INL/MIS–18-50203

Project ID: EEMS046

U.S. DEPARTMENT OF ENERGY

SMARTMOBILITY

Systems and Modeling for Accelerated Research in Transportation

Understanding Connected and Automated Vehicles in Automated Mobility Districts

PI: Matt Shirk

Annual Merit Review and Peer Meeting

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

HPC4Mobility & Big Transportation Data Analytics

Core Evaluation & Simulation Tools

Advanced Fueling Infrastructure

Connected & Automated Vehicles

Urban Science

SMART MOBILITY LAB

CONSORTIUM

7 labs, 30+ projects, 65 researchers,
$34M* over 3 years.

Mobility Decision Science

Multi-Modal Transport

*Based on anticipated funding

OVERVIEW

Timeline

Start: 10/1/2017

End: 9/30/2018

Complete: 45%

Barriers Addressed

- Difficulty in sourcing empirical real-world data applicable to new mobility technologies such as connectivity and automation
- Accurately measuring the transportation system-wide energy impacts of connected and automated vehicles
- Computational difficulty of accurately modeling and simulating large- scale transportation systems

Budget

FY 2017: $0

FY 2018: $100k INL, $50k NREL

Partners

- Idaho National Laboratory (Lead)
- National Renewable Energy Laboratory
- University of Michigan
- SUNY University at Buffalo & NYSERDA

RELEVANCE

The automated mobility district (AMD) is a popular concept for enabling early deployment of CAVs, with automated vehicles deployed in proof-of-concept testing in the U.S. and Europe. These pilots present opportunities to understand vehicle usage and energy consumption by CAVs operating in AMDs, relevant to the **EEMS Mission** to **conduct early-stage R&D at the vehicle, traveler, and system levels, creating new knowledge, tools, insights, and technology solutions that increase mobility energy productivity for individuals and businesses.**

Project Objectives	EEMS Barrier Addressed
Identify automated vehicle pilots in AMDs for testing in advance of commercial rollout	Rapid evolution of vehicle technologies and services enabled by connectivity and automation
Characterize energy consumption & develop stochastic models	Difficulty in sourcing empirical real-world data applicable to new mobility technologies such as connectivity and automation
Provide results to simulations tasks to improve understanding of infrastructure needs and energy savings	Accurately measuring the transportation system-wide energy impacts of connected and automated vehicles

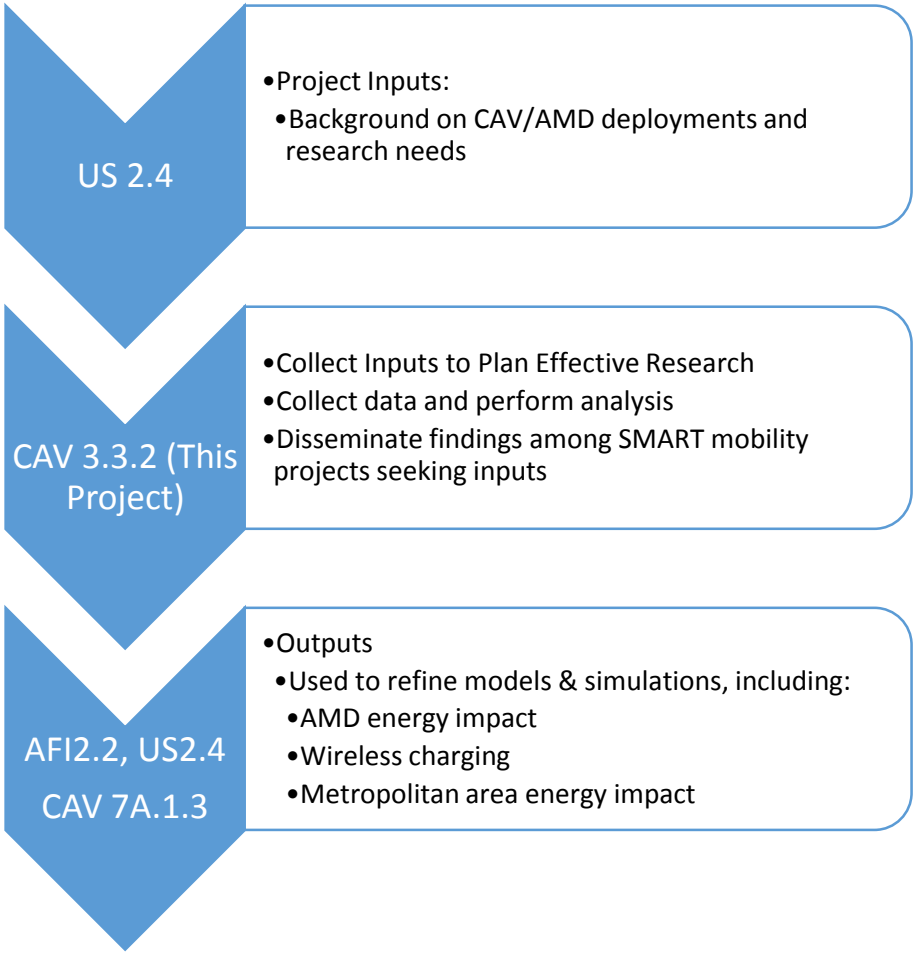
MILESTONES

Past milestones were completed and reported on-time, and upcoming milestones are on track for timely completion

Fiscal Year	Date	Description	Status
2018	3/31/2018	Q2 Progress Report: AMD/CAV Pilots Identified	Complete
2018	6/30/2018	Q3 Progress Report: Test Plan and Partnerships Developed	On-Track
2018	9/30/2018	Annual Report on Energy Consumption Characterization	On-Track

APPROACH

- In coordination with Urban Science Pillar Task 2.4, review planned AMD projects in the U.S. and abroad to identify early CAV/AMD deployments
- Partner with external organizations developing AMDs to instrument and collect data from early CAVs being used in AMD pilots
- Characterize vehicle energy attributes providing key performance metrics of to Urban Science and Advanced Fueling Infrastructure pillar tasks which can further accurate simulation to compare to baseline



TECHNICAL ACCOMPLISHMENTS AND PROGRESS

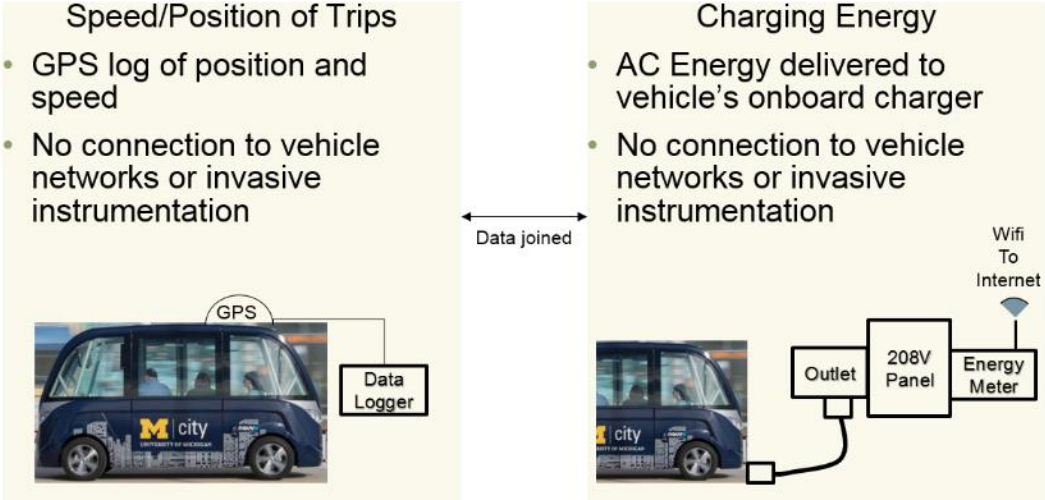
- Several CAV pilots were identified and contacted with partnership inquiries
- First/Last mile automated electric shuttles were identified as offering data collection partnership opportunities in FY-2018

Location	Contacts	Vehicles
University of Michigan, Ann Arbor, MI	Director of Mcity at Umich and Mcity Lab Director	(2) Navya Arma shuttles
SUNY University at Buffalo, Buffalo, NY	Clean Transportation Project Manager at NYSERDA and Professors at SUNY UB	(1) Olli shuttle
Bishop Ranch business park, San Ramon, CA	Executive Director of Contra Costa Transportation Authority	(2) EasyMile EZ10 shuttle
Peña Station NEXT, Denver, CO	EasyMile North America staff and NREL researchers	TBD
Babcock Ranch, FL	Transdev	(1+) EasyMile EZ10 shuttle
Las Vegas, NV	Keolis North America	(1) Navya Arma shuttle

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Automated Electric Shuttle Characterization (University of Michigan example shown)

- INL collecting the charging data from two NAVYA AES vehicles
  - Data collection hardware has been installed as of early April 2017
- U of M researchers collecting high-fidelity vehicle travel data & passenger data
- Joined shared data sets will provide trip level energy consumption data over a range of operating conditions for analysis, yielding stochastic energy consumption models



AES vehicle and charger data collection schematic, showing University of Michigan's shuttle pilot as an example

AES charging station energy metering equipment installed at University of Michigan's Mcity

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Energy and Route Logging

- Instrumentation packages prepared for field deployments
  - Charging hardware energy meters with remote networked data access
    - Meter accuracy of <0.5% verified using NIST-traceable instrumentation
  - 10hz GPS interfaced to CAN data loggers
    - Allows for simple expansion of data collection to vehicle networks if/when available

Vehicle side data logging hardware: serial-to-CAN gateway, CAN logger, and 10hz GPS receiver and antenna

Charger side data logging hardware: current transformers, networked energy meter and data logger, and cellular modem

RESPONSES TO PREVIOUS YEAR REVIEWERS' COMMENTS

This is a new project for FY-18, and has not been reviewed in past years

COLLABORATION

AMD/AES Data Collection Partnership Agreements Being Developed:

- University of Michigan
  - AES pilot with riders on campus route
- SUNY University at Buffalo will collaborate with INL to collect energy-centric data per discussions with NYSERDA project management
  - NYSERDA funded the majority of the AES purchase
- Bishop Ranch AES pilot is interested in collaboration with INL to collect AES energy data, per early discussions with Contra Costa transportation authority
  - No decision has been confirmed yet

Sharing of collected data and analysis results offered as in-kind contribution back to pilot projects bearing high costs(~$300k per shuttle + operation costs)

- Incentive to allow valuable field data collection with limited resources

Three models of Automated Electric Shuttles will be characterized across various climates and operating scenarios, enabled by collaborations

REMAINING CHALLENGES AND BARRIERS

Sub-Trip and Sub-System Power & Energy Data Challenges:

- Collection of time-series power & energy data requires access to vehicle networks and/or physical instrumentation
- This more invasive level will be proposed following development of INL & pilot partner relationships
  - May require OEM buy-in in addition to owner agreement
  - Some OEMs strictly won't allow connection to vehicle data bus

Diversity in CAV Architecture Challenges:

- The three models identified for the ongoing work are similar; ~10 passenger low speed automated electric shuttles
- A larger range of vehicle classes is sought, but limited vehicle types have been deployed in AMD environments

PROPOSED FUTURE RESEARCH

FY 18 Upcoming Research

- Continue to develop field data collection partnerships and hardware deployments
- Merge vehicle and charging data, and analyze the results to form stochastic energy consumption models
- Further refine analyses to best inform cross-pillar SMART Mobility projects

Out-Year Related Future Research Needs

- Perform testing of AES vehicles in lab and on-road to better understand the proportion of energy consumed by sub-systems
- Characterize the energy attributes of additional CAV topologies operating in diverse conditions and environments
- Investigate the effect on CAVs operation when surrounded traditional vehicle traffic, since this mixed-technology scenario will dominate for the foreseeable future

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

SUMMARY

- Energy and travel data are being collected from field-deployed hardware at several Automated Electric Shuttle pilots with diverse operating climates and road-links
- Trip-level energy intensity will be calculated and characterized relative to operating conditions, route attributes, and longitudinal vehicle dynamic data
- External partners are crucial to collection of this data, and are provided access to the data collected through their pilots and research insights to support energy efficient development of their transportation systems
- Dissemination of results across SMART mobility pillars supports development of new tools to better understand and ultimately improve energy efficient mobility

TECHNICAL BACKUP SLIDES

SMART MOBILITY PROJECT QUAD CHART

TASK: 7A.3.3.2 Understanding CAVs in Automated Mobility Districts
PILLAR: CAVs **PI:** Matt Shirk (INL)

Objectives:

The automated mobility district (AMD) is a popular concept for enabling early deployment of CAVs, with vehicles deployed in proof-of-concept testing in the U.S. and Europe. This presents an opportunity to understand vehicle usage and energy consumption profiles by CAVs operating in AMDs. The objectives of this task are to:

1. Identify vehicle use cases in AMDs for testing
2. Characterize CAV energy consumption in these use cases
3. Provide findings to simulation tasks to improve estimates of energy impacts

Approach:

- In coordination with Urban Science Pillar Task 2.4, review planned AMD projects in the U.S. and abroad to identify early CAV/AMD deployments
- Coordinate with external partners developing AMDs to instrument and collect data from early CAVs being used in actual AMDs
- Characterize vehicle energy characteristics (i.e. sensor/computational power, energy storage size, etc.) providing key performance metrics of to Urban Science and AFI Pillar tasks which can further accurate simulation to compare to baseline

Task Summary

New/Continuing:	Continuing – revised data collection task
Proposed Funding:	**$150k**
Lead Lab:	INL
Other Participants:	NREL
Interdependencies:	**Requires outputs from:** Urban Science pillar task 2.4 **Provides inputs to:** AFI 2.2 and CAVS 7A.1.3
Models / Tools:	
Priority:	Important

Milestones/Deliverables:

- Q2: AMD or surrogate AMD scenarios identified
- Q3: Test plan and partnerships developed
- Q4: Testing results
- Annual: Report on use cases and energy characterization

Outcomes/Impact:

- Provide automated vehicle use data and vehicle characteristics to AFI Task 2.2 to enable accurate vehicle fuel selection and fueling infrastructure requirements definition
- Provide vehicle characteristics back to Urban Science Task 2.4 and external AMD developers for their AMD planning
- Establish foundational data set for CAVs pillar modeling efforts (CAV 1.3) addressing CAVs energy impact assessment in agent based modeling

Proposed Budget ($k):

Lab	FY16	FY17	FY18	FY19	TOTAL
ANL					$ -
INL			$ 100		$ 100
LBNL					$ -
NREL			$ 50		$ 50
ORNL					$ -
PNNL					$ -
LANL					$ -
TOTAL	$ -	$ -	$ 150	$ -	$ 150