EEMS076
Pillar: Mortar

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

Workflow to Simulate Connected and Automated Vehicle Control under Realistic Traffic Conditions

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2019 DOE Vehicle Technologies Annual Merit Review - June 2019

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

Project Overview

Timeline

- Project start date : Jan. 2019
- Project end date : Sep. 2019
- Percent complete : 20%

Budget

- FY19 Funding (ANL): $285,000
- FY19 Funding (LBNL): $90,000

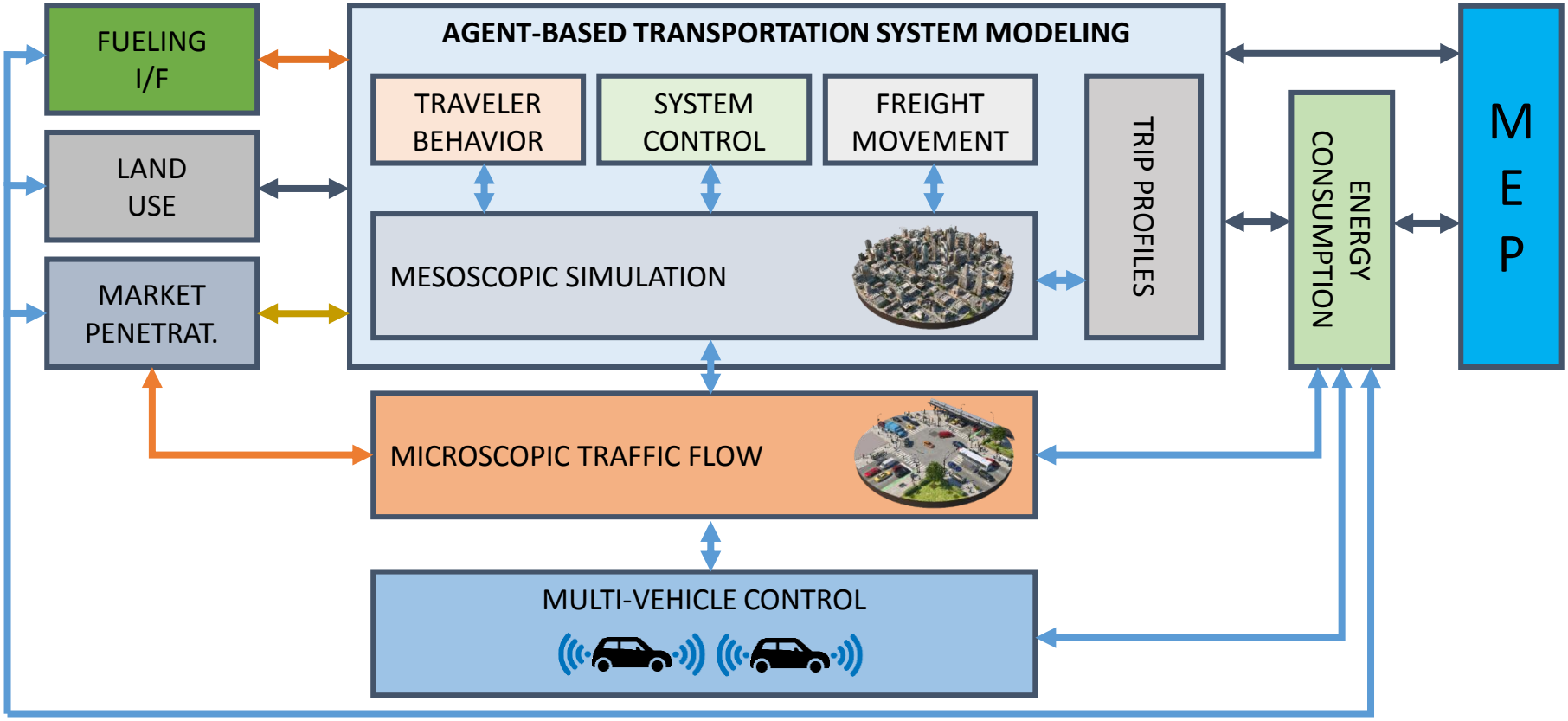
Partners

- Argonne: Vehicle-centric simulation
- LBNL: Traffic-flow simulation

Barriers

- Tools for vehicle-centric eco-driving research:
  - do not take into account traffic well
  - do not evaluate traffic flow impacts
- Traffic flow simulation tools use simplified vehicle models, limiting usability for in-vehicle implementation

Objectives & Relevance: Enable SMART Workflow



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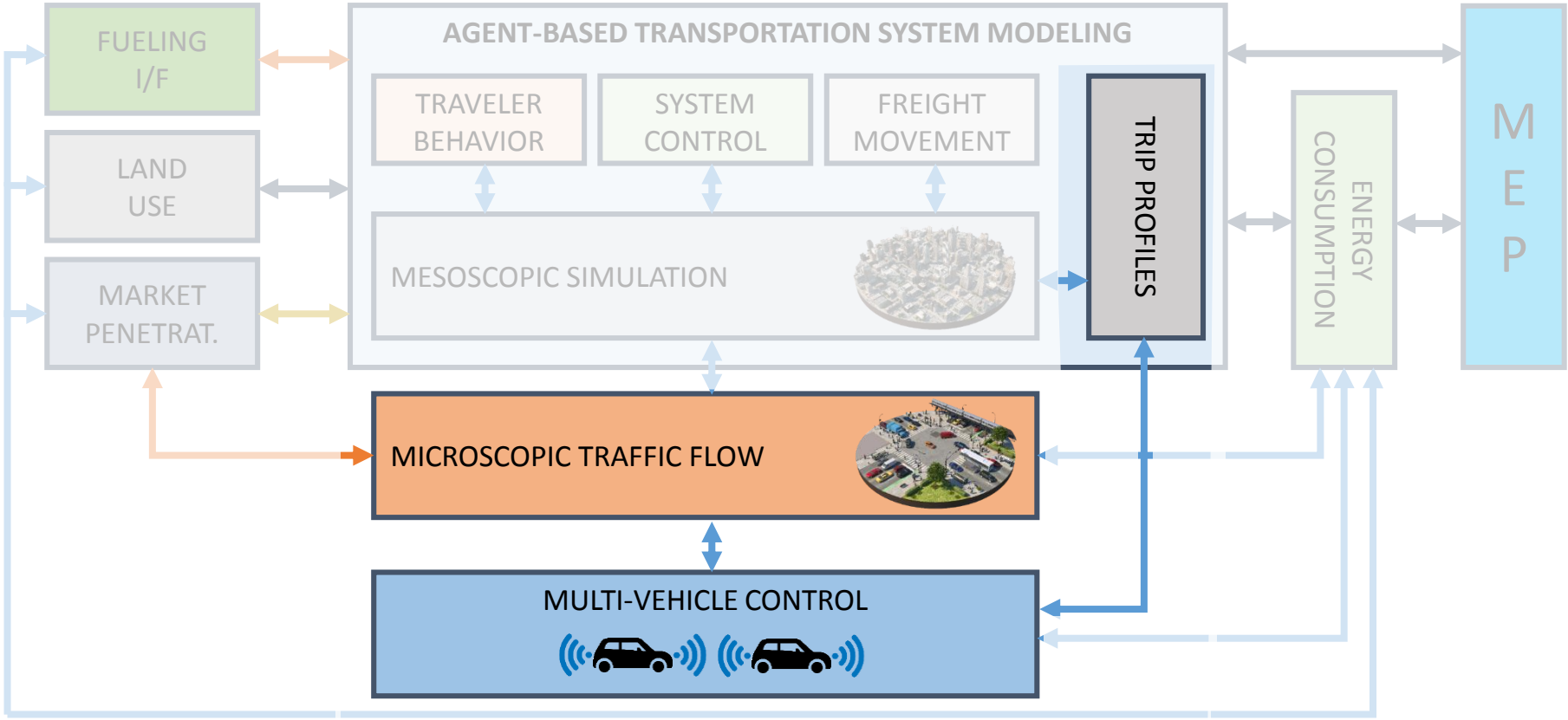


Approach – Link Tools Used in SMART: RoadRunner with SVTRIP and Aimsun

POLARIS

Transportation System Simulation
Developed by ANL

Travel time

Road attributes: speed limit, grade, traffic lights, etc.

SVTRIP

Data-Driven Vehicle Speed Generation
Developed by ANL

Traffic via speed target

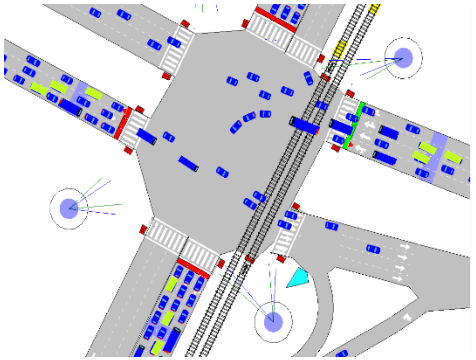
ROADRUNNER

Multi-Vehicle Powertrain and Driving Dynamics for CAVs
Developed by ANL

Traffic conditions

Compiled Vehicle

aimsun.



Traffic flow micro-simulation
Commercial tool
Customization/Calibration by LBNL

Travel time

Road attributes: speed limit, grade, traffic lights, etc.

here

Digital Maps
Commercial tool

Milestones

2019Q3	**On Track**
Demonstrate linkage between RoadRunner and SVTRIP	

2019Q4	**On Track**
Demonstrate linkage between RoadRunner and traffic flow microsimulation tool	

Accomplishments

Simulation of Driving and Traffic: Need Linkages between Tools

	SVTriP	RoadRunner	Micro-simulation
Focus	"Drive cycle" generation	Powertrain and driving dynamics	Traffic flow, density, traffic control
Inputs	Mesoscopic description of road segments for the trip, incl. travel time (i.e. "traffic")	Mesoscopic description of road segments for the trip	Detailed road network configuration Vehicle inflow/outflow levels
Number of vehicles	1	~10	~1000
Geography	Entire trip	Entire trip	Corridor/small network
Traffic	Input (high-level/travel time) Output (1Hz speed)	N/A	Full dynamics modeled
Scenario building	Easy	Easy	costly
Driver Model description	Data-driven / Statistical	"Physical" driver (open-road, car-following)	"Physical" driver (open-road, car-following, lane-change)
Use cases	Energy consumption for trips	Vehicle control (speed, powertrain)	Traffic flow optimization

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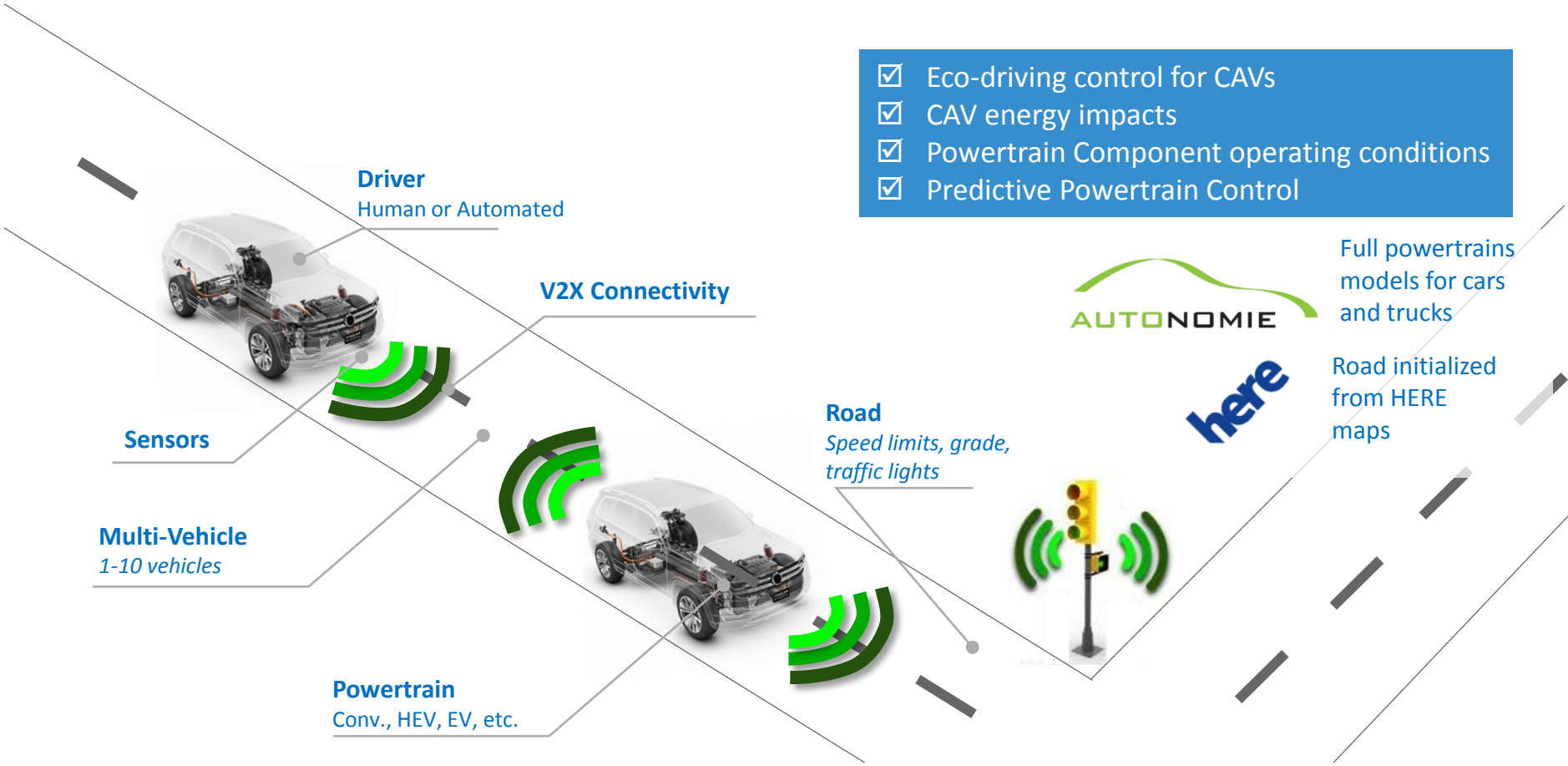
Traffic is not modeled in RoadRunner!

ROAD RUNNER

Simulation of Powertrain and Driving Dynamics for Connected and Automated Vehicles

- ☑ Eco-driving control for CAVs
- ☑ CAV energy impacts
- ☑ Powertrain Component operating conditions
- ☑ Predictive Powertrain Control



AUTONOMIE

Full powertrains models for cars and trucks

here

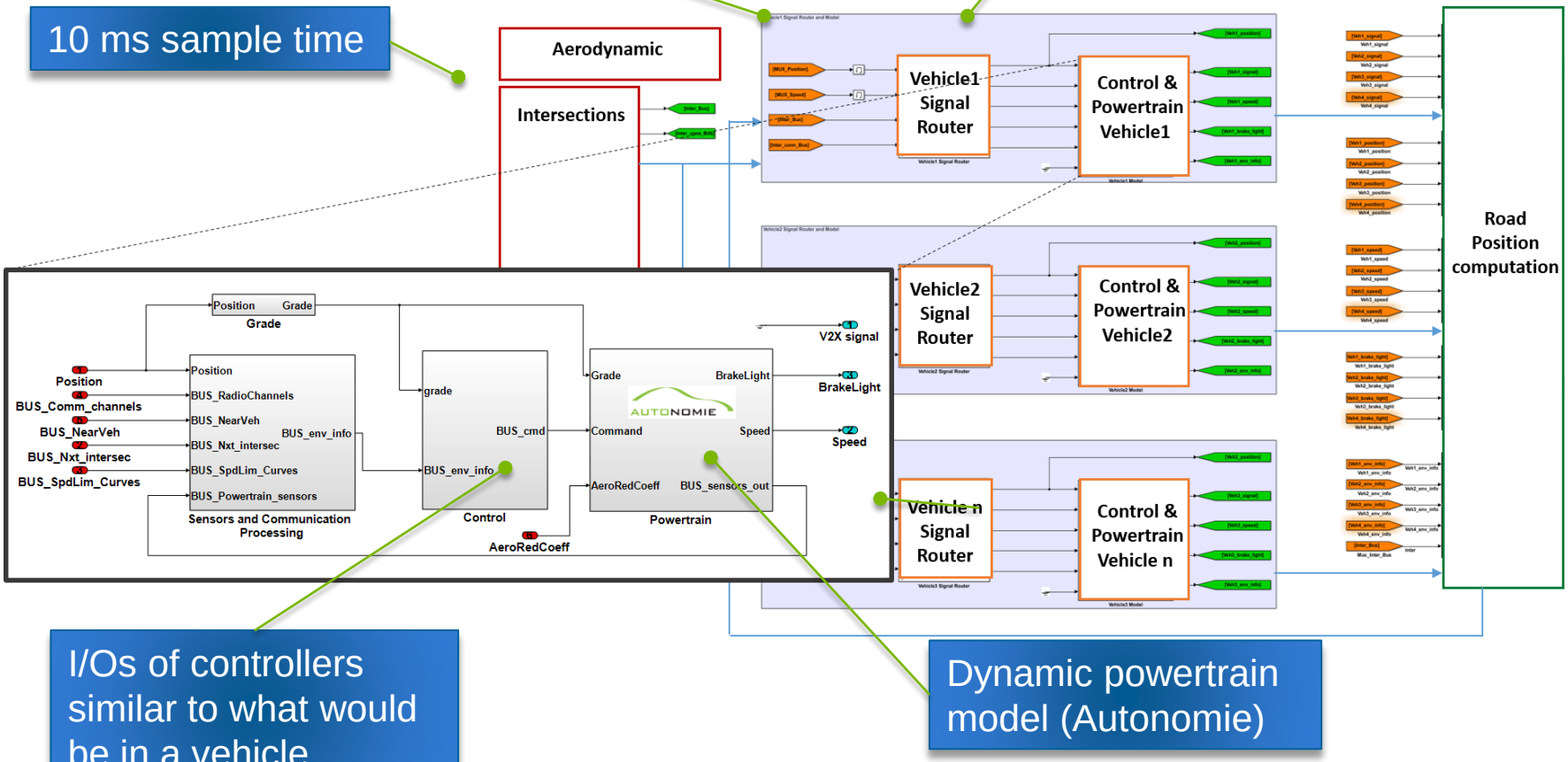
Road initialized from HERE maps

RoadRunner Designed for CAV Eco-driving Control Development

Simulink-based simulation framework

Multi-Vehicle

10 ms sample time



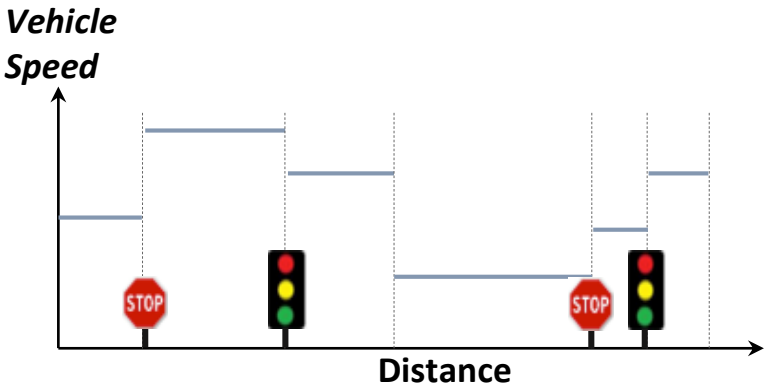
I/Os of controllers similar to what would be in a vehicle

Dynamic powertrain model (Autonomie)

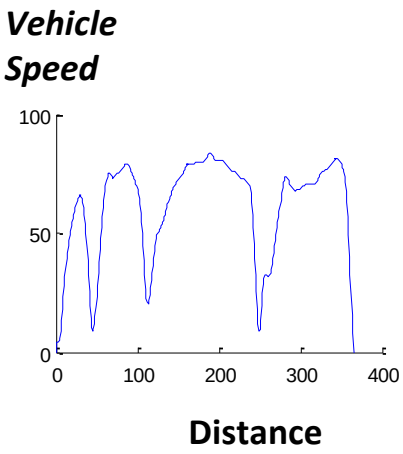
SVTriP Generates Naturalistic Speed Profiles

Generate trip in transportation simulator or define in digital map

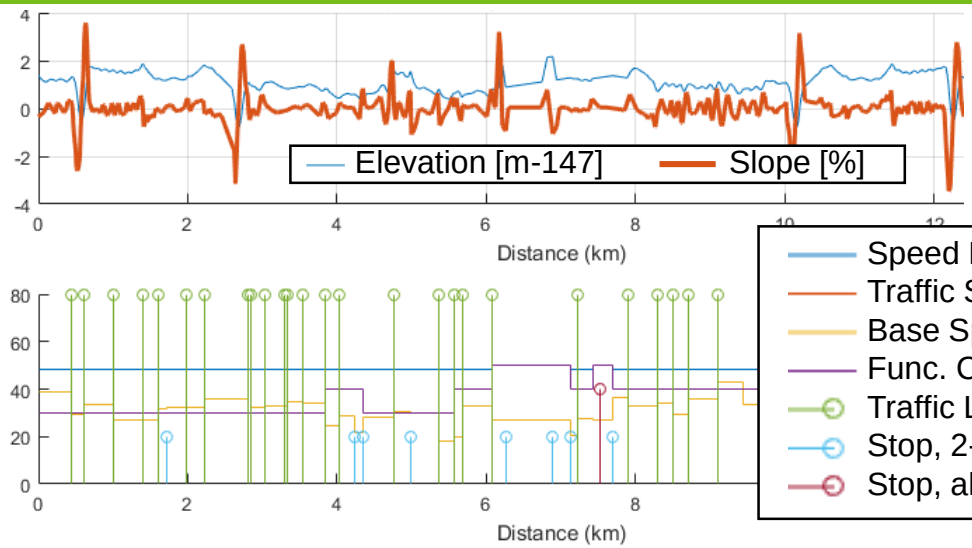
Segment-by-segment trip characteristics: speed limit, average speed, stops, etc.



SVTriP generates a naturalistic 1 Hz speed profile for that trip



Example of a Naturalistic Speed Profile Generated from SVTRIP



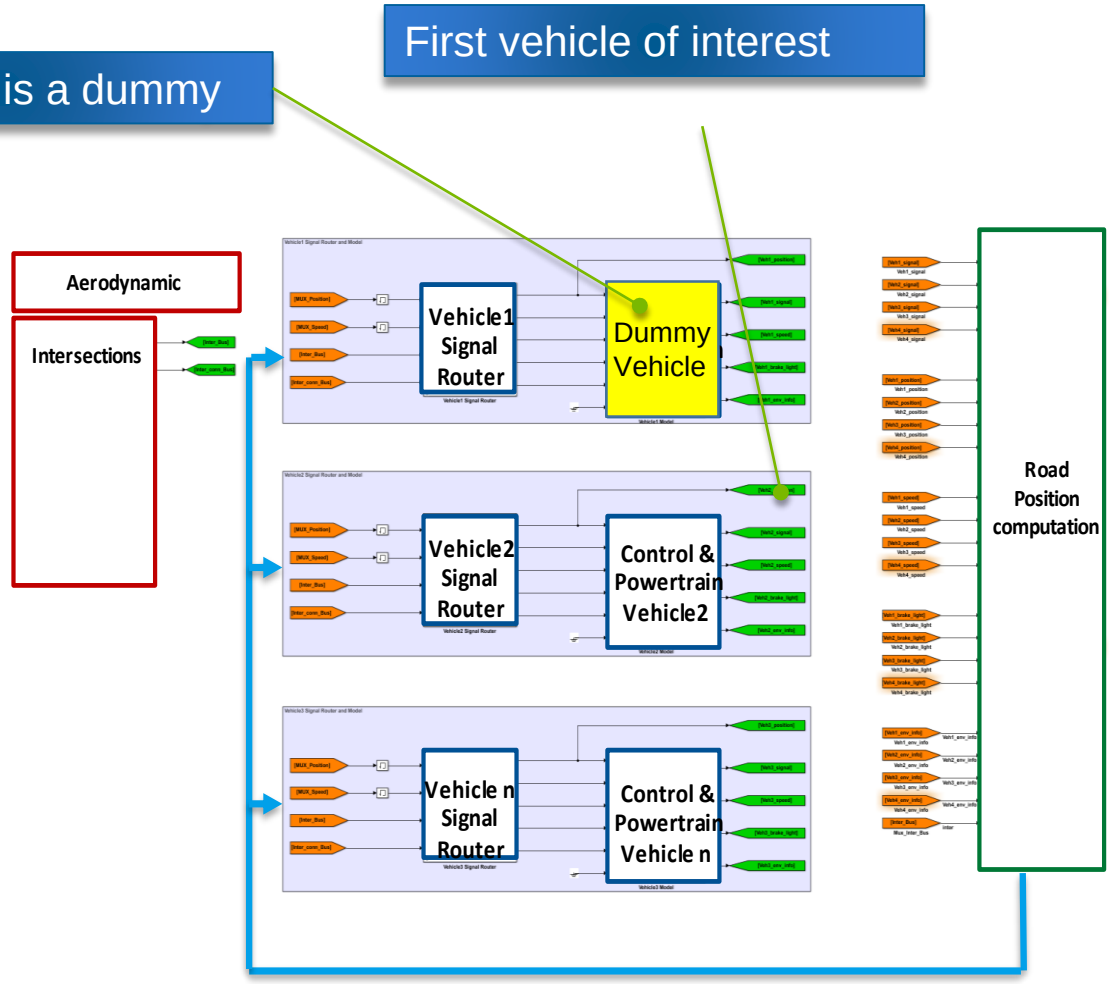
Segment-by-segment attributes

The output models real-world traffic:

- Matches travel times in traffic, provided as inputs (from HERE or POLARIS)
- Data-driven approach replicates real-world speed transitions

Integrating RoadRunner and SVTRIP through Dummy Vehicle

- Lead vehicle is a “dummy” that represents traffic
- During one simulation, dummy may represent multiple vehicles: all the vehicles that precede vehicle 2 (vehicle of interest)
- Dummy speed:
  - From SVTRIP away from intersections
  - From baseline model around intersections to obey traffic light state.



Integrating a RoadRunner Vehicle in Aimsun

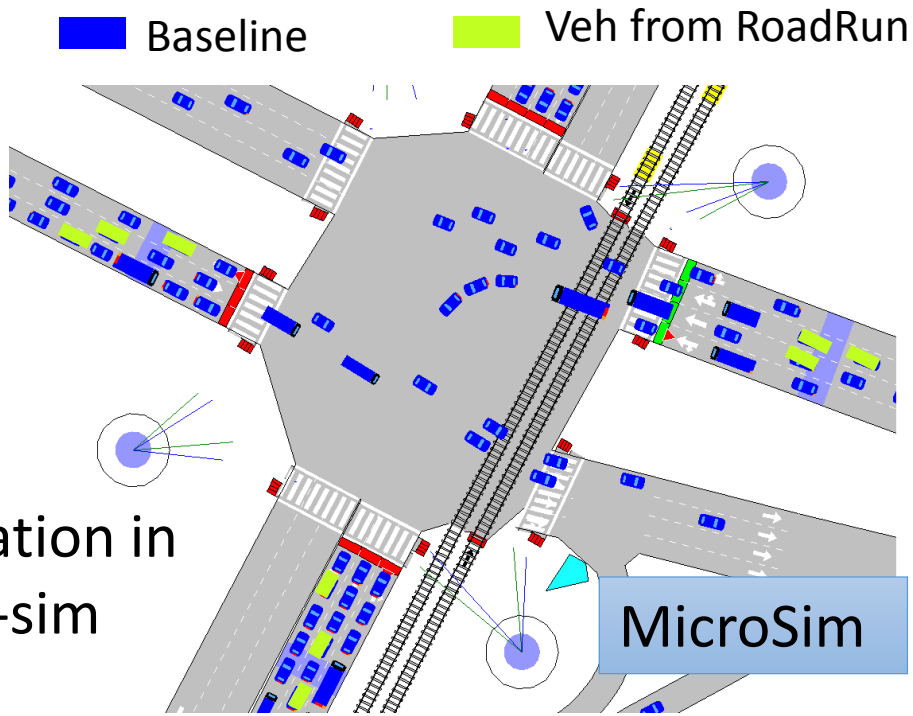
RoadRunner

I/O formating

Integration w/ lane change control

Compiling into dll

Simulation in Micro-sim



Closing Remarks

Response to Previous Year Reviewers' Comments

New Project

Partnerships and Collaborations

BERKELEY LAB	LBNL develops and runs models of real-world network traffic in Aimsun;
Argonne NATIONAL LABORATORY	ANL develops RoadRunner and SVTRIP

Remaining Challenges and Barriers

- **Compilation of RoadRunner Models**
  - Adjustments to the model need to be made to allow “hands-free” compilation
- **Integration of controls from mixed sources:**
  - RoadRunner: longitudinal speed control
  - Aimsun: lateral speed control

Proposed Future Research*

- **RoadRunner**
  - Complete compilation compatibility
  - Create input and output blocks compatible with Aimsun
  - Create dummy lead vehicles (for Aimsun and SVTRIP linkages)
- **Aimsun**
  - Develop wrappers in Aimsun API to accommodate RoadRunner
  - Simulate various scenarios using RoadRunner vehicles with various levels of penetration
- **SVTRIP**
  - Create a process to generate speed traces with and without stop for each traffic light intersection

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

Summary

- We are working on:
  - Developing a process to transfer a RoadRunner vehicle to micro-simulation
  - Linking RoadRunner and SVTriP for traffic conditions simulation
- This project will add traffic conditions considered through lead vehicle speed trace, generated from map data with traffic conditions and stochastic vehicle trip profile generation tool (SVTriP)
- Thanks to the linkage with Aimsun, we will be able to evaluate the impact of control strategies on traffic flow

Technical Back-up Slides

REVIEWER-ONLY BACK-UP SLIDES

Critical Assumptions and Issues

- Critical assumptions:
  - Traffic conditions can be represented through SVTRIP
  - Aimsun provides capability to use compiled Simulink models
- Issues:
  - Long time (3 months) to procure a license of Aimsun for Argonne