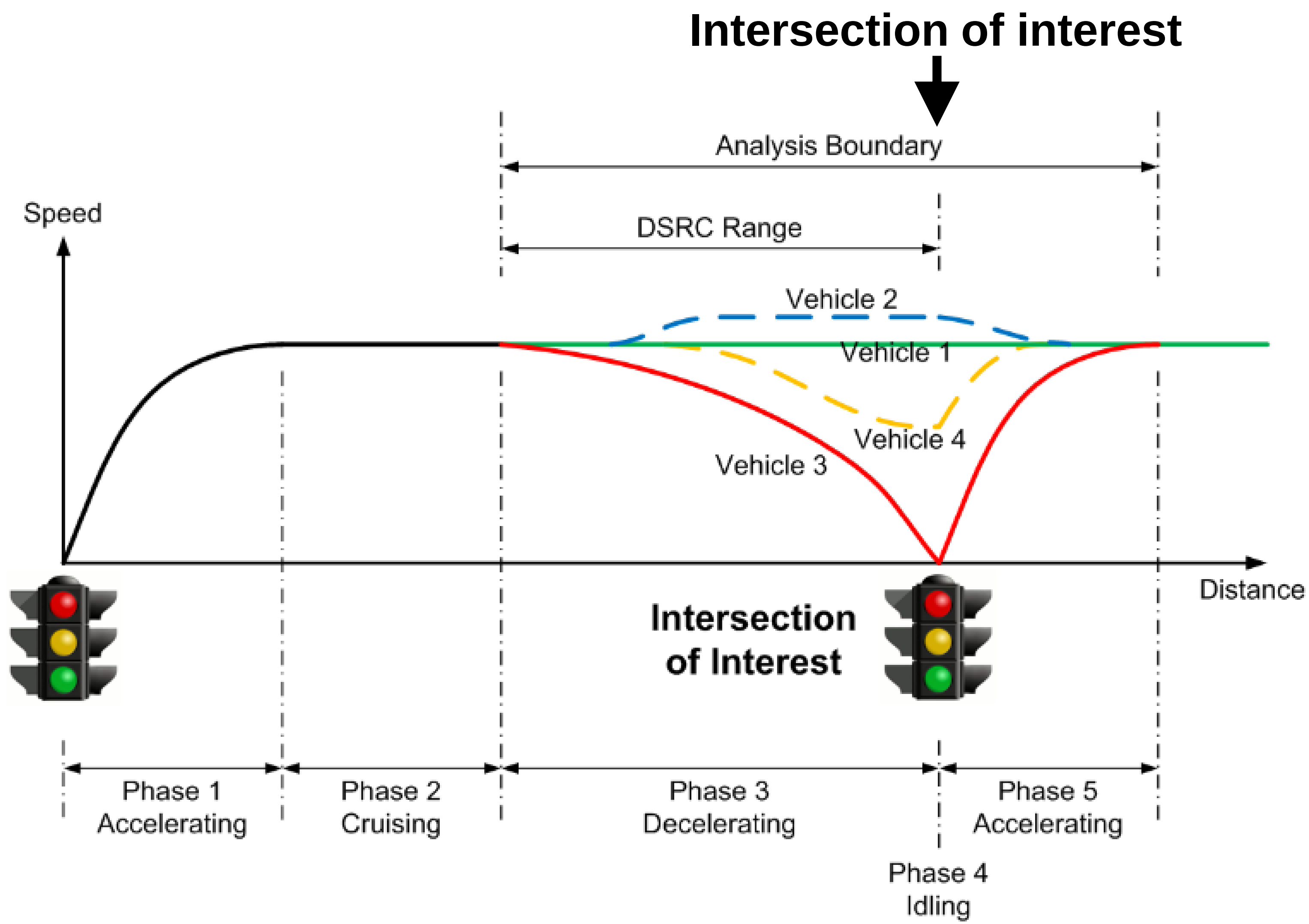


Source: Noblis, November 2013

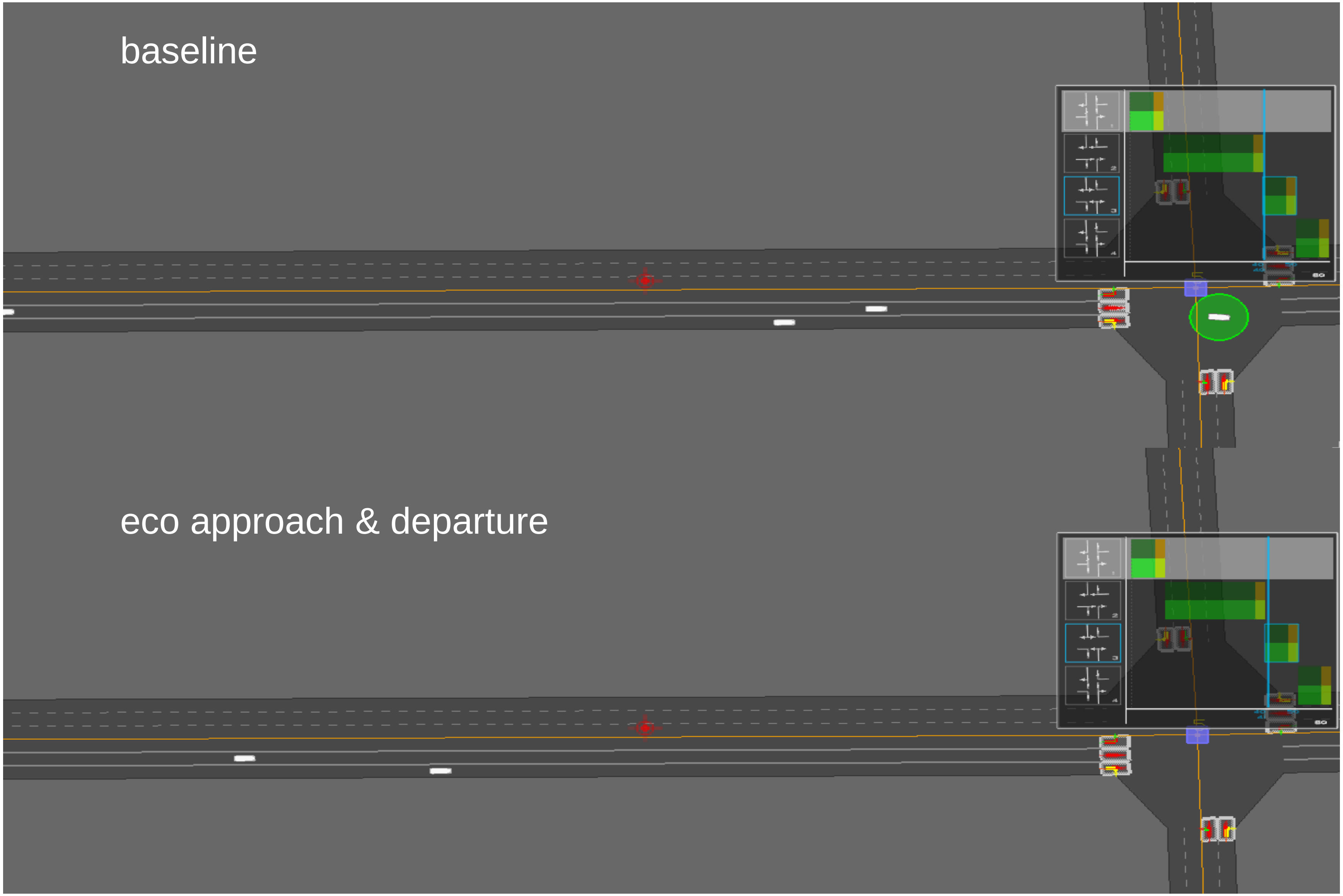


More benefits for fixed time control

Vehicles Approaching an Intersection



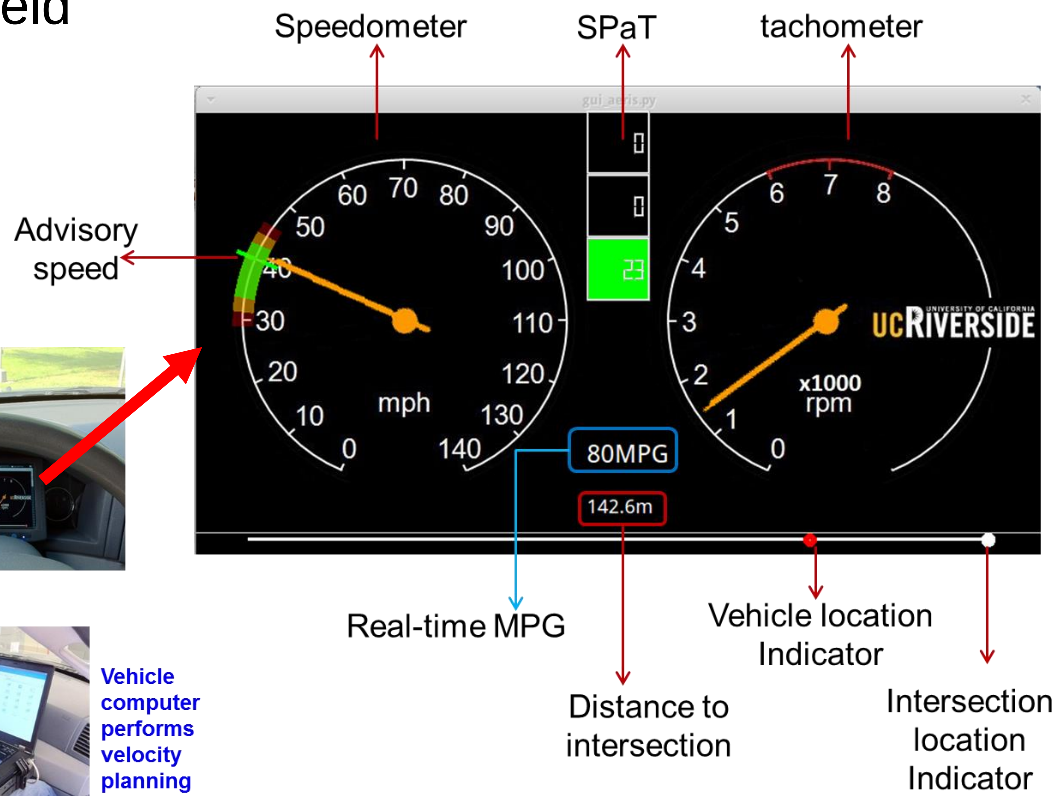
EAD Microscopic Simulation

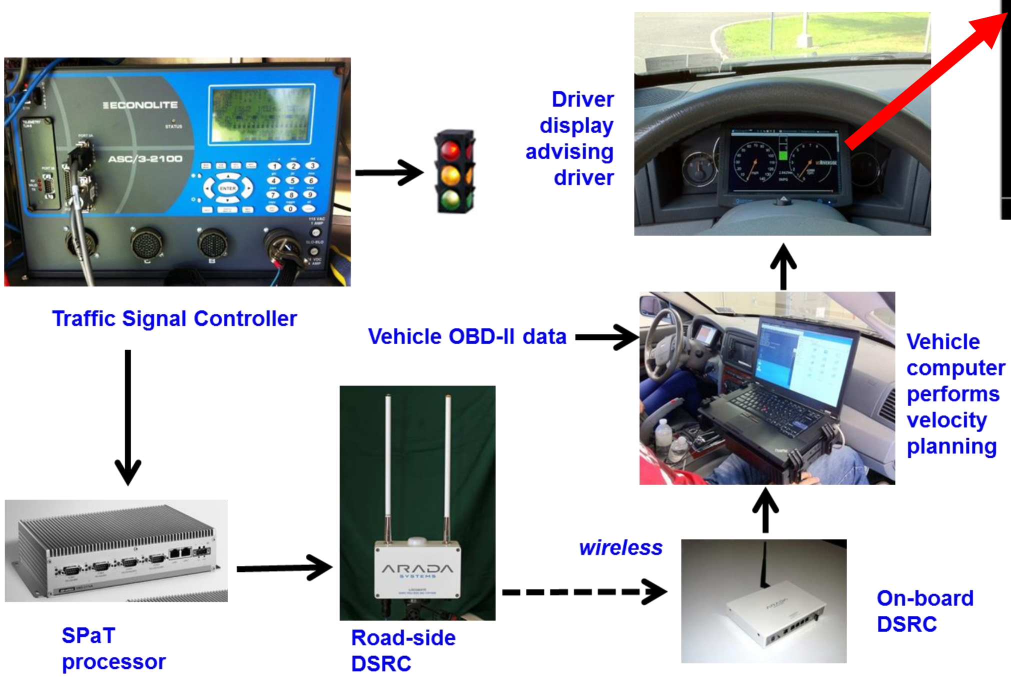


UCR College of Engineering- Center for Environmental Research & Technology

AERIS Connected Vehicle Research

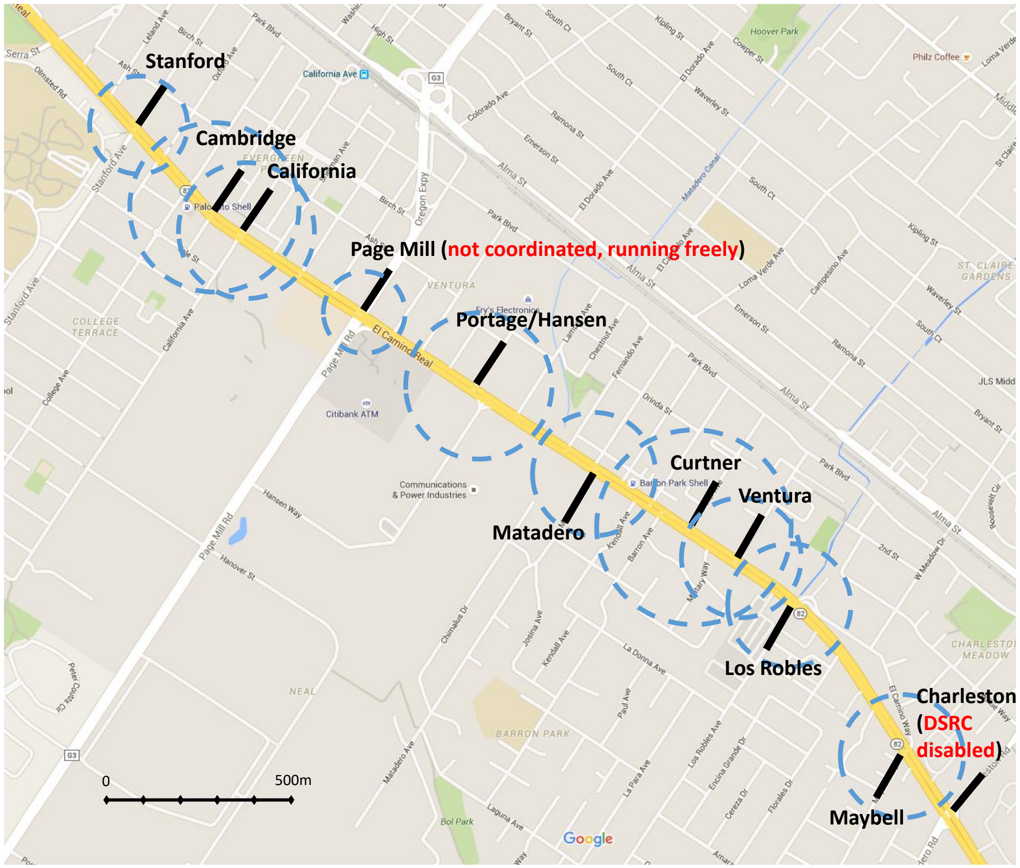
- Developed, modeled, and field tested Connected Vehicle applications targeting at reducing energy and emissions

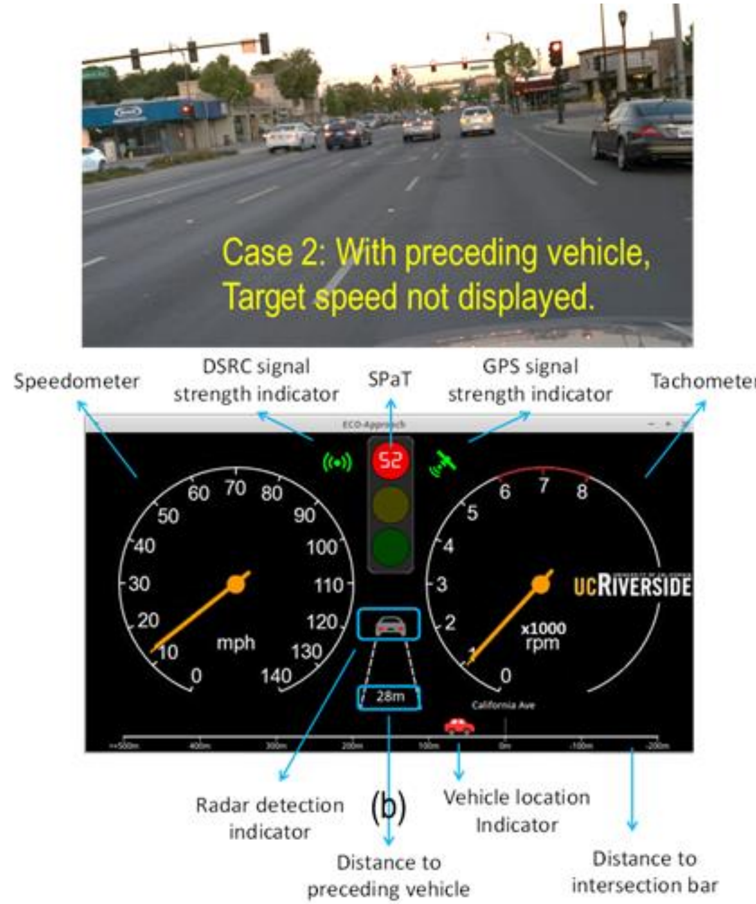




5-20% fuel savings from field experiments

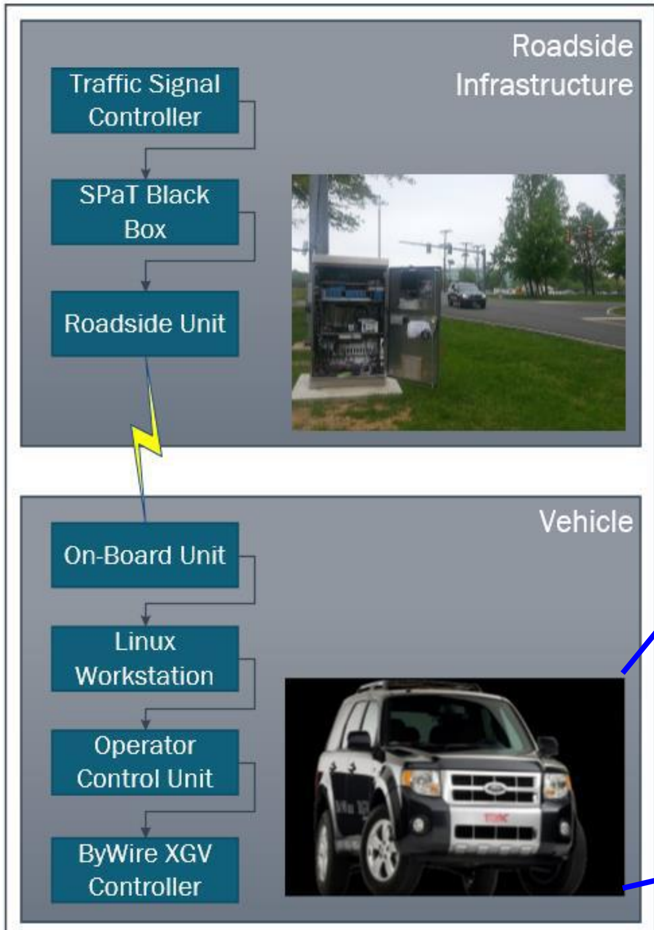
Field Testing in Palo Alto, CA

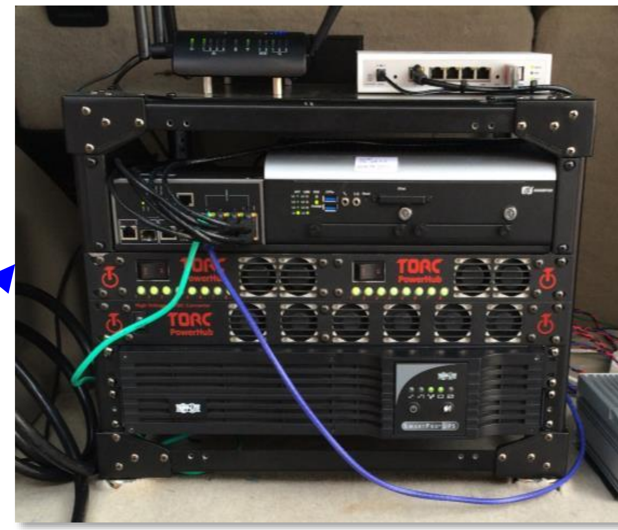




GlidePath

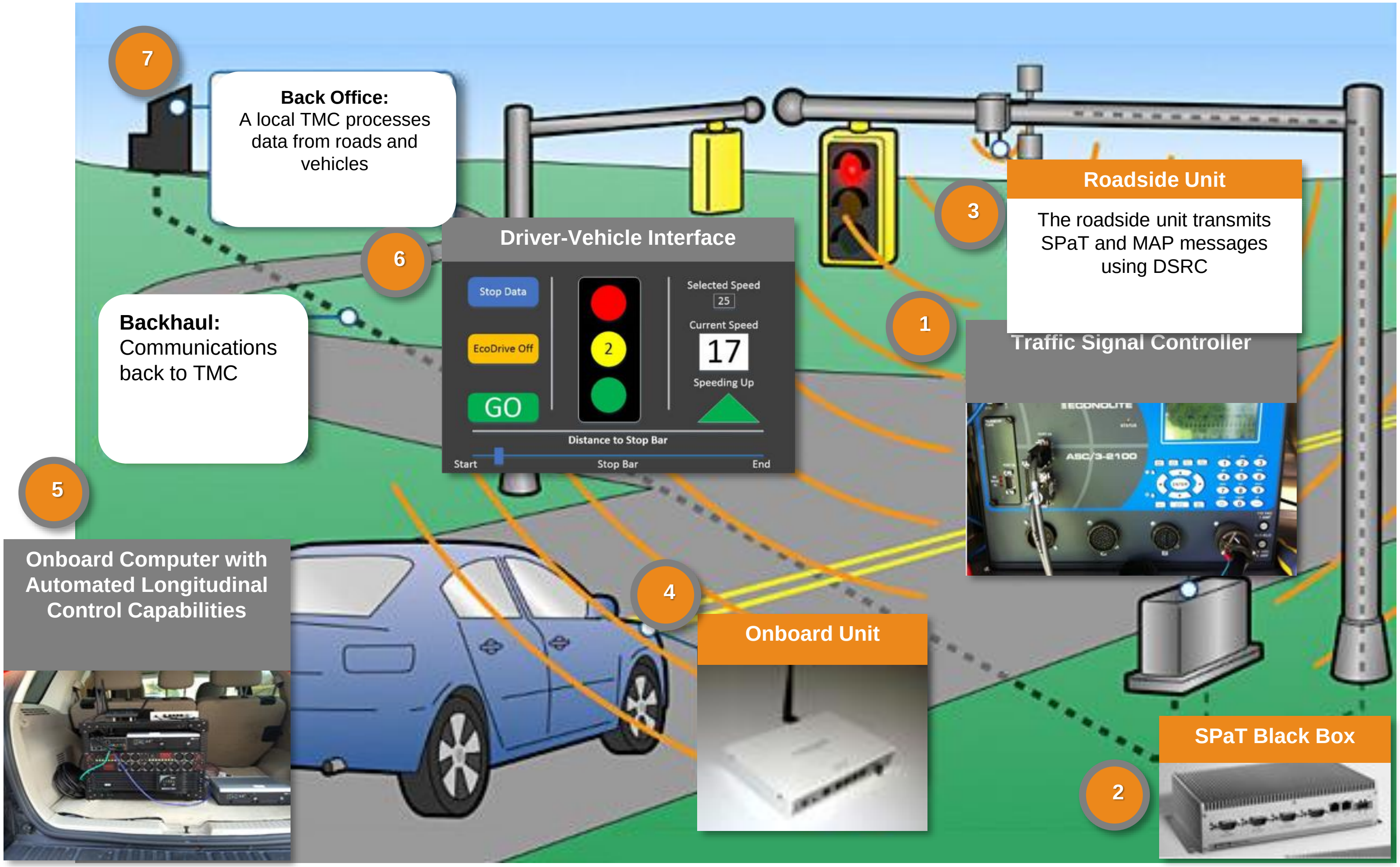
- EAD with Partial Automation (Tested in TFHRC in McLean, VA)

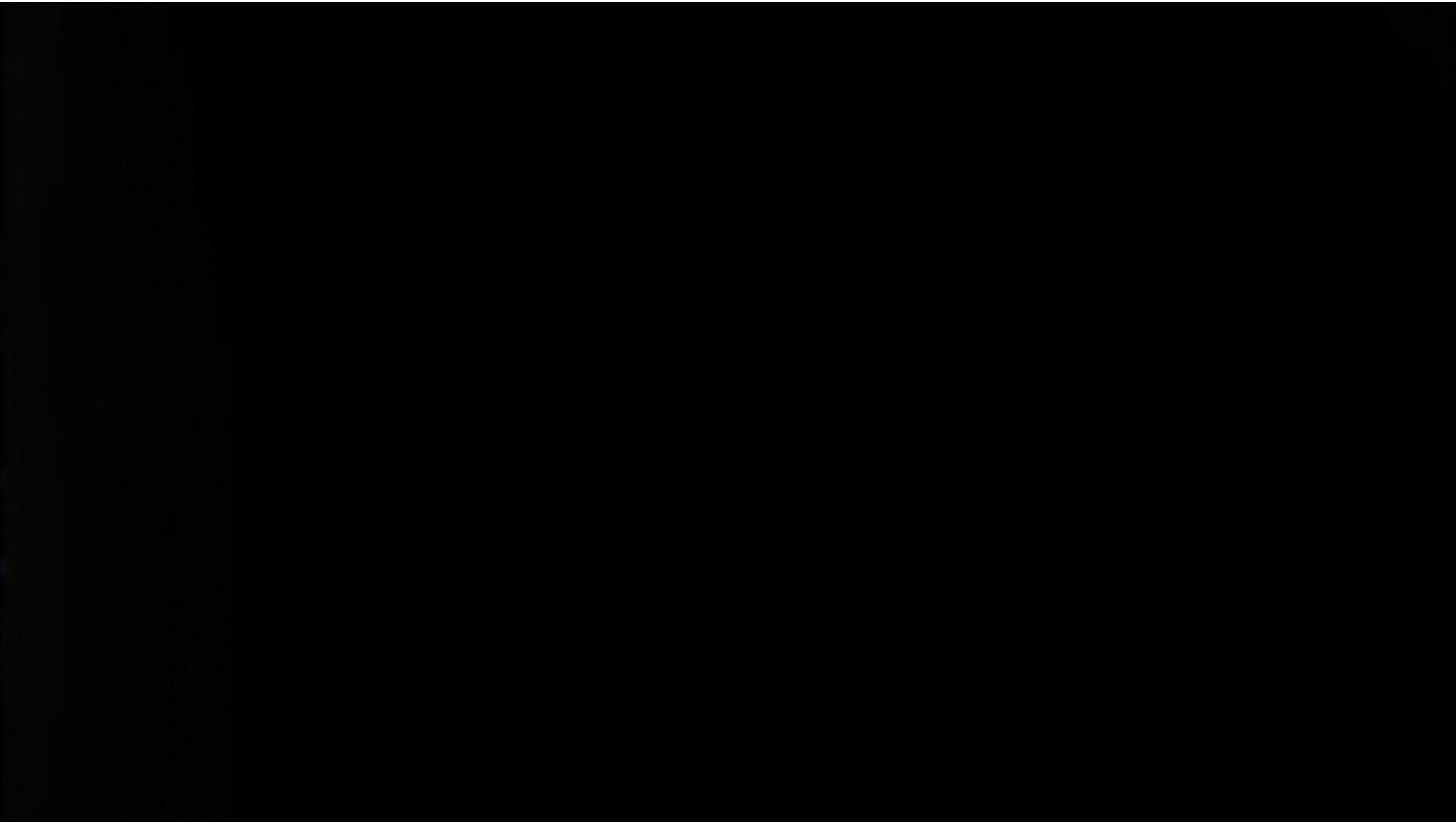




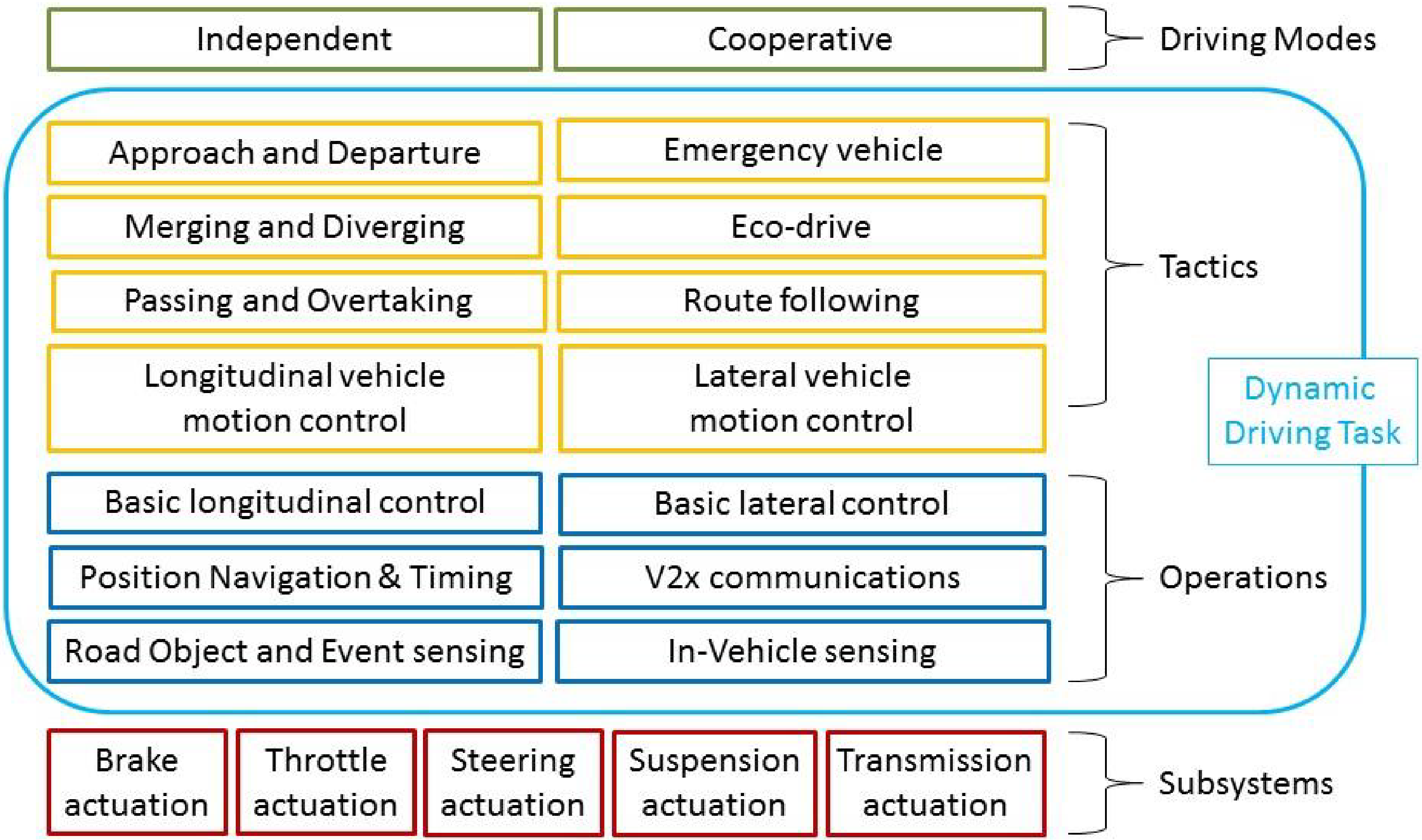
Ford Escape Hybrid developed by TORC with ByWire XGV System

GlidePath I: Partially Automated EAD





GlidePath II: CAV Platform Capabilities

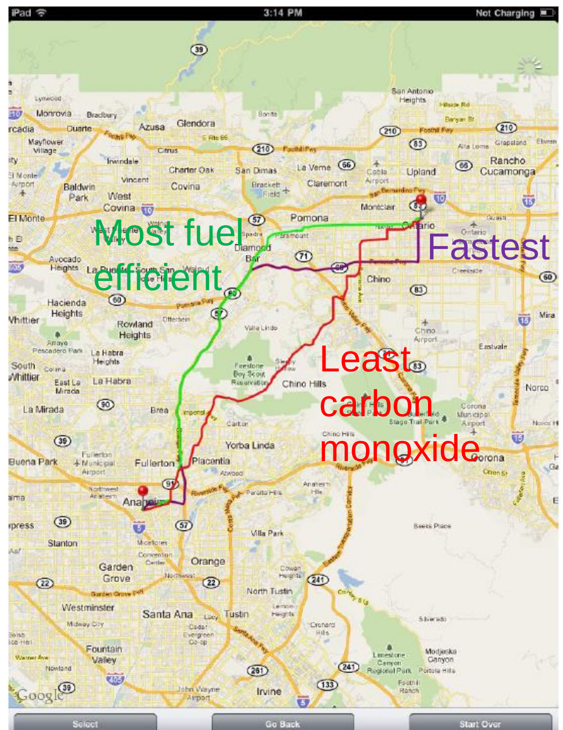


Source: Leidos, 2017

Eco-Routing Navigation

- Eco-Routing Navigation module – route evaluation
- When considering intersection delays, optimal routes tend to contain fewer turns and consist more of freeway driving.

Without Intersection Delays



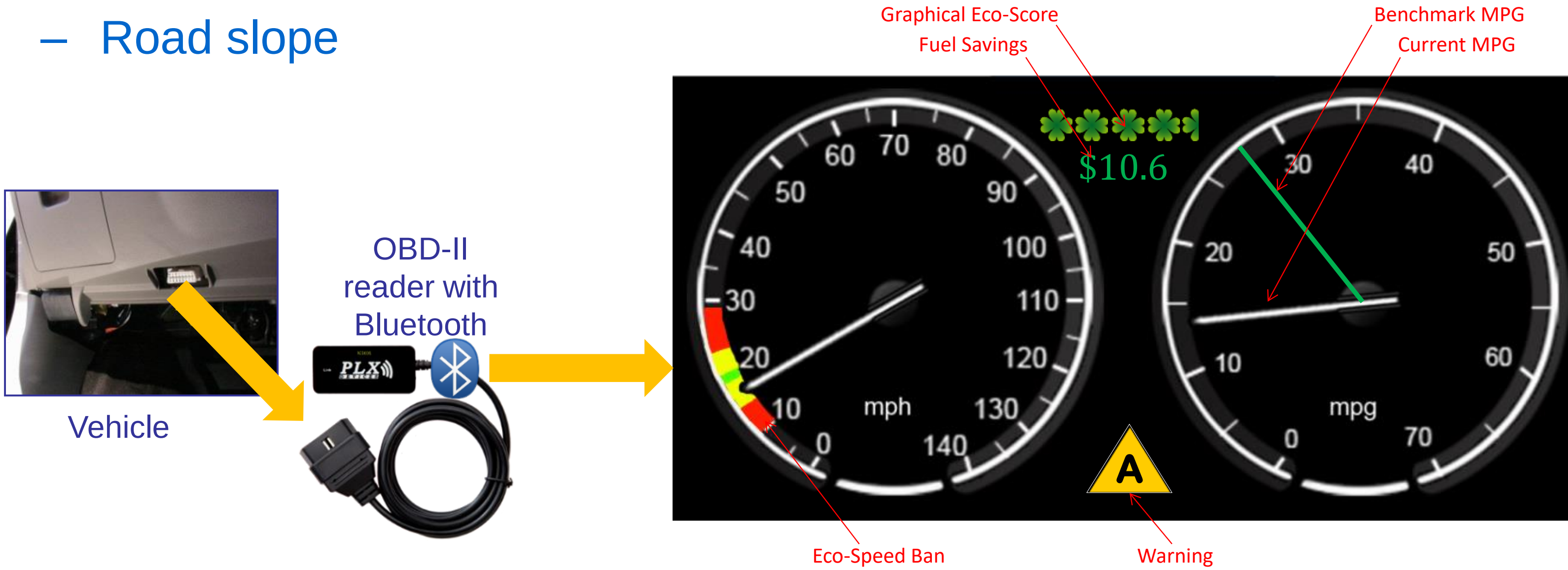
Route	Distance (miles)	Time (minutes)	Fuel (gallons)	Emissions
Time	29.2	36.2	0.92 $3.82	
Fuel	27.4	43.1	0.85 $3.53	
Carbon Monoxide	28.5	60.3	0.93 $3.89	

With Intersection Delays

Route	Distance (miles)	Time (minutes)	Fuel (gallons)	Emissions
Time	29.2	38.8	1.06 $4.41	
Fuel	28.4	42.1	1.04 $4.35	
Carbon Monoxide	28.7	63.6	1.22 $5.08	

Eco-Driving Feedback

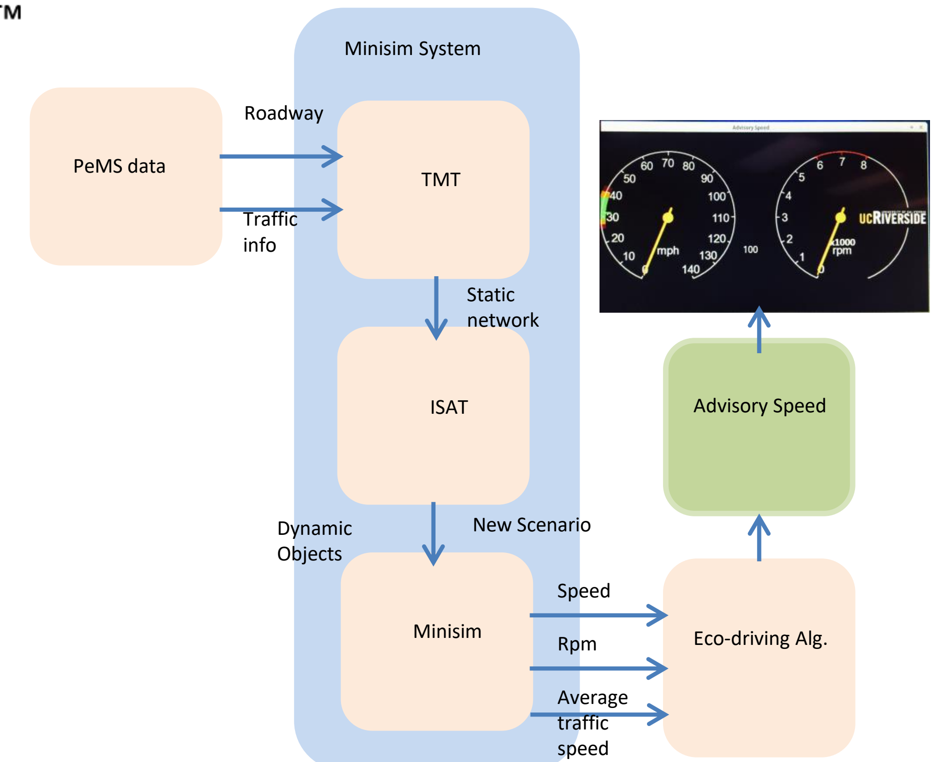
- Eco-Driving Feedback module – user interfaces
- Simple and intuitive; similar to current vehicle dashboard, which should help reduce “eyes-off-road” time
- Feedback determined based on:
  - Actual fuel use (from vehicle’s OBD-II)
  - Real-time traffic
  - Road slope



ECO-Driving Technology for Heavy-Duty Trucks

Simulator System

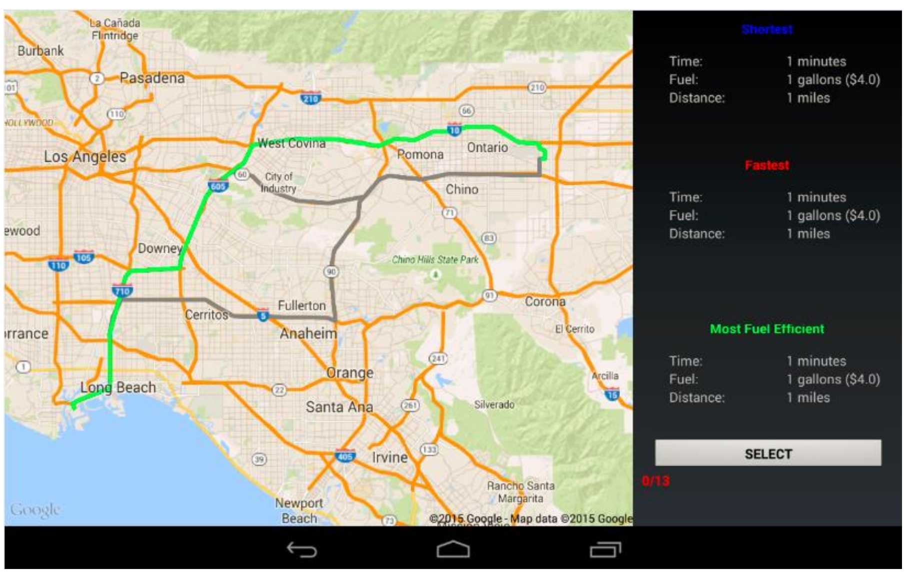
Data Stream

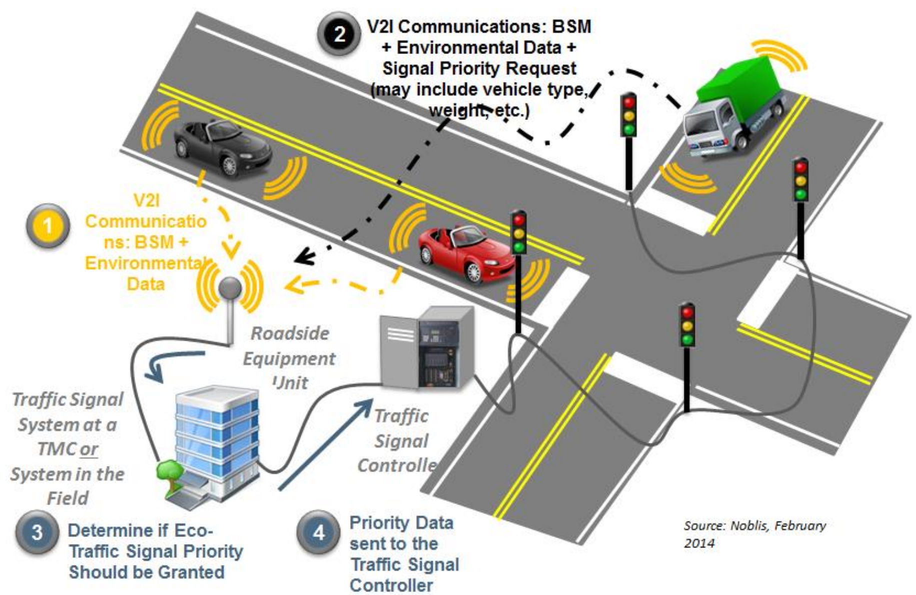


https://www.youtube.com/watch?v=jQsm3mOGSBg

Freight Eco-ITS Technologies

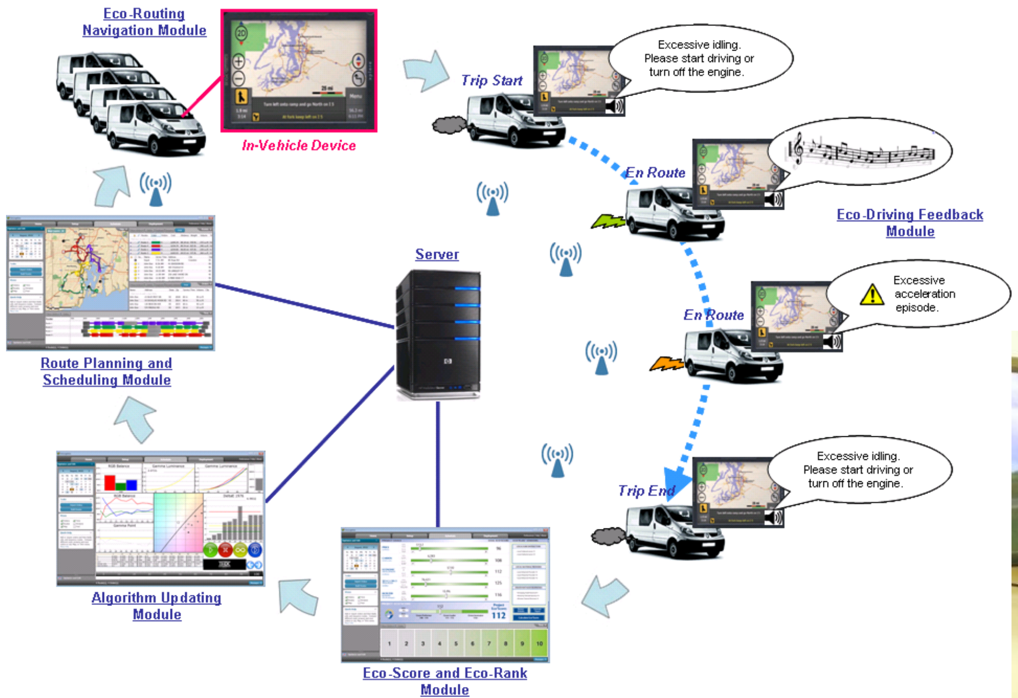
- Freight-focused ***eco-friendly intelligent transportation system*** technologies
  - Take advantage of real-time traffic information e.g., truck eco-routing
  - Supported by connectivity e.g., eco-freight signal priority
  - Enhanced by automation e.g., truck platooning

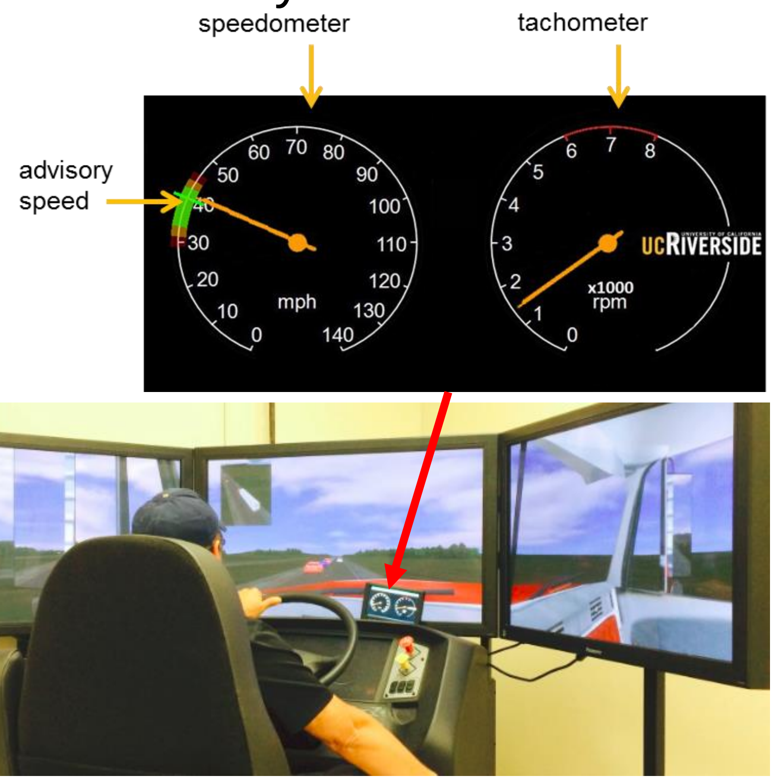




Freight Efficiency Improvements

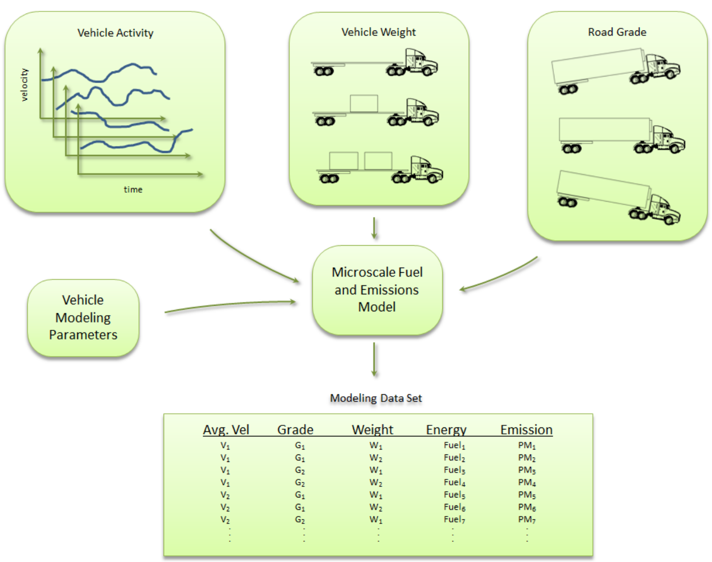
- Improved ***operational and environmental*** efficiency
  - Eco-trip planning and scheduling
  - Eco-routing and eco-driving
- Based on real-time information and advanced analytics



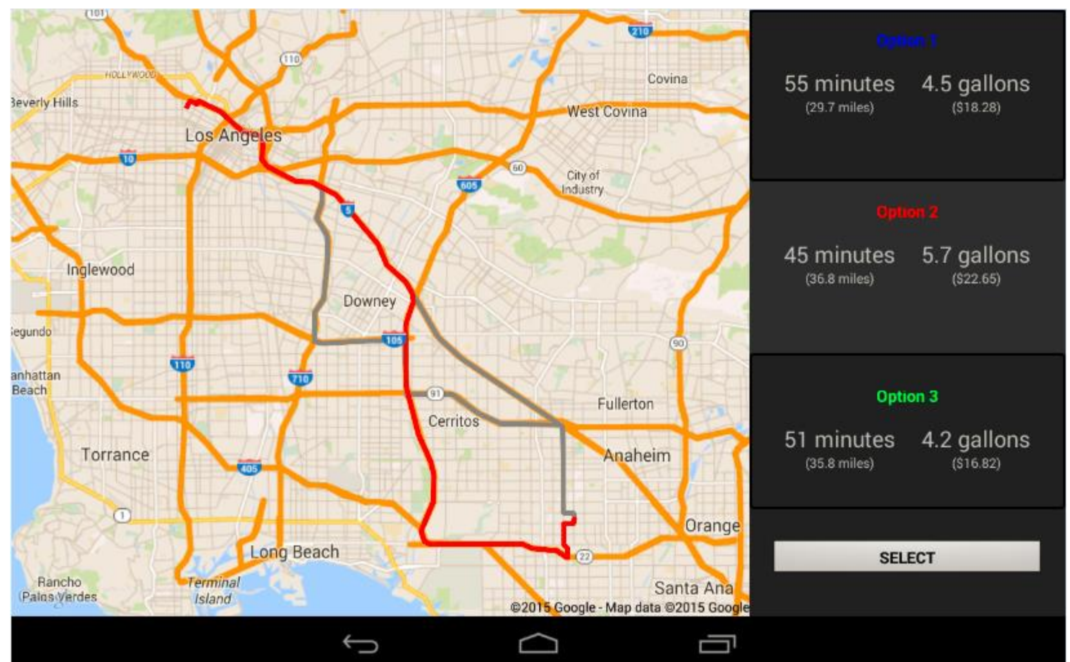


Truck Eco-Routing

- Calculate route that minimize fuel consumption or a specific emission.
- Account for real-time traffic, road grade, and combined vehicle weight.
- Simulation shows tradeoff between fuel consumption and travel time.
  - 9%-18% fuel savings with 16%-36% travel time penalty.



Avg. Vel	Grade	Weight	Energy	Emission
V_1	G_1	W_1	$Fuel_1$	PM_1
V_1	G_1	W_2	$Fuel_2$	PM_2
V_1	G_2	W_1	$Fuel_3$	PM_3
V_1	G_2	W_2	$Fuel_4$	PM_4
V_2	G_1	W_1	$Fuel_5$	PM_5
V_2	G_1	W_2	$Fuel_6$	PM_6
V_2	G_2	W_1	$Fuel_7$	PM_7
⋮	⋮	⋮	⋮	⋮



City of Riverside Innovation Corridor

- Six mile section of University Avenue between UC Riverside and downtown Riverside
- All traffic signal controllers are being updated to be compatible with SAE connectivity standards
- UC Riverside is providing the Dedicated Short Range Communication modems in each traffic signal
- Corridor will be used for connected and automated vehicle experiments (ARPA-E hybrid bus, light-duty vehicles, etc.)

An Innovative Vehicle-Powertrain Eco-Operation System for Efficient Plug-in Hybrid Electric Buses

UCR College of Engineering- Center for Environmental Research & Technology

Project Team

Matthew Barth: *faculty, electrical and computer engineering*
Kanok Boriboonsomsin: *research faculty, transportation engineering*
Guoyuan Wu: *research faculty, mechanical engineering*
Mike Todd: *development engineer, environmental engineering*

Oak Ridge National Laboratory

Dr. Zhiming Gao: *R&D Staff, hybrid powertrain simulation & analysis*
Dr. Tim LaClair: *R&D Staff, hybrid powertrain testing & analysis*

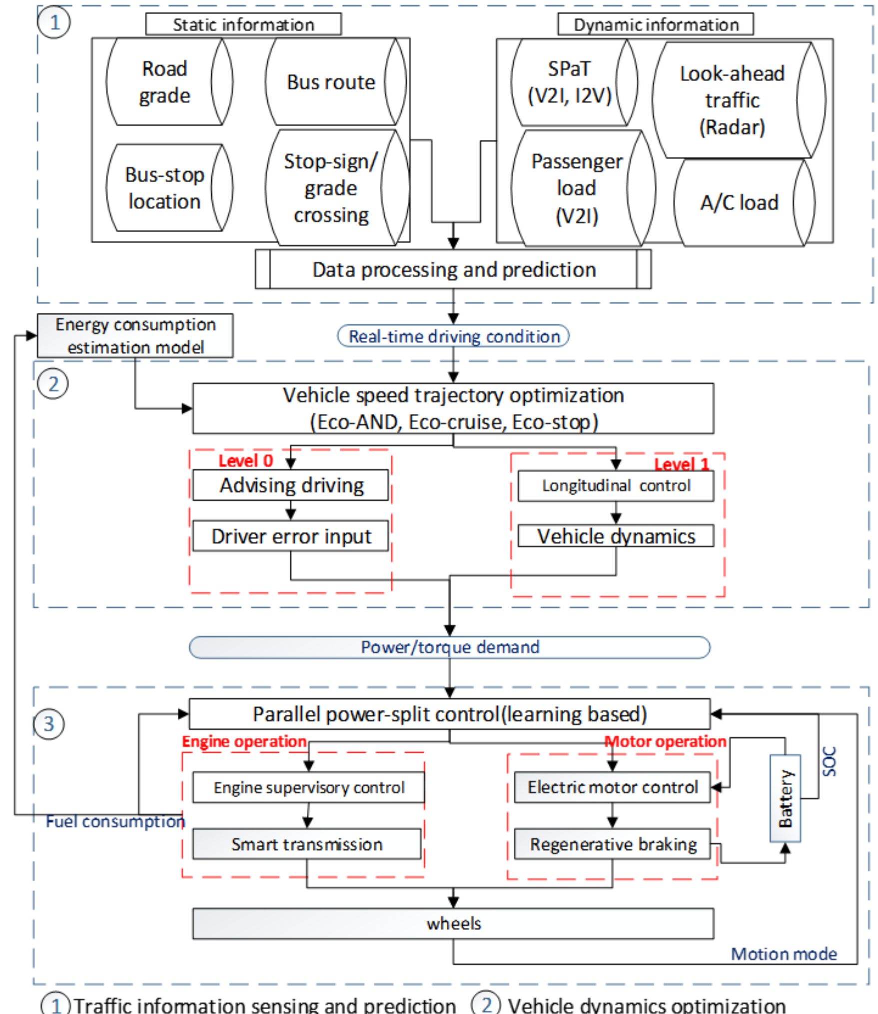
US Hybrid

Dr. Abas Goodarzi: *president; hybrid powertrain design, manufacturer & integration*

Riverside Transit Agency:

Connected Eco-Bus

- An Innovative Vehicle-Powertrain Eco-Operation System for Efficient Plug-In Hybrid Electric Buses
  - Co-optimization of vehicle dynamics and powertrain control
  - 20% energy consumption reduction target



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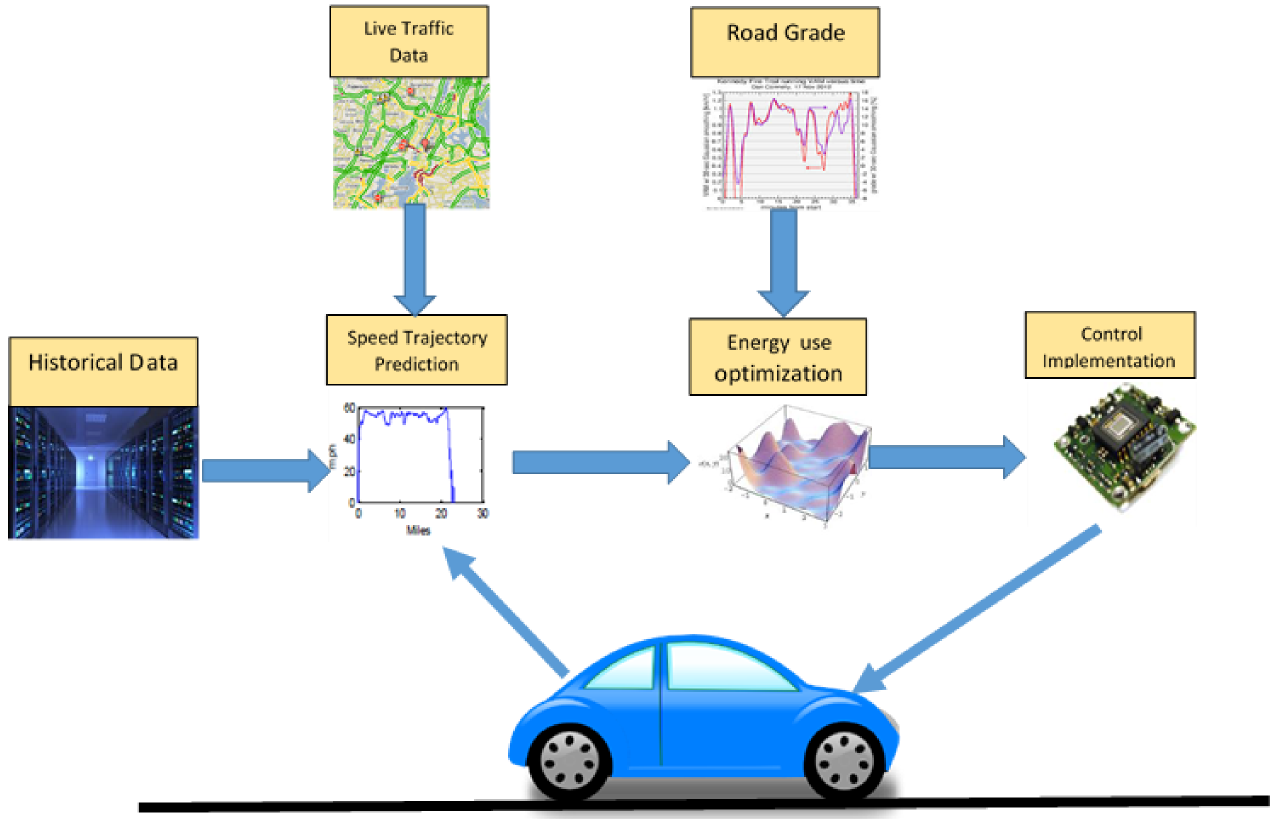
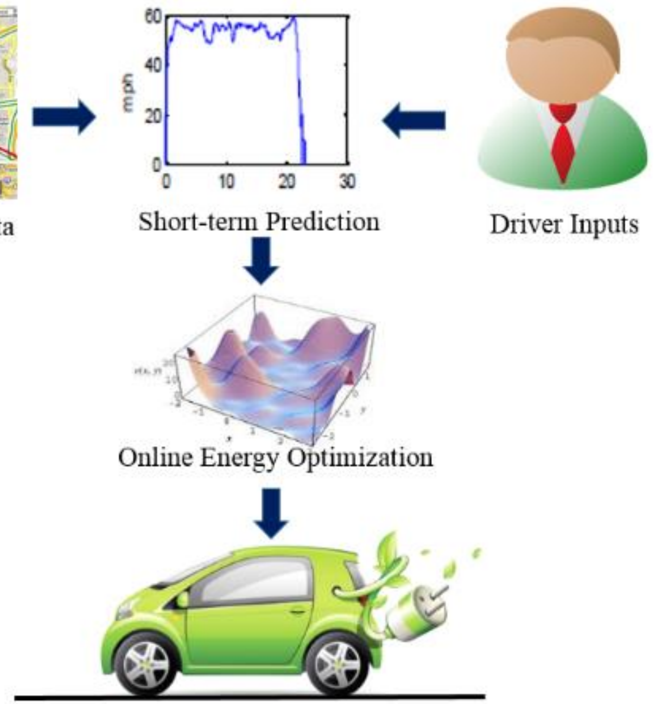
Energy Management System Research

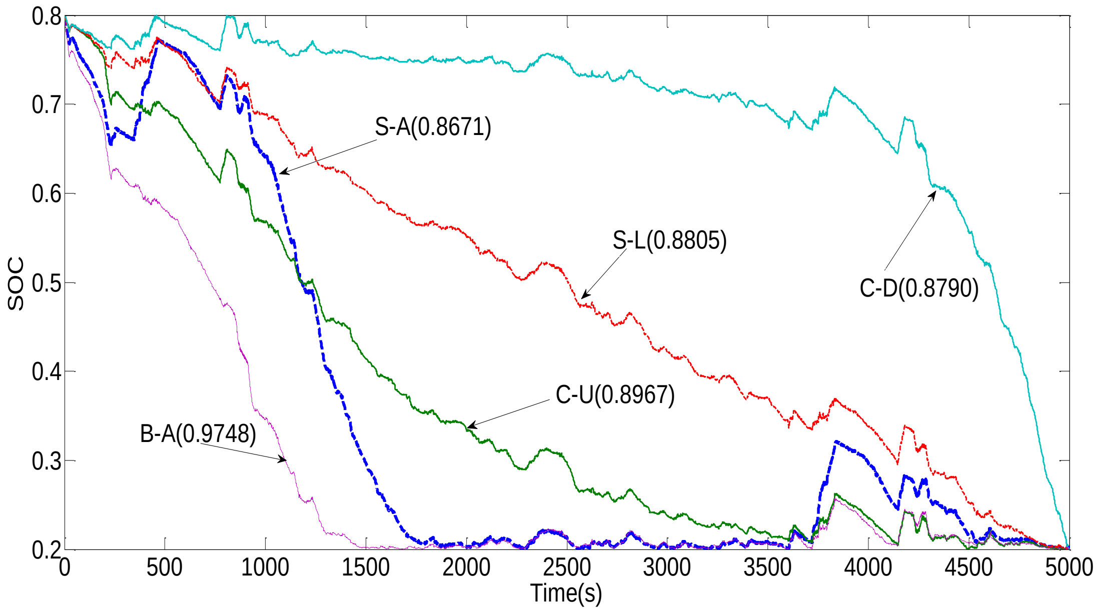
- For plug-in hybrid electric vehicles
- Optimize energy flow between ICE and motors using predictive analytics based on machine learning algorithms



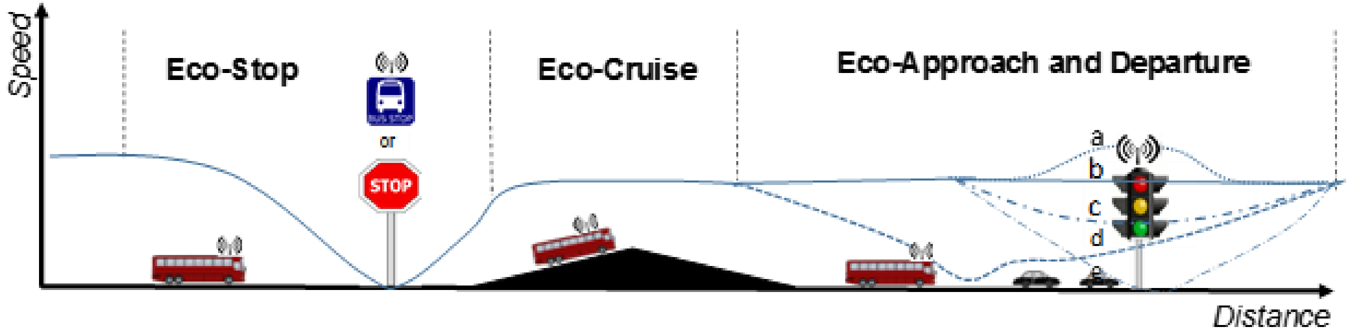
Advanced Energy Management System

- For PHEVs and HEVs
- Optimize energy flow between ICE and motors using predictive analytics based on machine learning algorithms





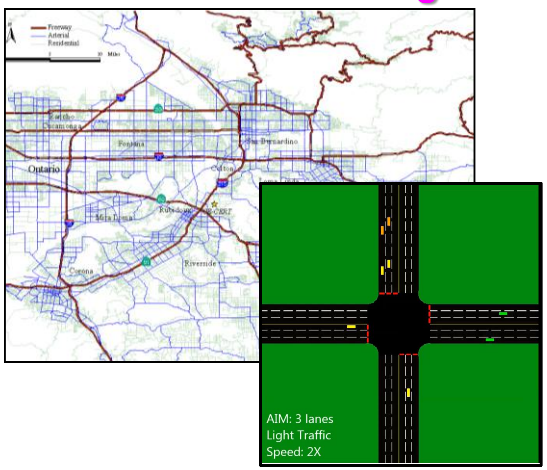
Technology



- Employ emerging connected vehicle applications:
  - Eco-Approach and Departure
  - Eco-Cruise
  - Eco-Stop
- Utilize advanced machine learning and prediction techniques to optimize both vehicle dynamics and powertrain controls
- Algorithm inputs:
  - On-board Sensors (drivetrain, vehicle position/state, passenger count)
  - Route Information (bus-stop, schedule, road grade)
  - Traffic/Signal Information (current and downstream)

Dyno-in-the-Loop Concept

Transportation Systems Research Microscopic Traffic Modeling



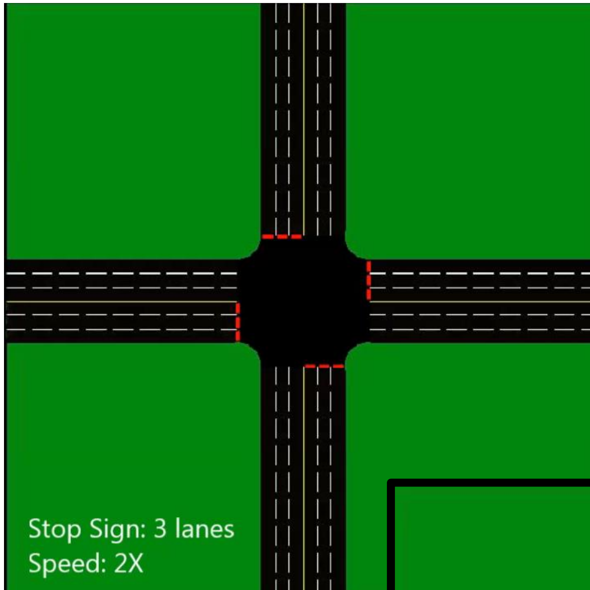
Dynamometer Operation

Real-Time Vehicle Trajectory Data

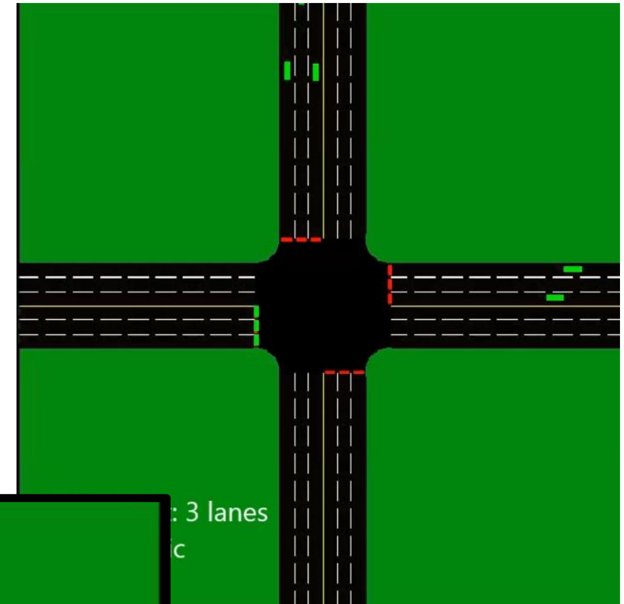

CATERPILLAR
CA 60953

Advanced Traffic Management Technology

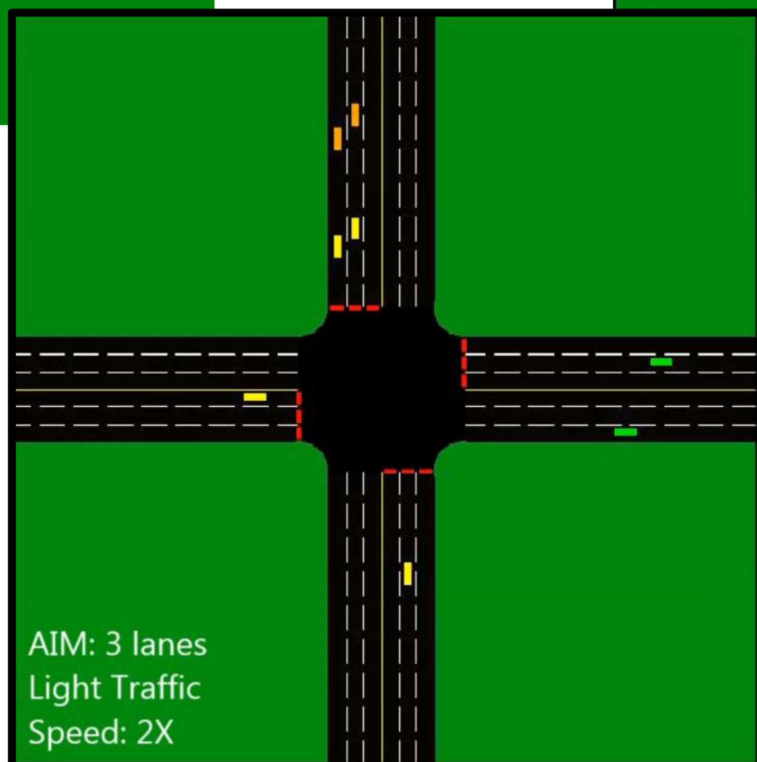
Different Intersection Management Systems



↑ **stop signs**

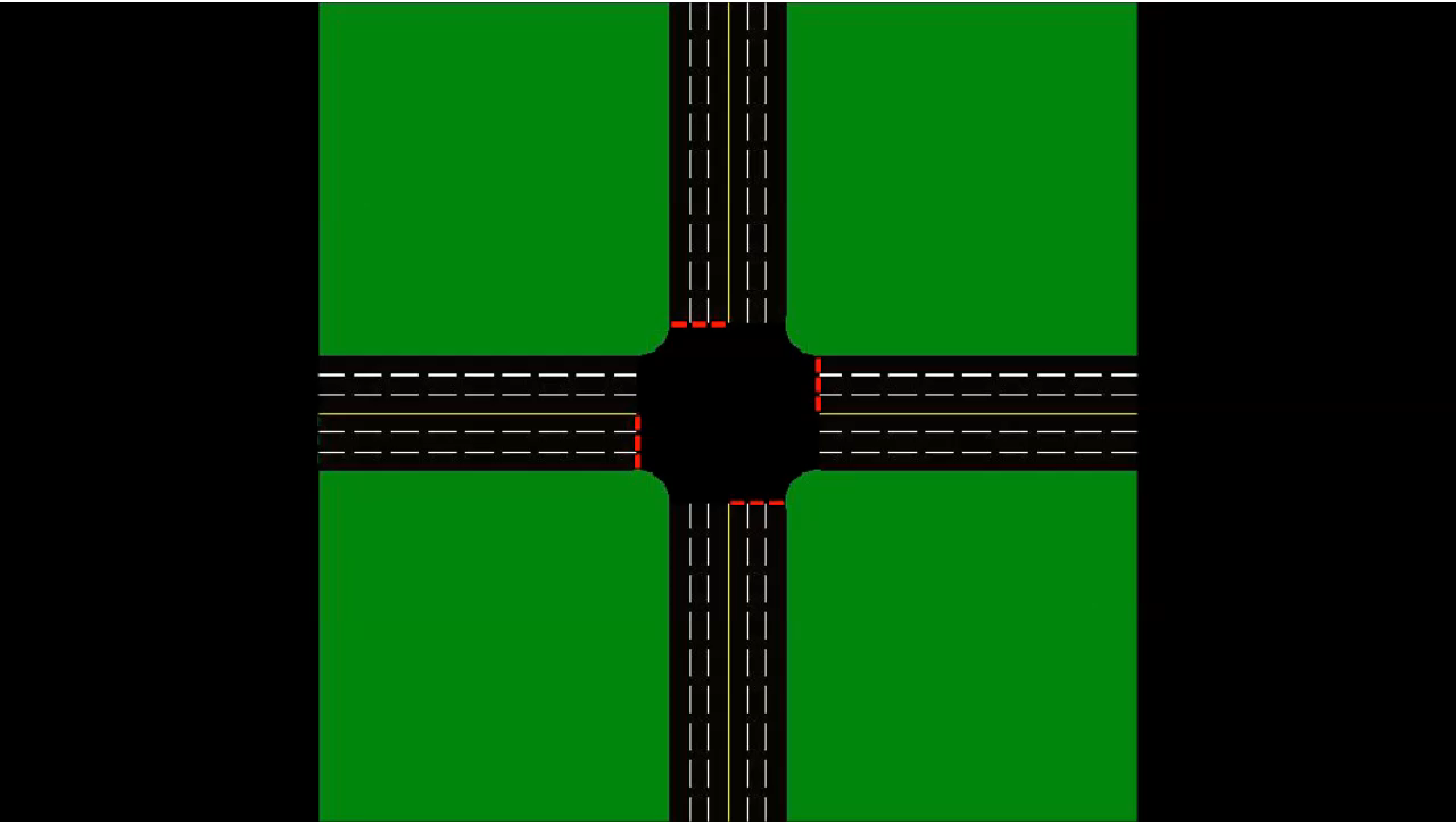


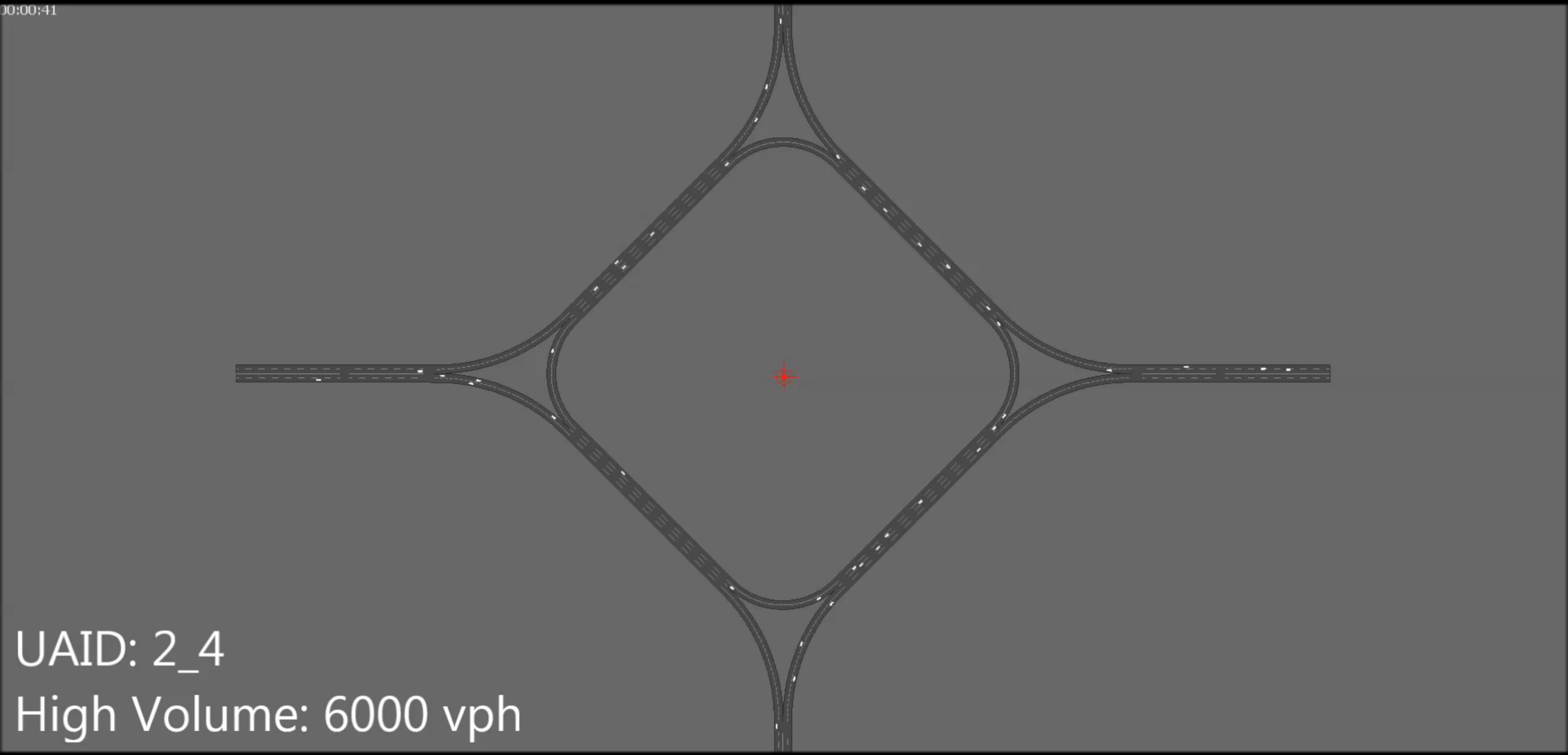
traffic light ↑



← **Intersection reservation system with automated connected vehicles**

Source: David Kari, UCR, 2014




UAID: 2_4
High Volume: 6000 vph

From CC to ACC to CACC

Cruise Control (CC)

Adaptive Cruise Control (ACC

From CC to ACC to CACC

- **Cruise Control (CC):**

Vehicle maintains a steady speed as set by the driver

↓

- **Adaptive Cruise Control (ACC):**

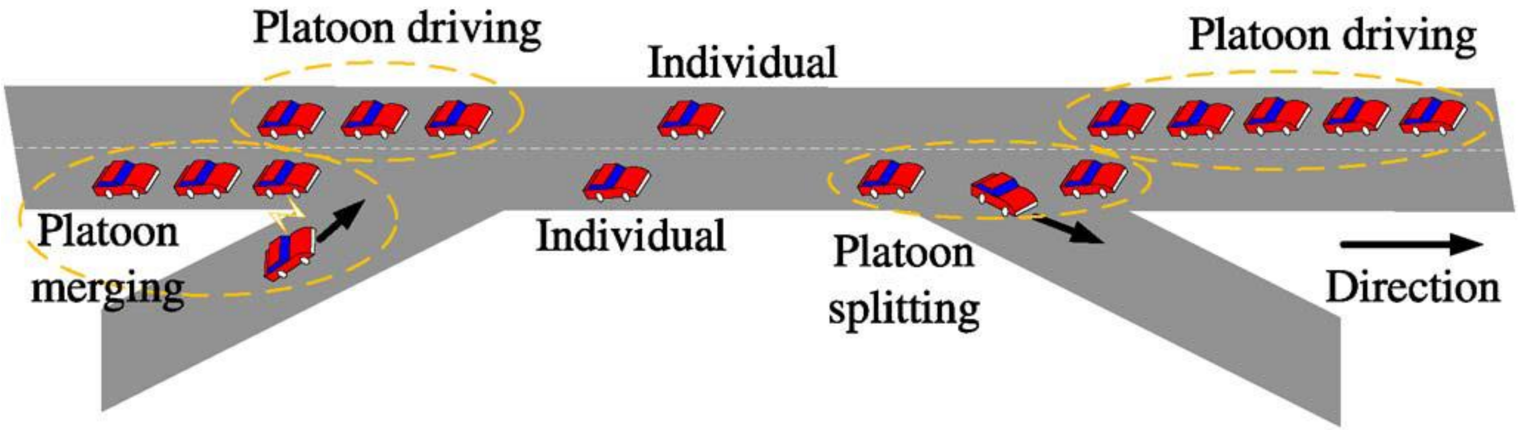
Vehicle automatically adjusts speed to maintain a safe distance from vehicle ahead

↓

- **Cooperative Adaptive Cruise Control (CACC)**

Cooperative Adaptive Cruise Control (CACC)

- Take advantage of connected vehicle technology and automated vehicle technology
- Form platoons and driven at harmonized speed with smaller time gap

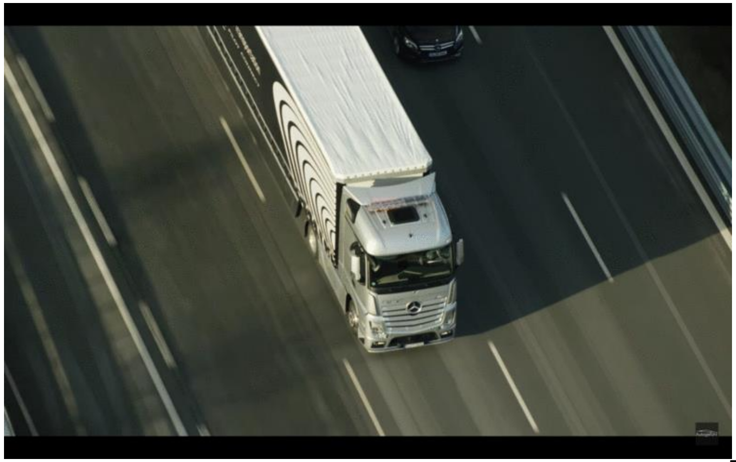


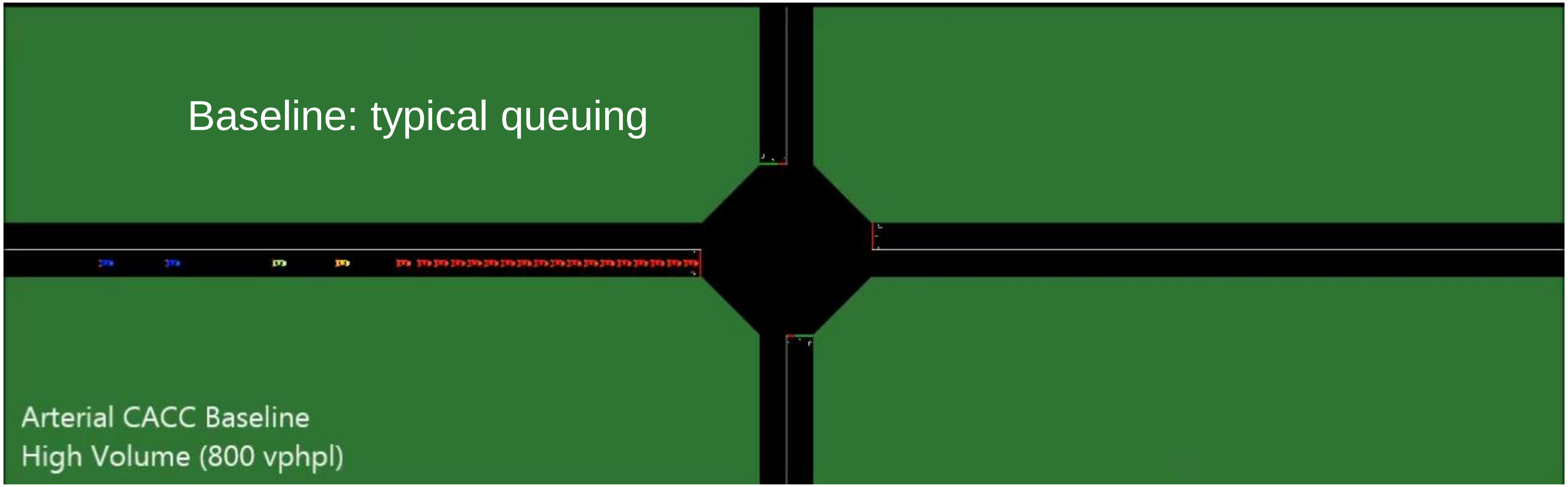
(D. Jia *et al.*, 2016)

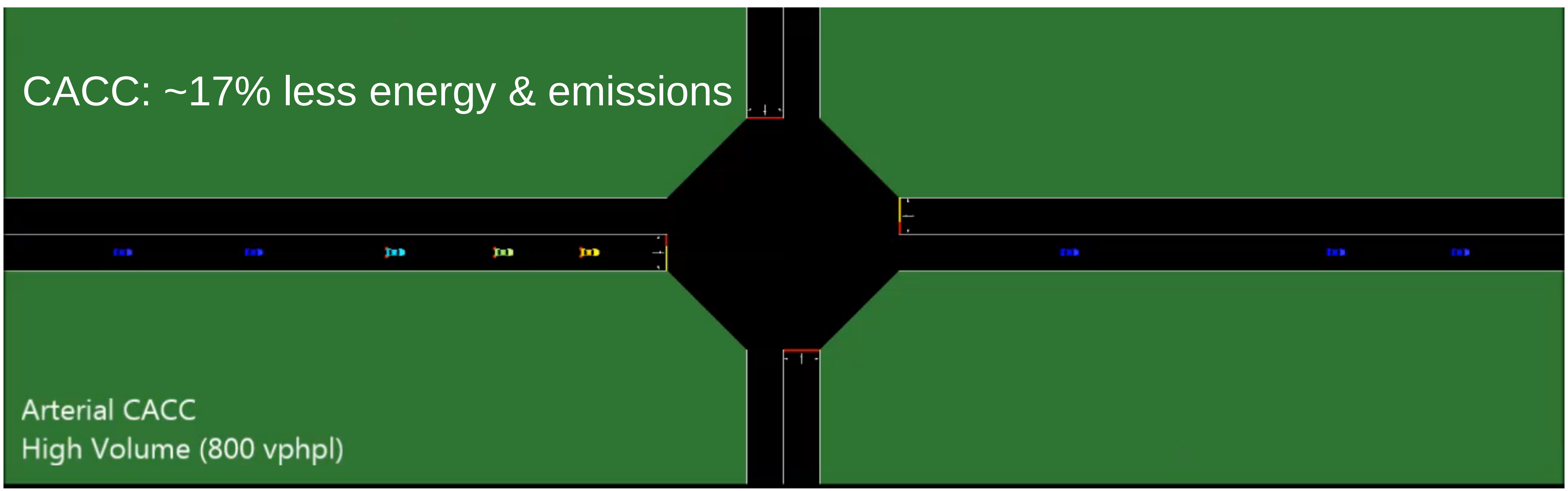
Advantages of CACC

- Safer than human driving by taking a lot of danger out of the equation
- Roadway capacity is increased due to the reduction of inter-vehicle time gap
- Fuel consumption and pollutant emissions are reduced due to the mitigation of aerodynamic drag of following vehicles

(S. Oncu *et al.*, 2014)


(source: www.youtube.com/watch?v=LljnfGXos4c)


Baseline: typical queuing
Arterial CACC Baseline
High Volume (800 vphpl)


CACC: ~17% less energy & emissions
Arterial CACC
High Volume (800 vphpl)

Q & A Time

Thank you very much for the attention!

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