Project ID: eems030

U.S. DEPARTMENT OF ENERGY
SMARTMOBILITY
Systems and Modeling for Accelerated Research in Transportation

Experimental Evaluation of Eco-Driving Strategies

PIs and Presenters: Joshua H. Meng, Xiao-Yun Lu
Lawrence Berkeley National Laboratory

DOE VTO Annual Merit Review
June 19, 2018

Argonne NATIONAL LABORATORY | INL Idaho National Laboratory | BERKELEY LAB | OAK RIDGE National Laboratory | NREL NATIONAL RENEWABLE ENERGY LABORATORY

ENERGY EFFICIENT MOBILITY SYSTEMS PROGRAM INVESTIGATES

MOBILITY ENERGY PRODUCTIVITY

THROUGH FIVE EEMS ACTIVITY AREAS

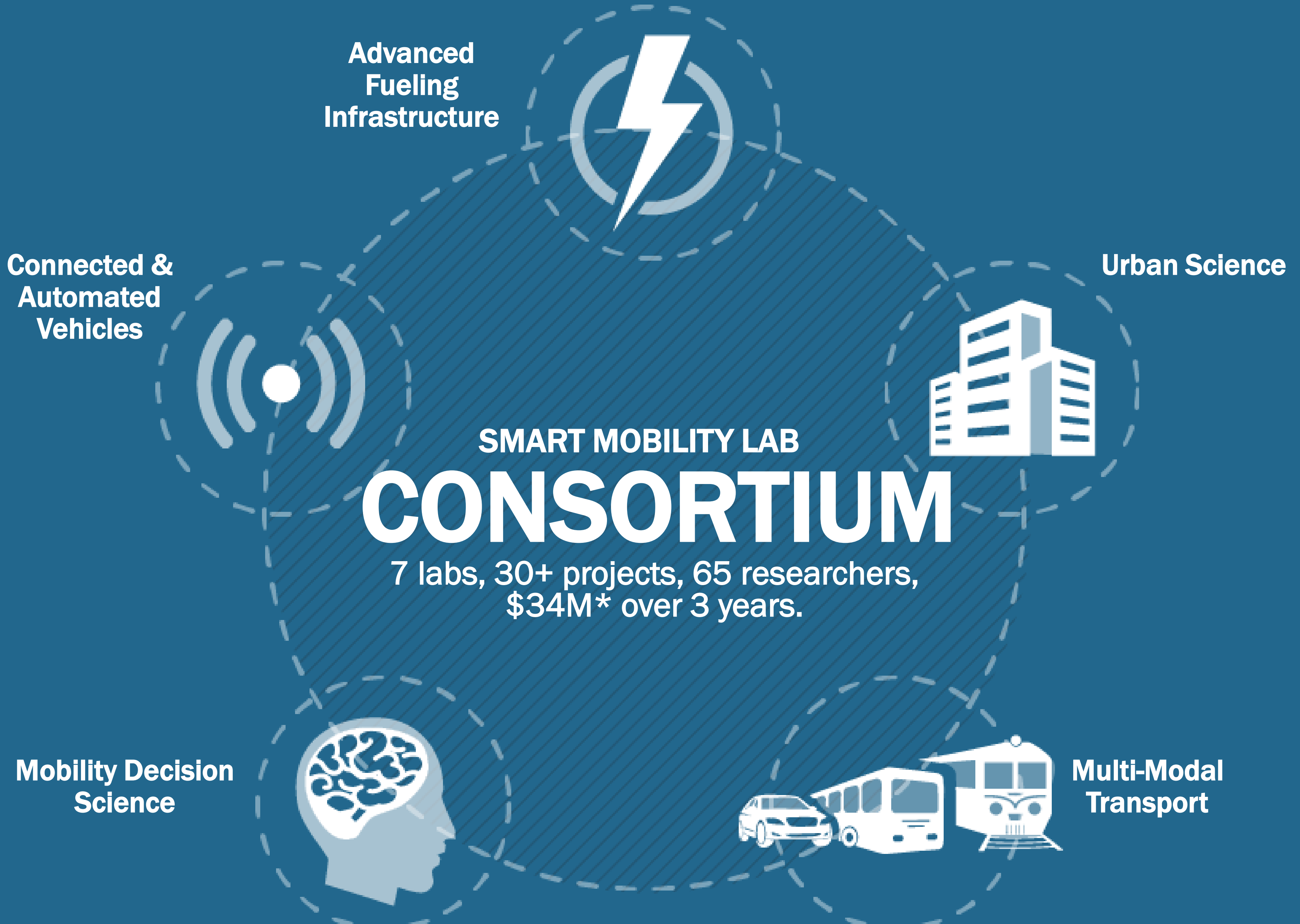
Advanced R&D Projects

Living Labs

Smart Mobility Lab Consortium

Core Evaluation & Simulation Tools

HPC4Mobility & Big Transportation Data Analytics



*Based on anticipated funding

OVERVIEW

Two Subtasks

***(1) Analytical and Experimental Evaluation of Eco-Driving Strategies* (PI, Joshua Meng)**

***(2) The energy impact of passenger car Cooperative Adaptive Cruise Control (CACC) and Platooning* (PI: Xiao-Yun Lu)**

- **Timeline**
  - **Project start date: March 2018**
  - **Project end date: Jun 30 2020**
  - **Percent complete: 5%**
- **Budget**
  - **Total project funding: $695K**
    - **100% DOE/VTO**
  - **Funding for FY 2018: $300K**
    - **LBL: $200K**
    - **INL: $100K**
  - **Funding for FY 2019: $395K**
    - **LBL: $395K**

- **Barriers**

  (1) Methods to realistically estimate fuel saving for Eco-Driving strategies

  (2) How to quantify fuel saving benefit for CACC passenger at high speeds on test track
- **Partners**
  - **Berkeley Lab (project lead)**
  - **INL**
  - **UC Berkeley**
  - **FHWA Saxton Lab**

The Team

Joshua H. Meng, PhD
PI
California PATH
Expert in CAV sensing and communication

Wei-Bin Zhang
IEEE Fellow
California PATH
LBNL
Expert in vehicle automated control and transit operation

Xiao-Yun Lu, PhD
PI
LBNL

Expert in vehicle system modeling and control, CAVs, Vehicle and Highway Automation, traffic system modeling and control, and Active Traffic Management

Steven Shladover, D. Sc.
Former PI
LBNL

Expert in CAV, Vehicle and and Highway Automation, traffic system modeling, ITS, and transportation planning

Dachuan Li, PhD
California PATH
Postdoc, Expertise in automated control

Senyan Yang
PhD student
California PATH
Expertise in traffic flow analysis

John Spring
R&D Engineer
–PATH, ITS, UCB

Experienced senior R&D engineer in software development

Project One: Analytical and Experimental Evaluation of Eco-Driving Strategies (PI, Joshua Meng)

Framework to Accomplish the Objectives of EEMS & SMART Mobility

Scenario: Urban Arterial, signalized intersections

Objects: Light-duty cars

Performance: Fuel/Energy Saving

This task FY18 objectives:

- **Quantify the effectiveness of Eco-approach driving strategies for influencing driving behaviors and fuel use in light-duty vehicles**
- **Establish a preliminary system design thru analysis of eco driving approaches**

Framework to Accomplish the Objectives of EEMS & SMART Mobility (Cont'd)

Approach:

- Previous Studies on Eco-Driving have mostly been focusing on achieving maximum fuel savings/emission reductions.
- This study intends to assess realistic benefits and impacts of Eco-Driving under real world conditions.

Proposed Scope:

- FY18: Analysis of Eco-Approach and Departure (EAD) assistant strategies using simulation tools
- FY19: Field testing of Eco-approach and Departure in real-world driving scenarios at CA Connected Vehicle affiliate test site (scope to be decided based on funding levels)

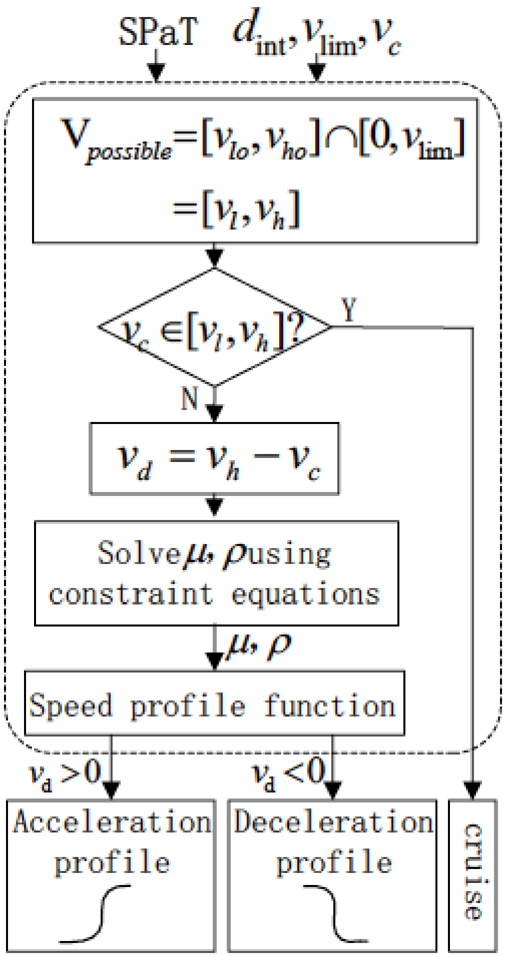
Subtasks and Milestones

Sub Task a: Development of EAD Models and algorithms**:**

Q3: The Eco-driving algorithm(s) that can be applied to both driver advisory as well as ACC-like Eco driving

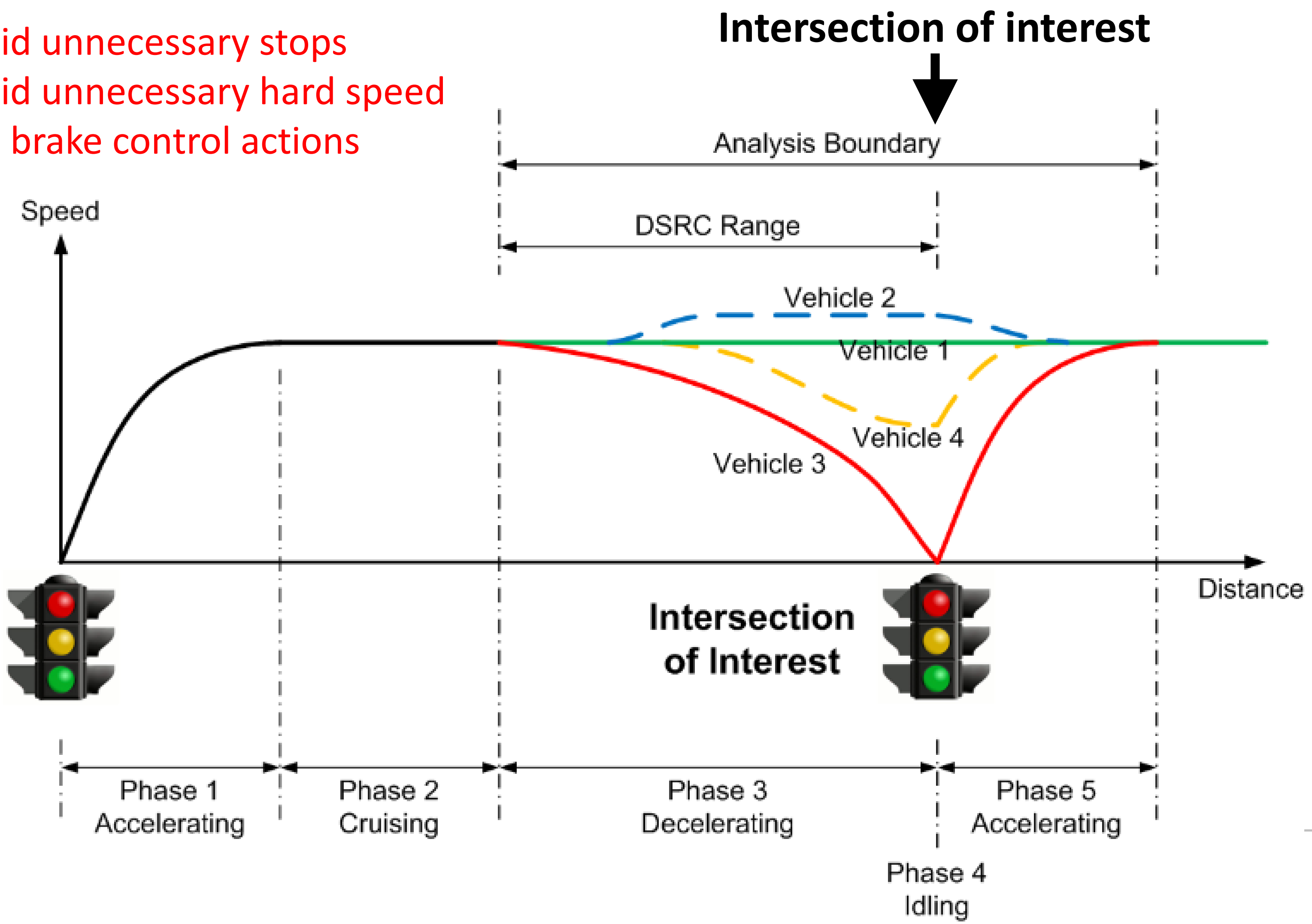
Challenges:

1. driver-in-the-loop sensitivity analysis
2. robust algorithms under inaccurate traffic signal timing prediction



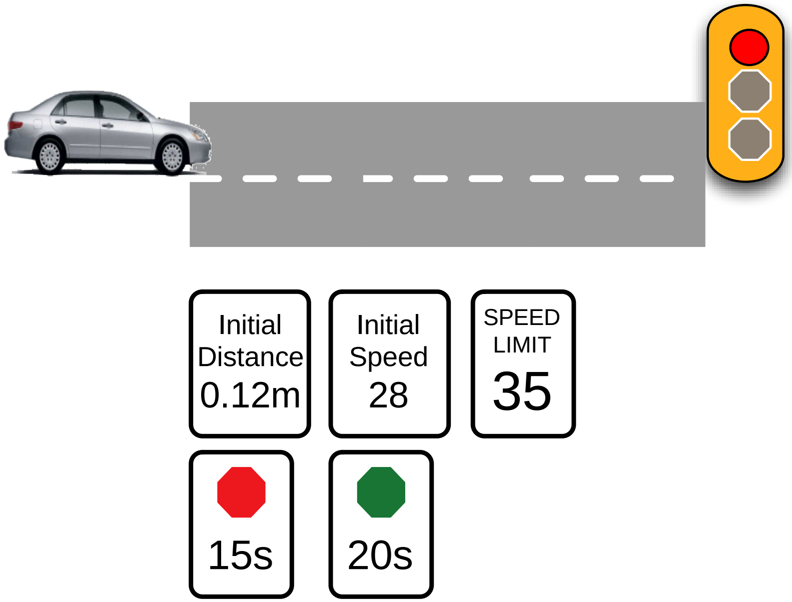
Eco-Approaching & Departure Scenario

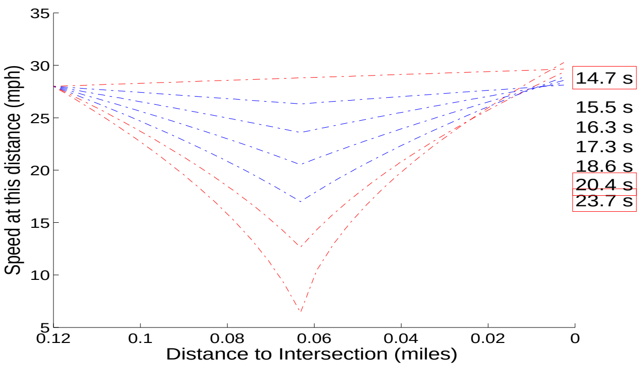
- Avoid unnecessary stops
- Avoid unnecessary hard speed and brake control actions



Trajectory Planning Algorithm

- **Choose the most fuel saving plan among all the candidate trajectories**





Saving
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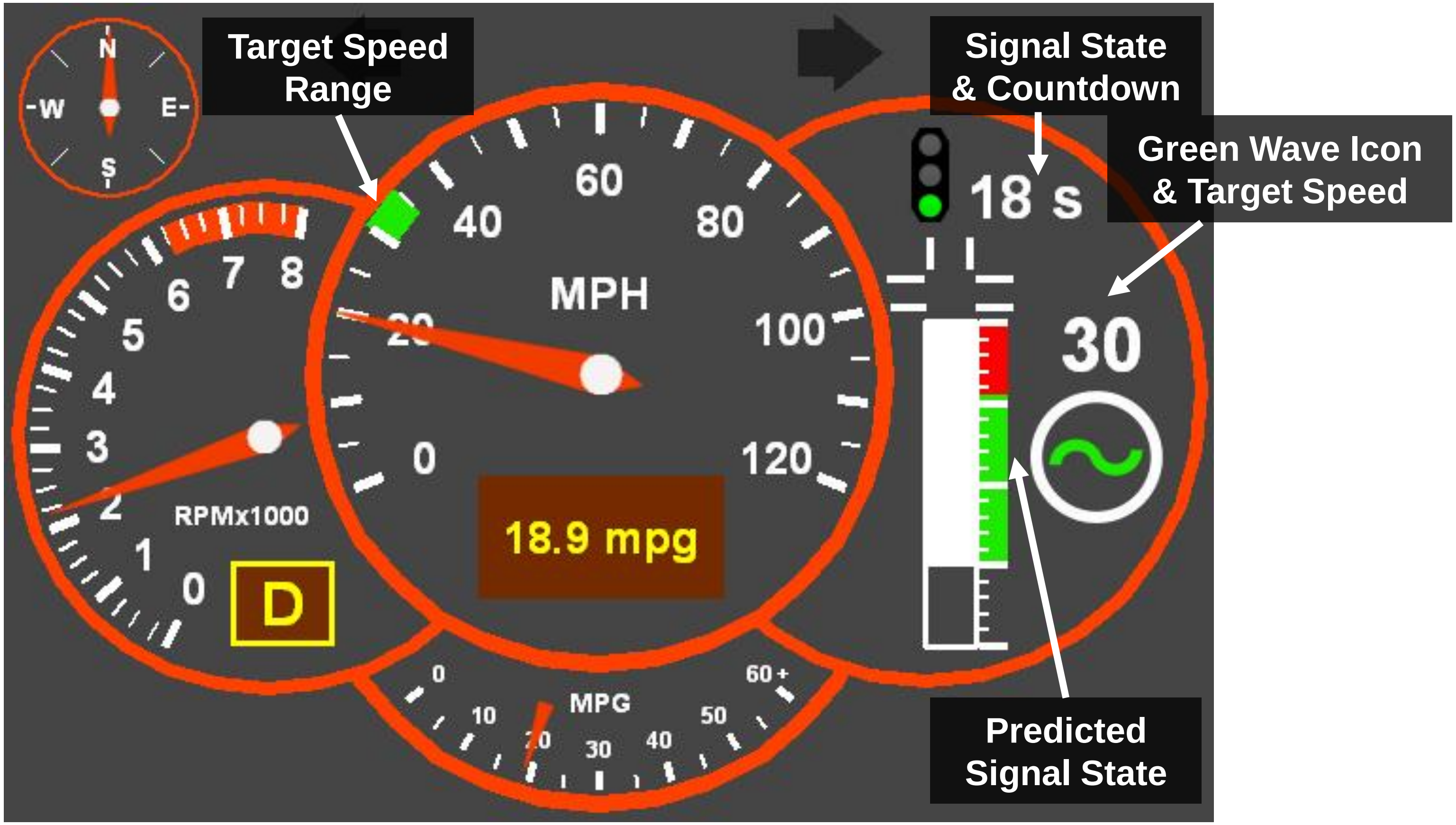
HMI design for driver assistance



Subtasks and Milestones

Sub Task b: Evaluating benefits and impacts of Eco-driving by simulation

Q4: Evaluation results on the benefits of Eco-driving strategies on fuel/emission reductions, and impacts on traffic behaviors.

Challenges:

1. To establish the Measurement-of-Effectiveness for arterial traffic scenarios
2. In which way does the eco-driving car influence other traffic participants?

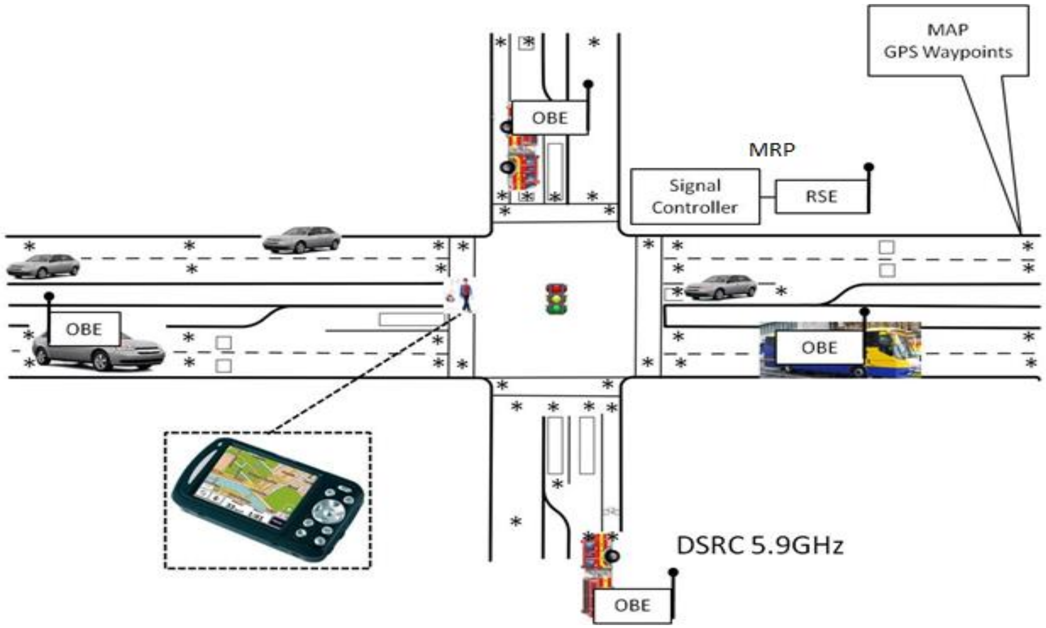
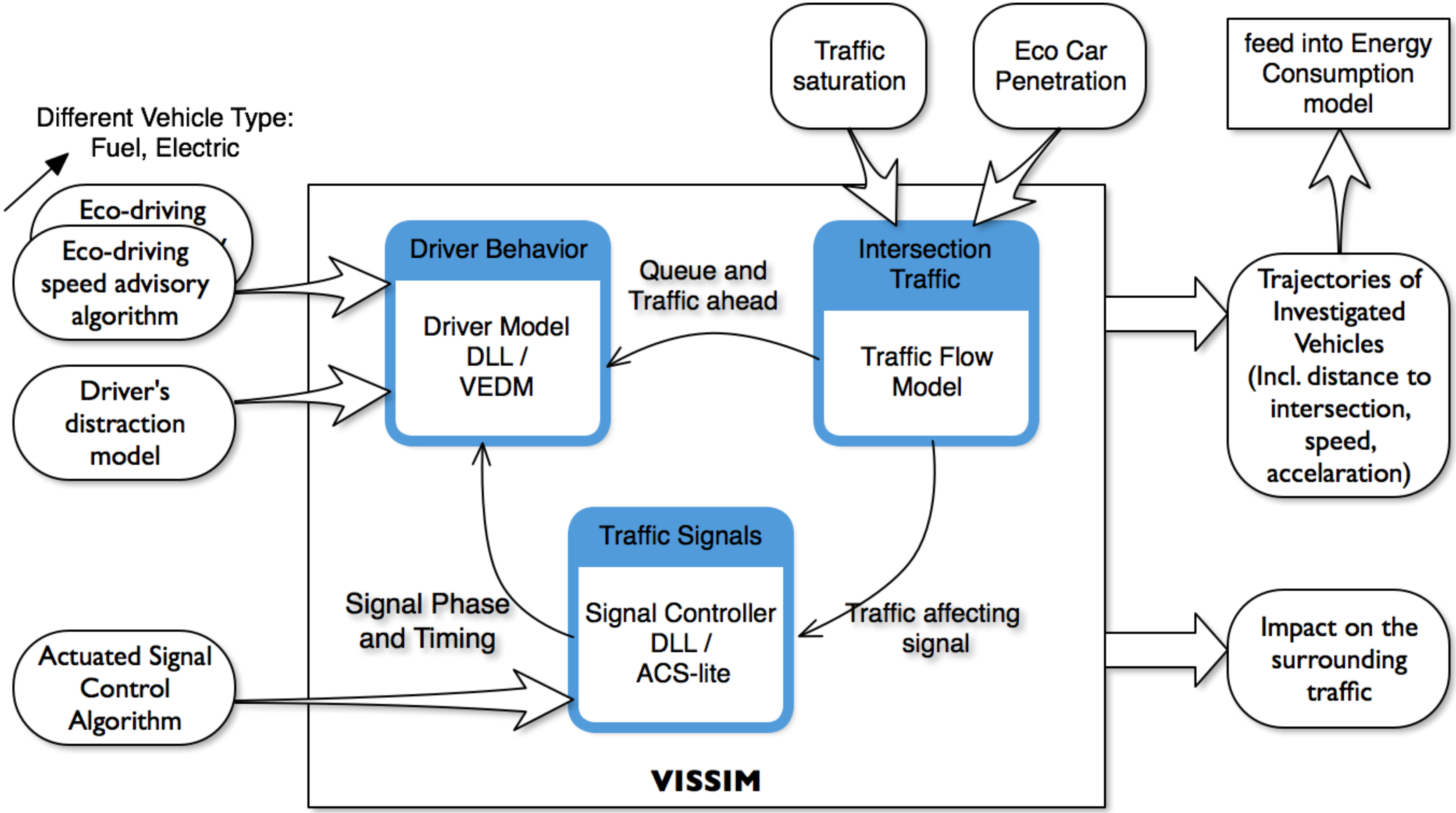
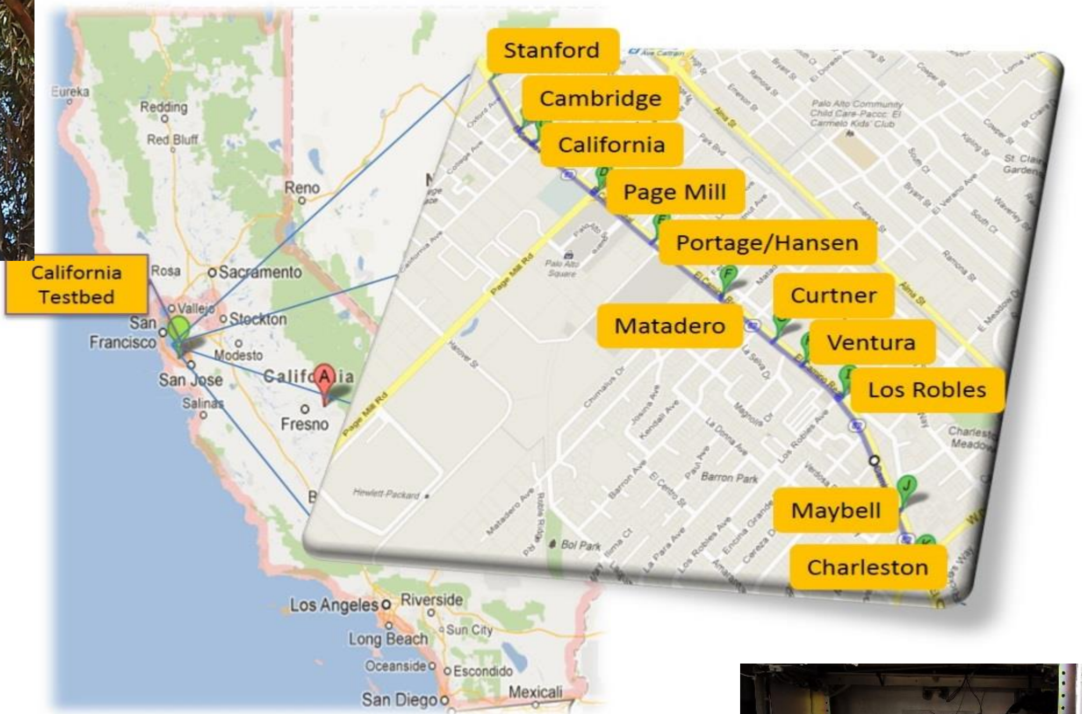


Diagram of Eco-Driving Simulation



FY 19: Field Testing at
CA Affiliated CV Testbed along El Camino Real



Project was not reviewed last year.

Project Two: Energy impact of passenger car Cooperative Adaptive Cruise Control (CACC) and Platooning (PI: Xiao-Yun Lu)

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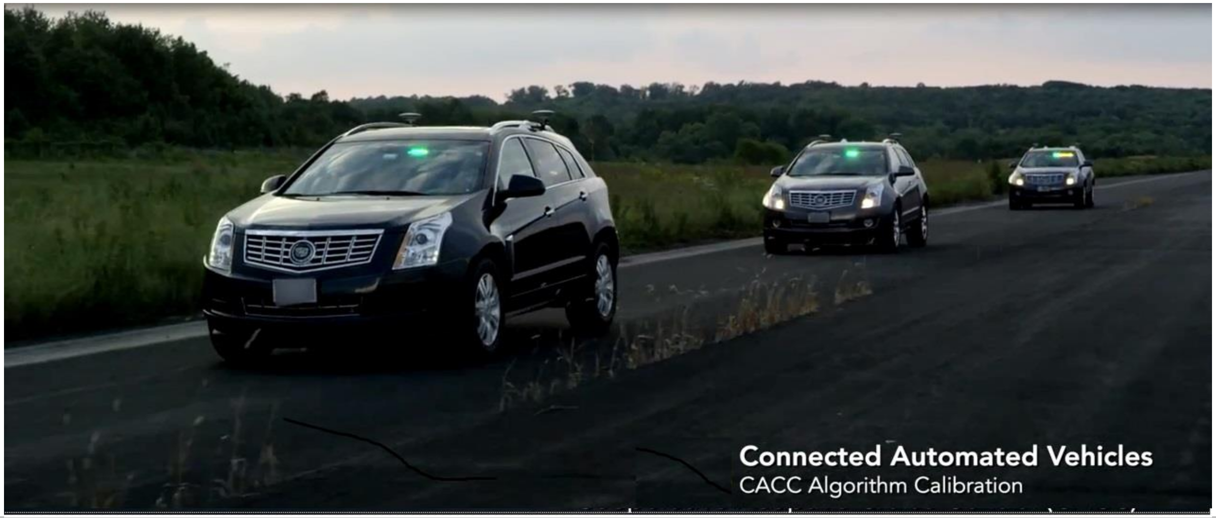
RELEVANCE – FY18

- **Challenges**
  - **The energy impact of passenger car Cooperative Adaptive Cruise Control (CACC) and Platooning can only be determined through physical experiments and should be quantified to highlight two key effects: changes to aerodynamic drag and variations in vehicle speed**
- **Objectives - FY 18**
  - **To investigate the impact of passenger car CACC/Platooning operation on energy saving at freeway speed on test-track**
- **Objectives - FY 19**
  - **To investigate the impact of passenger car CACC/Platooning operation on energy saving at a signalized intersection**

APPROACH – FY18

1. Revising CACC algorithm for full speed range operation (including *Stop&Go*) for 5 CACC vehicle in Saxton Lab
2. Refine CACC strategy for performance improvement and fuel saving
3. Designing test scenarios including CACC, default ACC (of manufacturer) and manually driving
4. Determining the test site and test team
5. Conducting systematic and extensive test on closed test track at freeway speed
6. Fuel consumption analysis: comparing manual driving mode, ACC, and CACC mode using J-Bus fuel rate

APPROACH: Test Facilities – FY18



MILESTONES – FY18

Subtasks / Months	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Revising CACC algorithm for full speed range operation	■	■	■	■	■	■								
2. Refine CACC strategy for performance improvement and fuel saving					■	■	■	■						
3. Designing test scenarios including CACC, default ACC and manually driving			■	■	■									
4. Determining the test site and test team			■	■	■									
5. Conducting systematic and extensive test on closed test track at freeway speed						■	■	■	■	■	■	■	■	
6. Fuel consumption analysis based on test data														■

PROGRESSES – FY18

- FHWA agreed for LBNL project team to use the 5 CACC vehicles of Saxton Lab for the test
- Selected test site:
  - Aberdeen Naval Air Station (tested CACC performance in 2017)
- We will specify the test scenarios and setup data collection mechanism; and the Professional Test Team onsite will conduct the actual tests
- We have developed a preliminary Test Plan and will continue working with FHWA Saxton Lab to finalize it
- Preliminarily coordinated with INL for joint work

COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS – FY18

- **LBNL will take the lead for test and conduct data analysis etc.**
- **INL will support the test in data collection**
- **FHWA Saxton Lab: to provide five passenger vehicles with CACC**

REMAINING CHALLENGES AND BARRIERS

- **To quantify fuel saving benefit for operation of passenger cars with CACC at a signalized intersection through experiments**
- **To use the test data to support the modeling of CACC operation at signalized intersection for simulation in other tasks under SMART**
- **To use the test data to support the calibration of fuel consumption model for CACC passenger car operation at signalized intersection for simulation in other tasks under SAMRT**

OBJECTIVES – FY19

To Test of passenger car ACC and CACC at a signalized intersection

N.B. Any proposed future work is subject to change based on funding levels

RESPONSES TO PREVIOUS YEAR REVIEWERS' COMMENTS

This project was not reviewed last year.

SUMMARY

- **CACC vehicle operation impact on energy saving of passenger car needs extensive testing**
- **To refine the CACC implemented on 5 Cadillac SUV at Saxton Lab**
  - **For full speed range operation including *Stop&Go***
  - **For better fuel consumption**
- **Conducting extensive test at variety of Time/Distance Gaps**
- **Conducting extensive test for some other scenarios**
- **Analysis for energy consumption based CAN Bus fuel rate data**
- **Using to support simulation modeling of fuel consumption modeling**
- **FY 19 (go/no-go)**
  - **Field test of five passenger car CACC operation at a signalized intersection**
- **N.B. Any proposed future work is subject to change based on funding levels**

Questions?