Project ID# eems059
Pillar: CAV

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

Experimental Evaluation of Cooperative Automated Cruise Control (ACC) for Passenger Cars

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2019 Vehicle Technologies Office Annual Merit Review
June 12, 2019

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

OVERVIEW

Timeline

- Project start date: 10/2017
- Project end date: 9/2019
  - Significant ramp-up in late FY18
- Percent complete: ~65%

Budget

- FY19 Funds – $200k LBL
  $250k ANL
  $100k INL
  $550k Total
- FY18 Funds - $370k Total

100% DOE Funds

Highlighted Barriers

- Difficulty in sourcing accurate and traceable real-world data
- Experimental verification and refinement of proposed CAV strategies [need flexible platforms!]
- Realistic mix of vehicles and powertrain topologies (within a CACC string)

Partners

- DOE-SMART consortium researchers
- LBNL, ANL, INL
- UC Berkeley

OVERVIEW

- **This project will develop CACC capabilities for 4 passenger cars with different powertrains, including:**
  - **Lower level torque mapping development**
  - **Upper level Cooperative Adaptive Cruise Control (CACC) development**
  - **Initial control tuning, and refinement at low speed**
  - **On-track testing of developed 4-vehicle CACC for fuel economy impacts of select CACC strategies at high speed**
  - **Resolving any implementation issues related to mixed vehicle performance envelopes and benefits (fast response) & challenges (SOC management and performance) due to electrification.**

RELEVANCE

- **Vehicle control capabilities for CAVs (Connected Automated Vehicles) need to be developed for field test:**
  - **To obtain test data for the modeling of vehicles in microscopic simulation, which will support the simulations at all levels of the SMART workflow**
  - **To test energy consumption and mobility in real traffic or appropriately created (controlled) environment with virtual traffic through real-time simulation**

MILESTONES

Milestone Name/Description	Criteria	End Date	Type
• Q2: CACC system development report/update on realistic operation;	Integrated CACC system including control computer, DSRC, remote sensor, upper and lower level control.	6/30/2019	Quarterly
• Q4: workable CACC system for 4 passenger cars with different powertrains;	Initial track test results for 4 CACC cars.	12/15/2019	Annual
• Q4: multi-vehicle experimental LD CACC platform onto which varying CACC strategies can be validated, refined, and evaluated;	4 cars with CACC capabilities, which can be driven at low and high speed	12/15/2019	Annual

APPROACH

- **Vehicle instrumentation**
  - **lower level interface with CAN Bus**
  - **Install PC-104 Control Computer, GPS, DSRC, …**
- **Developing Torque Mapping**
- **Installing driver for DSRC packet passing**
- **Developing vehicle dynamics modeling and Cooperative Adaptive Cruise Control (CACC)**
- **Control implementation and system integration**
- **Preliminary test on test track, control tuning, high speed field test**

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

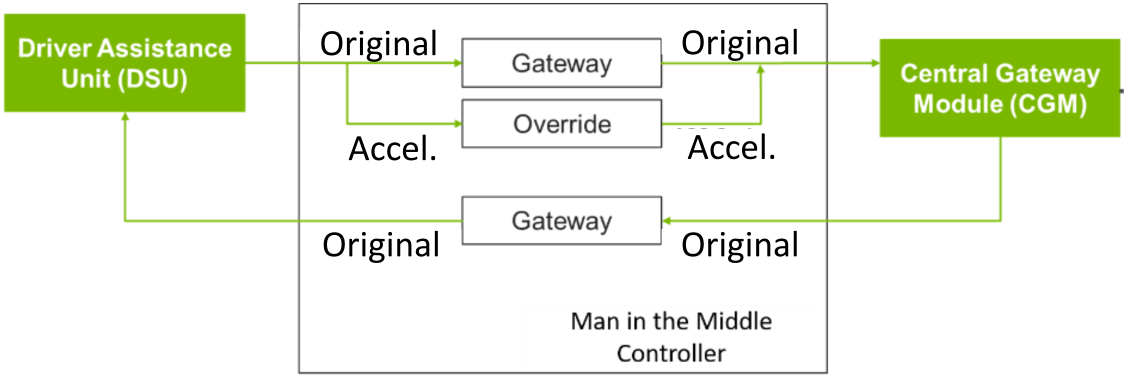
- **ANL accomplished interface and lower level control of vehicle torque response – Toyota Prius Prime (PHEV) @ LBL, other vehicles on-going using same methodology/connections**
  - Ford Taurus (Conv.), Honda Accord PHEV, TBD-BEV

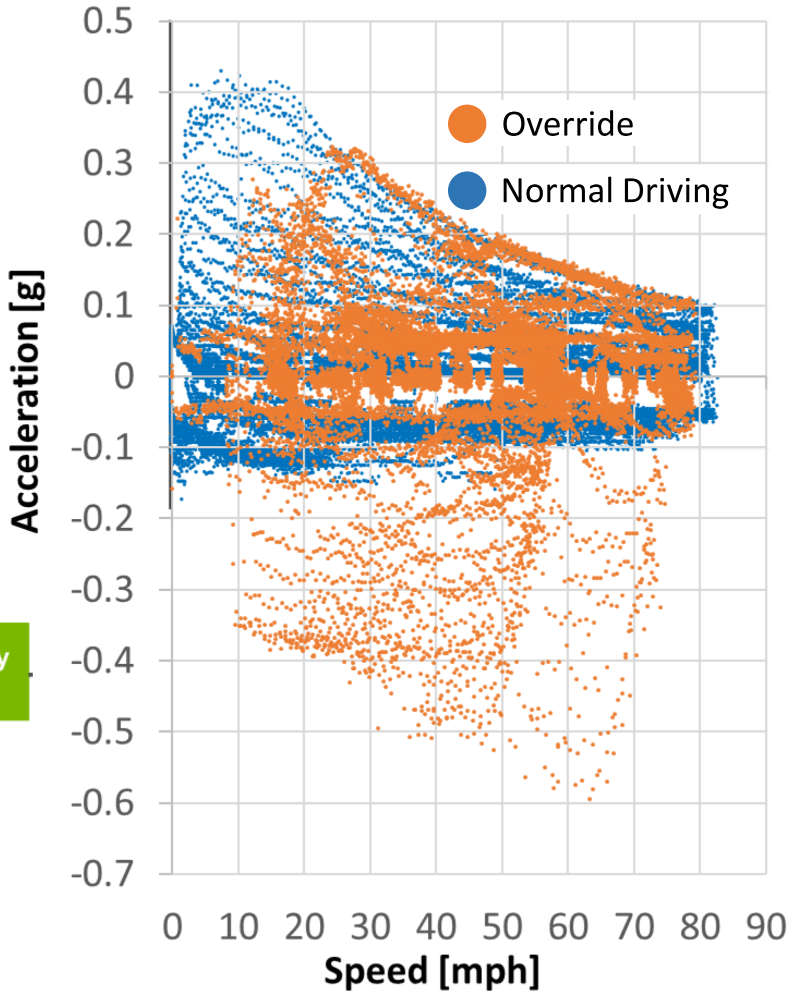
- **LBNL:**
  - **Preliminarily developed PC-104 control computer**
  - **Longitudinal control design**
  - **Preliminarily implemented longitudinal control**
  - **Two control methods implementation**
  - **Preliminary system integration**
  - **Preliminary low test on test track at Berkeley**

Low Level Torque Control

Utilizing Highly Instrumented Vehicles

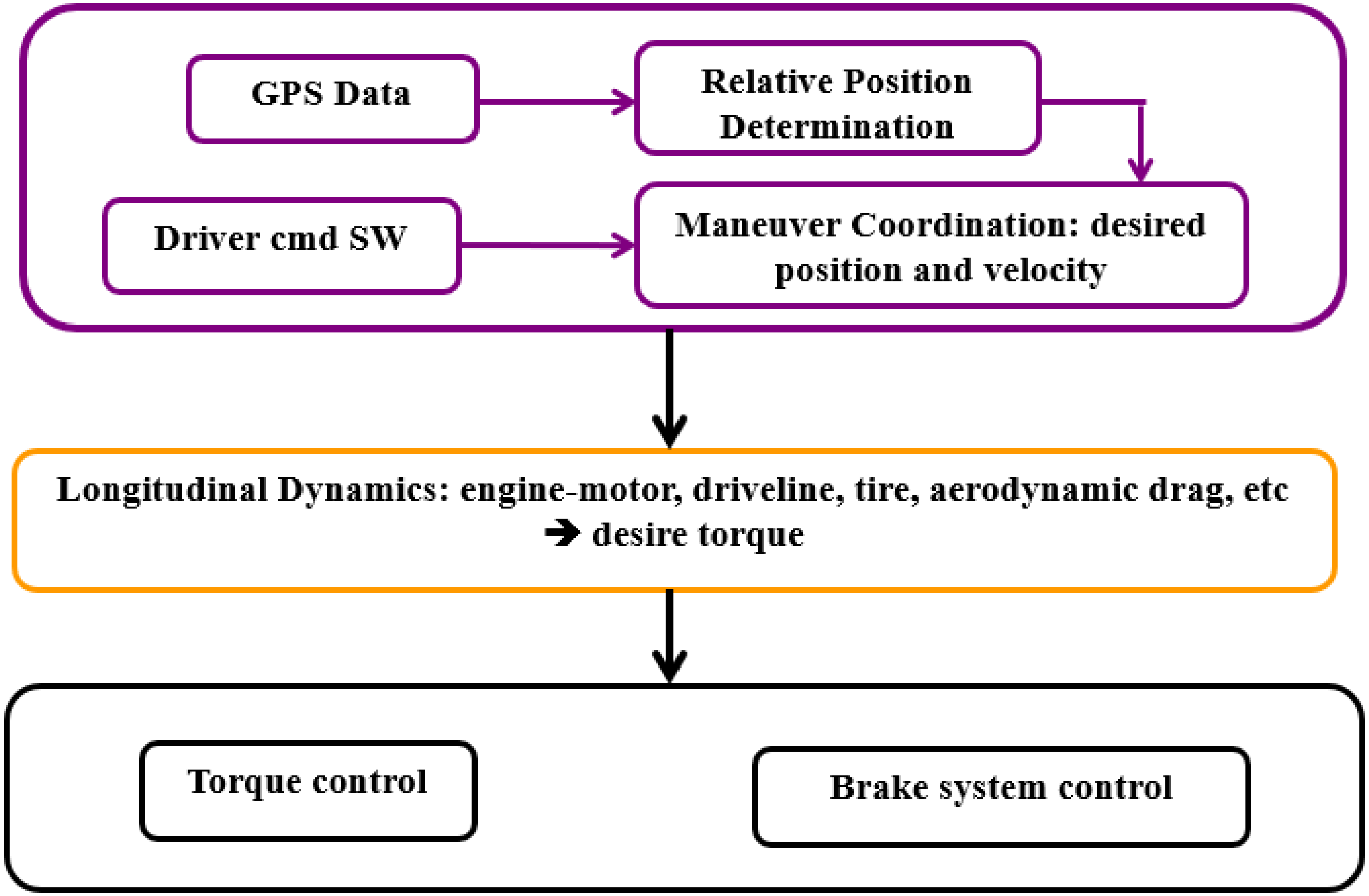
Overriding Vehicle Torque Controls





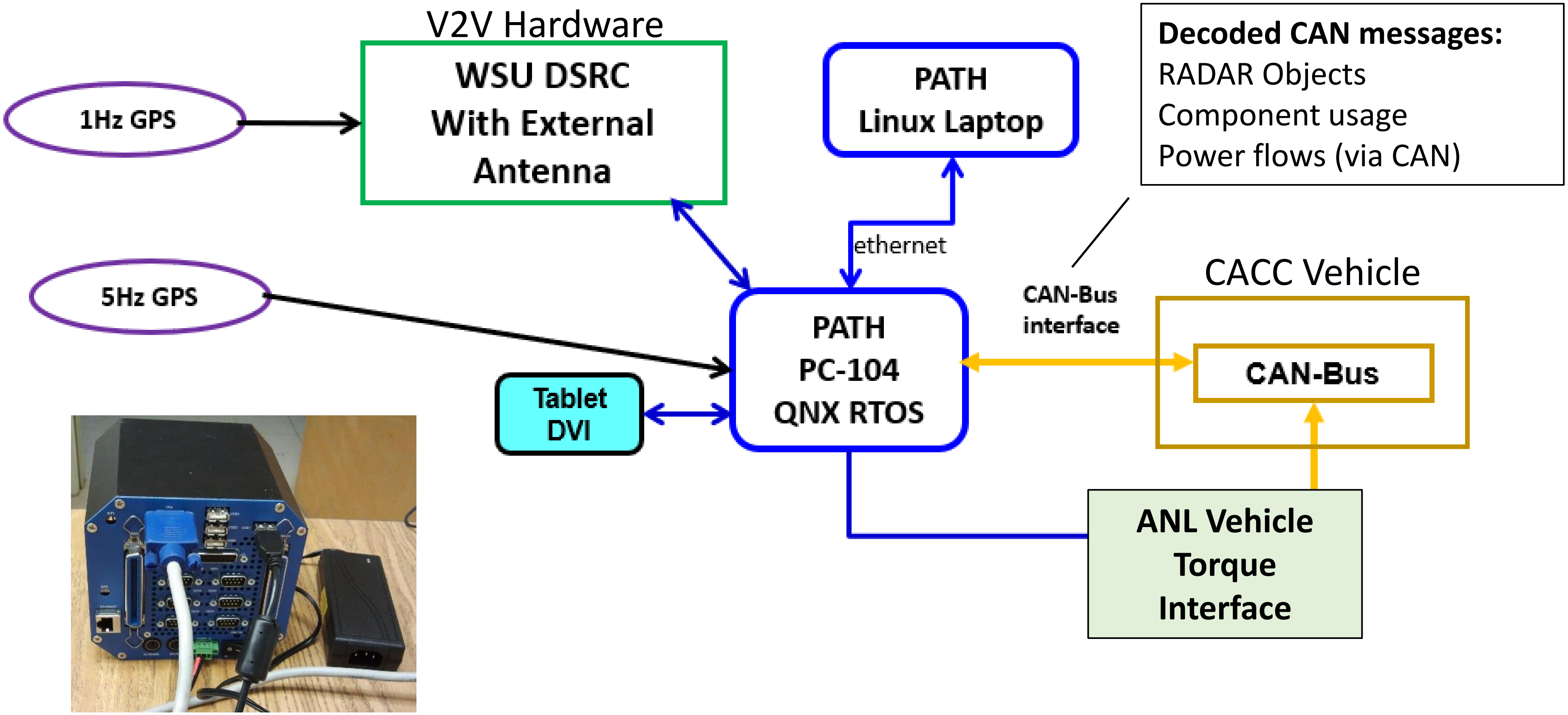
TECHNICAL ACCOMPLISHMENTS AND PROGRESS

CACC System Software Structure



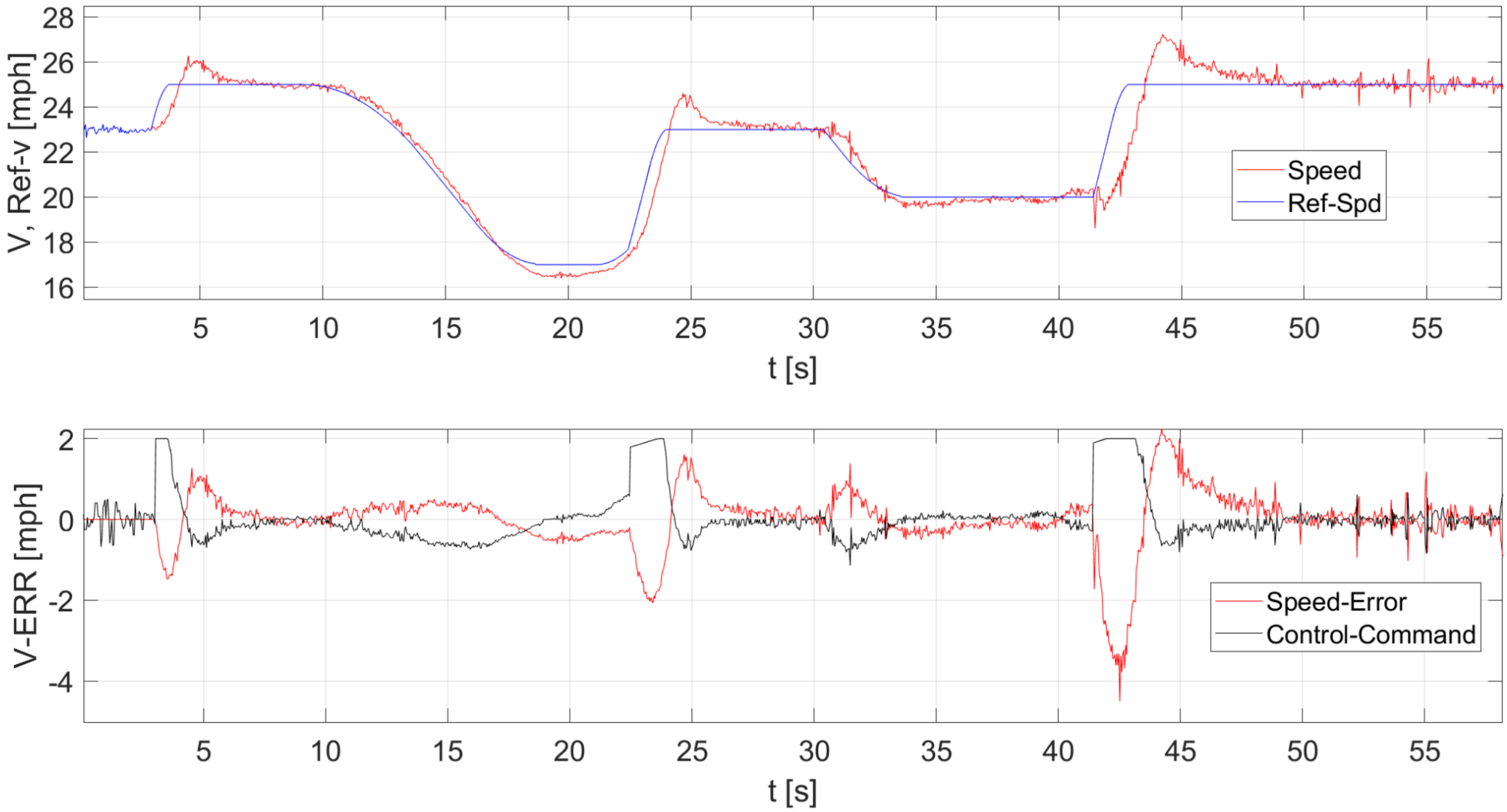
TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Main Data Flow between PATH Computer and Components



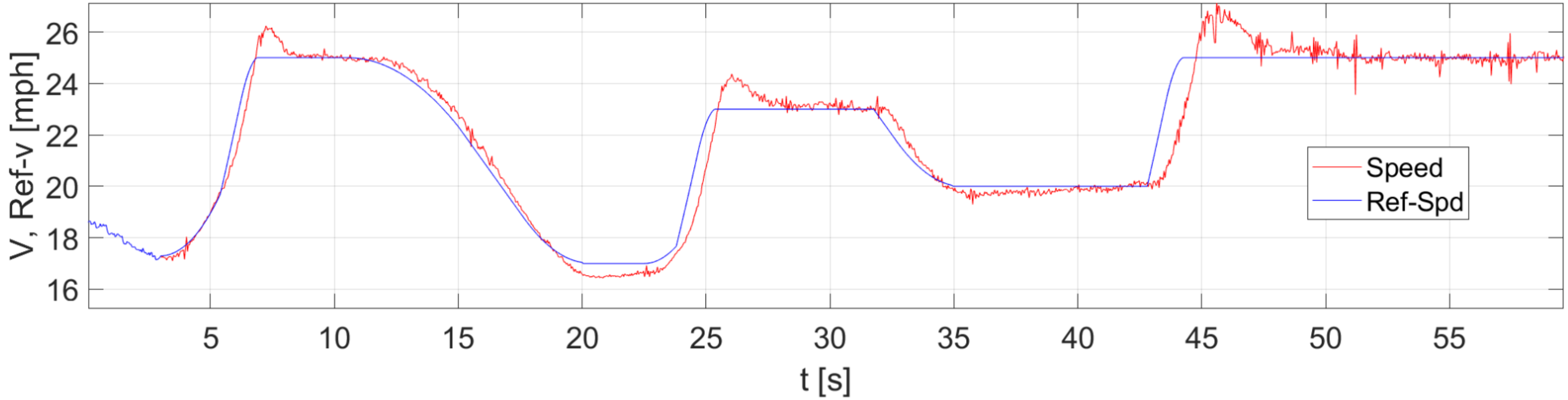
TECHNICAL ACCOMPLISHMENTS AND PROGRESS

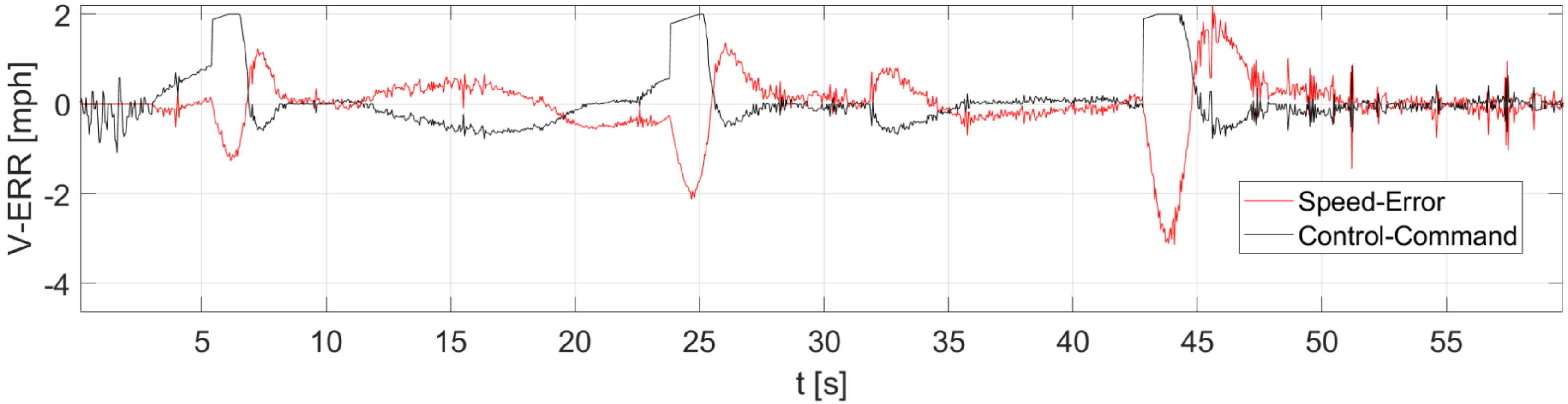
- **Control Method 1: Speed tracking error and control command**



TECHNICAL ACCOMPLISHMENTS AND PROGRESS

- **Control Method 2: Speed tracking error and control command**





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NEXT STEPS

- **Install PC-104 computer**
- **Developing CACC lead-vehicle "Adaptive Cruise Control" [to lead CACC string]**
- **Control tuning**
- **Install DSRC and developing communication packet**
- **Developing 2nd and 3rd car**
- **Design and implement Cooperative ACC (CACC)**
- **Low speed of 2-car CACC**
- **Extend CACC to 3~4 cars**
- **Preliminary field tests**

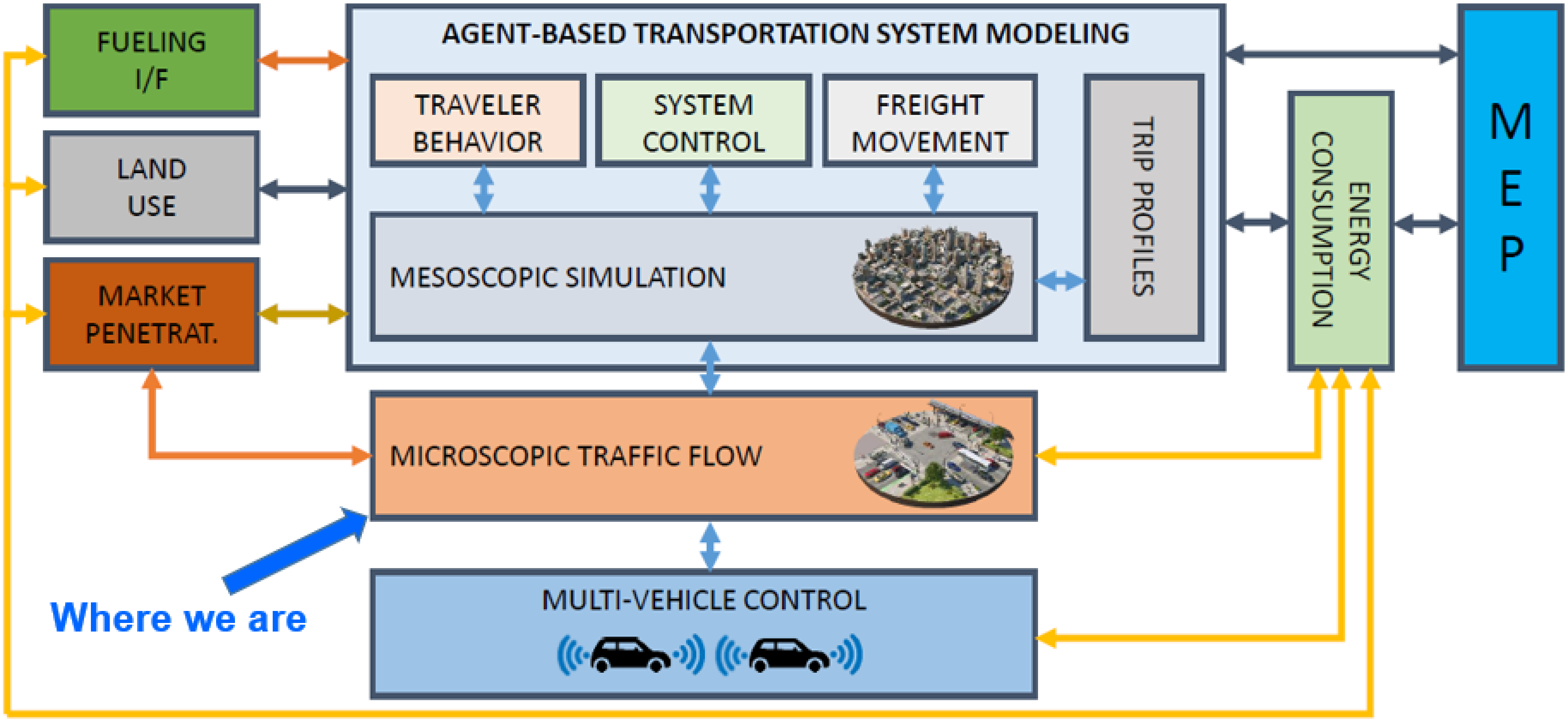
COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS

- **LBNL: Project lead, upper level vehicle control (control computer, DSRC communication, system integration and tuning, initial test, etc.)**
- **ANL: Lower level vehicle interface and torque mapping development**
- **INL: Will participate field test at later stages**

> Data dissemination and platform development for other SMART / DOE researchers

COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS – **Where it Fits in the WORKFLOW**

END-TO-END MODELING WORKFLOW



REMAINING CHALLENGES AND BARRIERS

- **Challenges:**
  - **To overcome and compensate for any possible delays caused by internal vehicle controls and behaviors**

PROPOSED FUTURE RESEARCH
Subject to future funding

- **Extending the CACC capability to more vehicles**
- **Developing other control capabilities including:**
  - **Perception**
  - **Localization**
  - **Lateral (steering) control**
- **Developing other maneuver capabilities:**
  - **Lane keeping**
  - **Lane changing**
  - **Merging from onramp with full coordination with mainline vehicles**
  - **Merging from onramp into mainline mixed traffic with manually driven vehicles (without full coordination)**
- **Integrate lower level active powertrain control with upper level CACC control to further minimize energy consumption while maintaining all require maneuver performances and string stability**

SUMMARY SLIDE

- **CACC is an important component to the CAVs experimental research portfolio**
  - Mobility and efficiency impacts (and sensitivities)
  - Advantages / disadvantages with electrification
- **Progress on both low-level and high-level operational controls on-going and moving towards track testing**
  - Man-in-the-Middle approach for vehicle torque control
  - High-level CACC implementation and development
- **Working towards CACC refinement and impacts experiments in-field with mixed fleet/powertrains**

QUESTIONS?