Project ID: eems045
CAVs Pillar

U.S. DEPARTMENT OF ENERGY

SMARTMOBILITY

Systems and Modeling for Accelerated Research in Transportation

Focused Validation and Data Collection to Support Systems and Modeling for Accelerated Research in Transportation (SMART) Activities

Eric Rask [1], Matthew Shirk [2], Jeff Gonder [3]
ANL [1], INL [2], NREL [3]
2019 Vehicle Technologies Office Annual Merit Review
June 12th, 2019

Argonne NATIONAL LABORATORY

Idaho National Laboratory

BERKELEY LAB

OAK RIDGE National Laboratory

NREL NATIONAL RENEWABLE ENERGY LABORATORY

OVERVIEW

Timeline

- Project start date: 10/2018
- Project end date: 9/2019
- Percent complete: ~43%

Budget

1) Highly Automated Vehicle [HAV] Electrical Load Investigation

- FY19 Funds – $243k

2) Data Collection from In-use Automated Shuttles

- FY19 Funds – $235k

100% DOE Funds

Highlighted Barriers

- Difficulty in sourcing accurate and traceable real-world data
- Rapid evolution of CAV technologies
- Significant variation in common assumptions for new AVs and components (often with minimal verifiable data)

Partners

- DOE-SMART consortium researchers
- FEV
- University of Michigan

RELEVANCE – Focused Data Collection and Analysis Snapshot of Current Technologies and Trends

Highly Automated Vehicle [HAV] Electrical Load Investigation

- AV related processing, actuation, and sensing loads are a critical assumption for energy estimation and even powertrain selection
- Significant uncertainty exists regarding current and future load projections (even for lower automation levels!)
  - Built-infrastructure starting to leverage these technologies too

Data Collection from In-use Automated Shuttles

- AV shuttles represent both a new vehicle topology as well as new usage mission versus historical LD & MD/HD technologies
- Significant uncertainty exists relative to both energy consumption of proposed/in-use systems as well as their usage profiles
  - SMART Automated Mobility District (AMD) work needs state-of-the-art data to inform modeling efforts

APPROACH – Focused Data Collection and Analysis Snapshot of Current Technologies and Trends

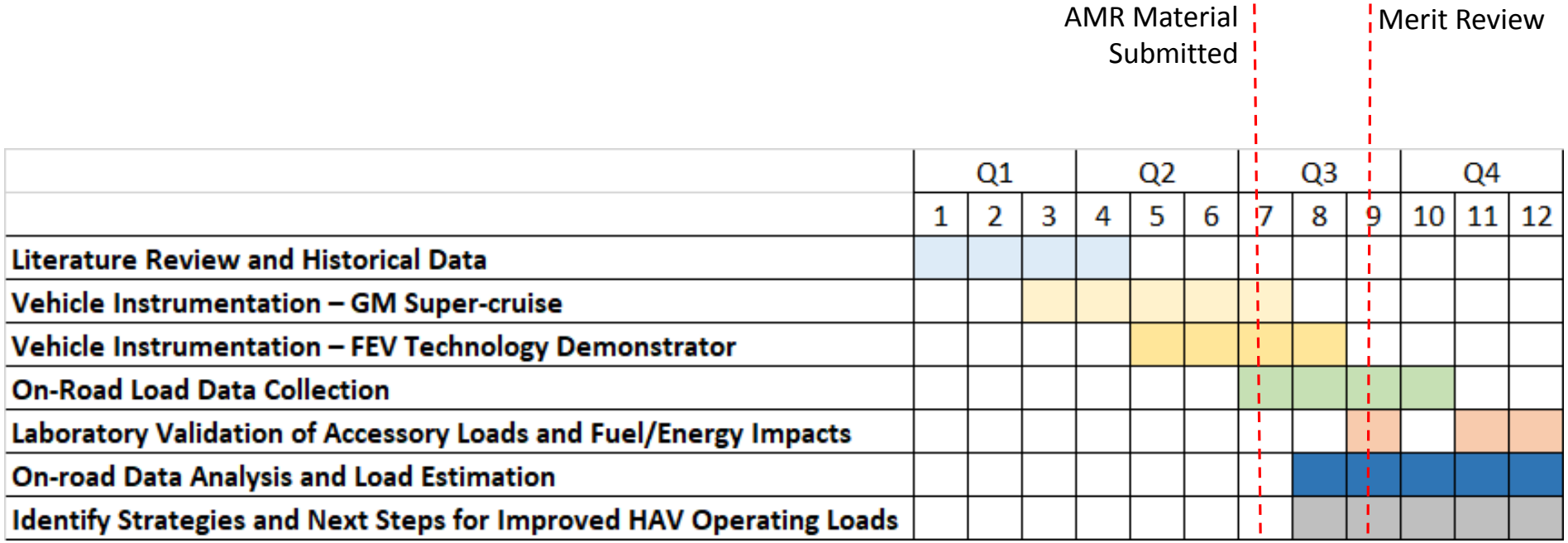
Highly Automated Vehicle [HAV] Electrical Load Investigation

1) Instrument baseline and HAV related sensing, processing, and actuation systems for on-road data collection for select candidate vehicles
2) Perform on-road data collection for baseline and HAV system loads across a range of operating scenarios and conditions (i.e. driving style, location, etc.)
3) Laboratory confirmation of accessory loads and translation of accessory loads to fuel/energy consumption increase
4) Aggregate accessory load impacts versus operating behavior and provide insights on expected loads and areas for additional development

Data Collection from In-use Automated Shuttles

1) Partner with organizations piloting highly-automated vehicle technology to collect field data under varying conditions and circumstances
2) Process data to produce information to characterize energy sensitivities and characteristics of new mobility technologies
3) Share information with related SMART projects to improve their assumptions and increase model fidelity

MILESTONES AND PROJECT OVERVIEW – AV Electrical Loads



MILESTONES AND PROJECT OVERVIEW – Automated Shuttle Data Collection

Milestone	Date	Status
Selection of additional shuttle data collection partners	31 March, 2019	Complete
On-road testing and data collection of HAV vehicle operation and loads	30 June 2019	On Track
Analysis and archiving of automated shuttle in-field data, along with reporting of efficiency and other key performance metrics	30 September 2019	On Track

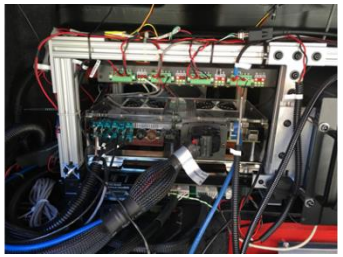
ACCOMPLISHMENTS – HAV Electrical Load Assessment: Highlighted Experimental Vehicles/Platforms

Cadillac CT6 with "SuperCruise"

- Important intermediate automation point
- Hands-free driving (actuation and sensing)
- Fused vision and RADAR systems

Prototype Highly Automated Vehicle

- Partnership with FEV
- Research test-bed for highly automated driving
- Flexible for direct load reduction experimentation

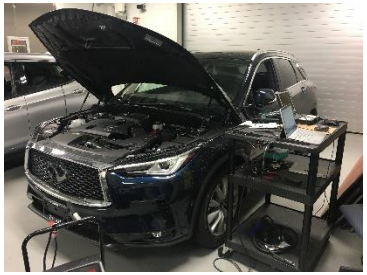


ANL HAV Sensor Evaluation Platform

- Highly configurable sensor platform for experimentation
- Abundance of CAV relevant sensors
  - Lidar (2-types), RADAR, vision, DSRC

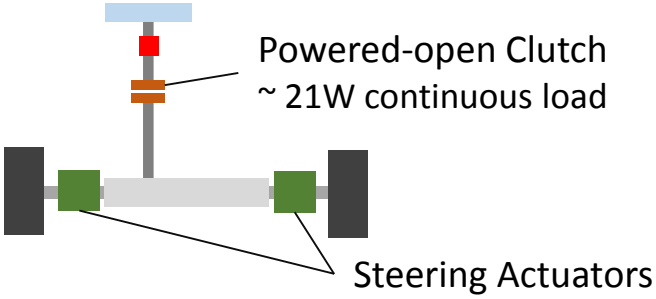
ACCOMPLISHMENTS – HAV Data Collection On-going – What have we learned so far…

ACCOMPLISHMENTS – HAV Electrical Load Assessment: Preliminary Actuation Loads



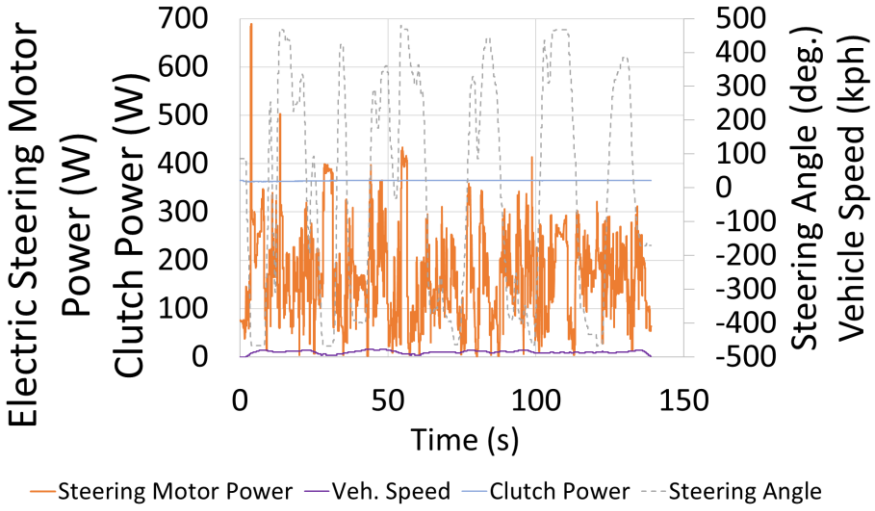
Infiniti QX50 – "Direct Adaptive Steering"

- Commercially available LD fully "by-wire" steering system



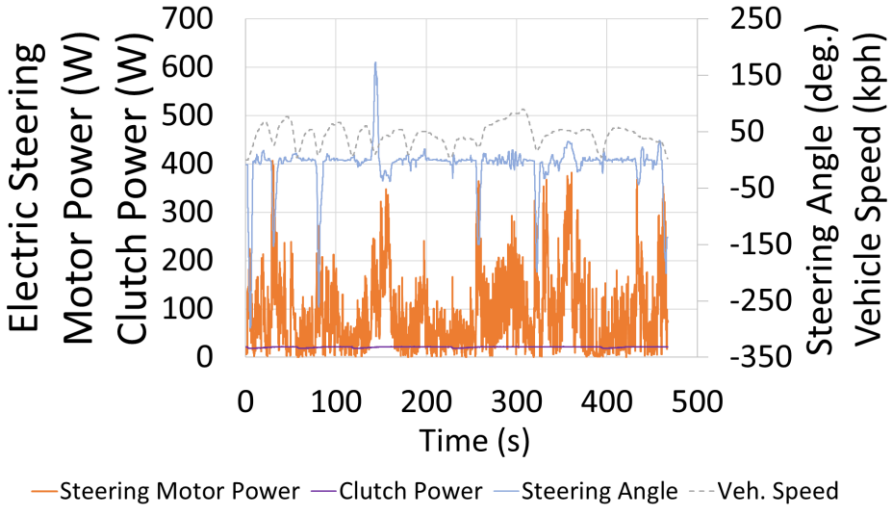
Low Speed Driving [parking]

Average Steering Motor Power = 169W



Moderate Speed Driving

Average Steering Motor Power = 89W

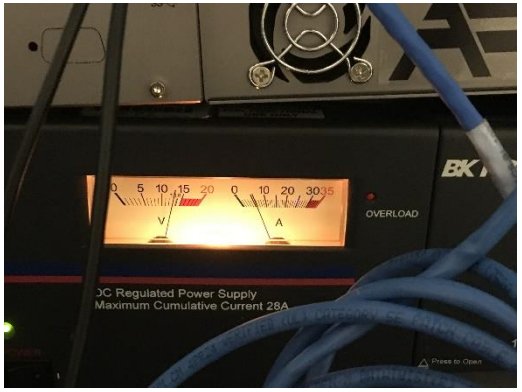


ACCOMPLISHMENTS – HAV Electrical Load Assessment: Example Sensor Loads – LIDAR System (all components)

IBEO Lux 4L From Specification Sheet:

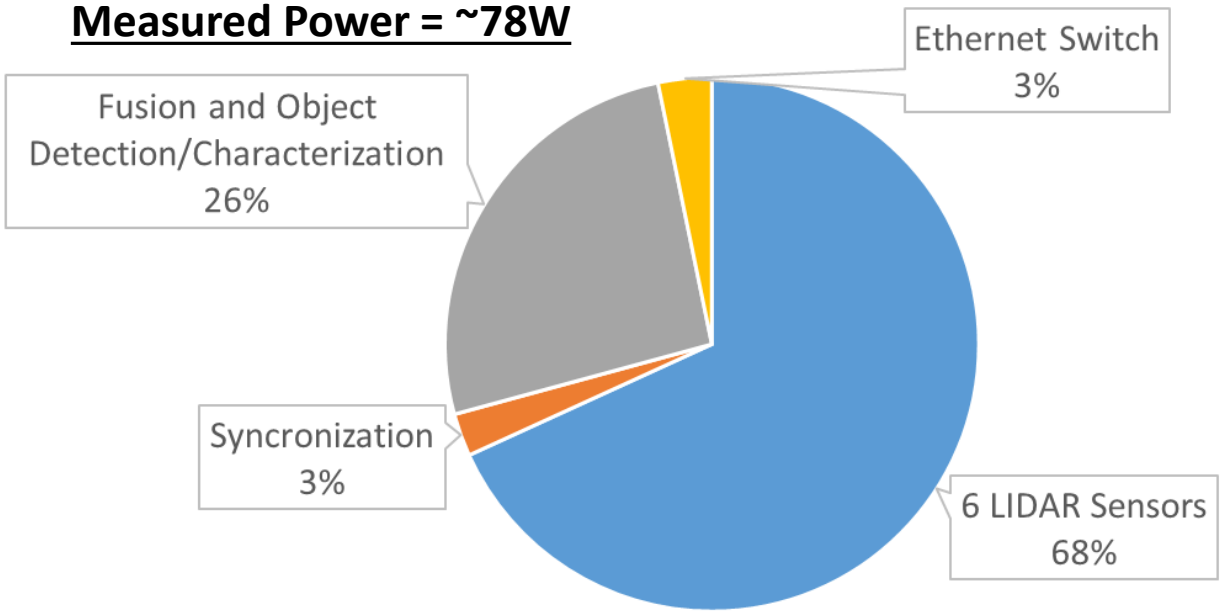
Single Sensor Power consumption: 7 W (average), < 10 W (max)

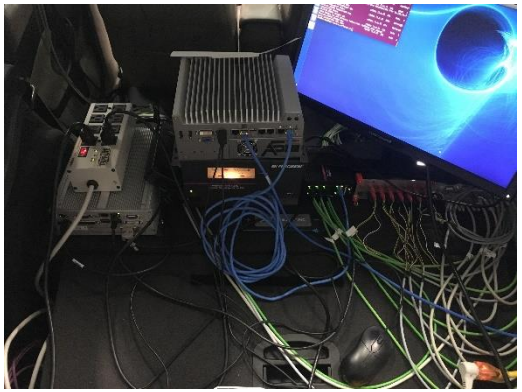
6x Sensors = 42W (average)



6x IBEO 4L+Associated Components:

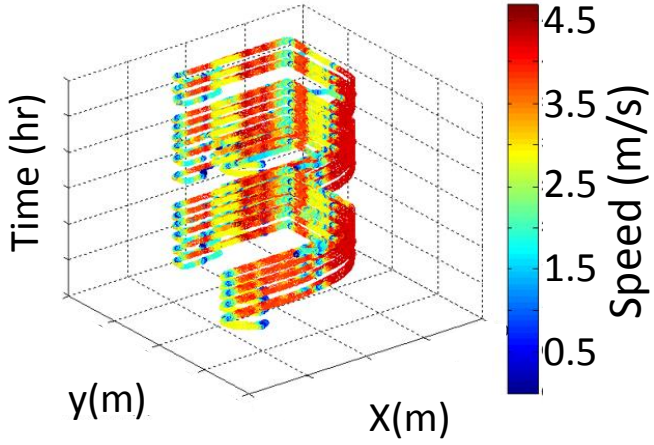
Measured Power = ~78W

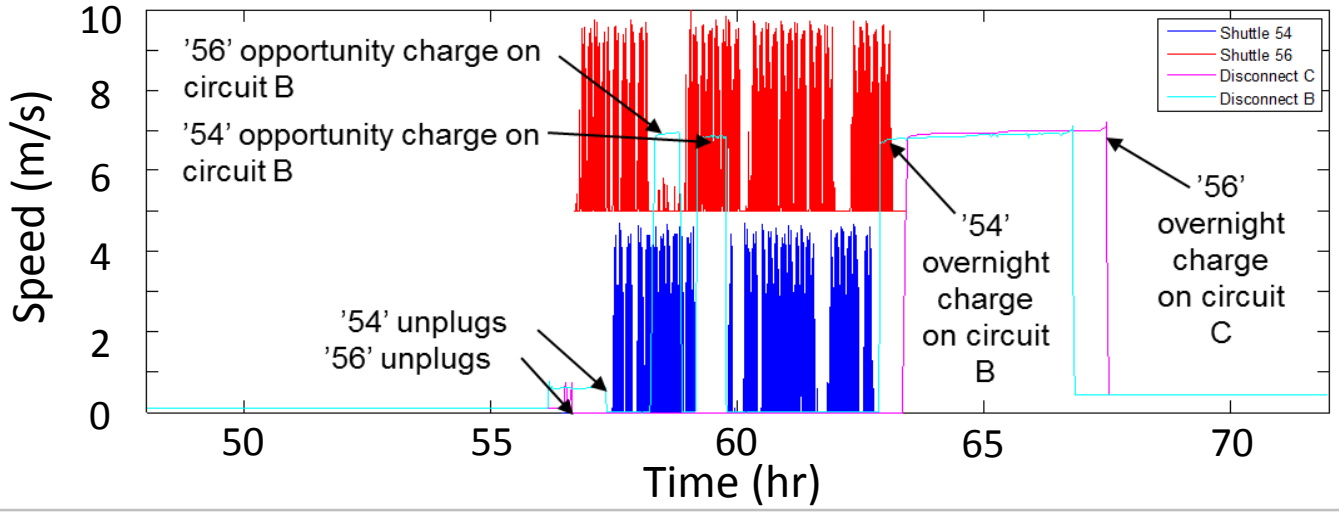




ACCOMPLISHMENTS – Automated Shuttle Data Collection: On-going Data Collection Example

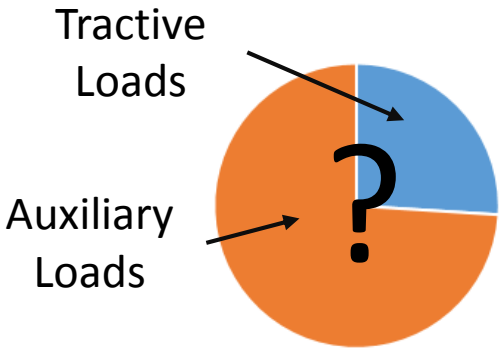
- **University of Michigan automated electric shuttle pilot – ongoing data collection & analysis**
  - Speed and position gathered from 2 shuttles operating on a fixed route
  - Recharge energy gathered from charging infrastructure
  - Data QA & down selection to complete days performed
  - Driving and charging data joined to produce daily energy intensity for each vehicle – daily AC Wh/mi
  - Processing and analysis continuing across different seasons to investigate effects of ambient temperature

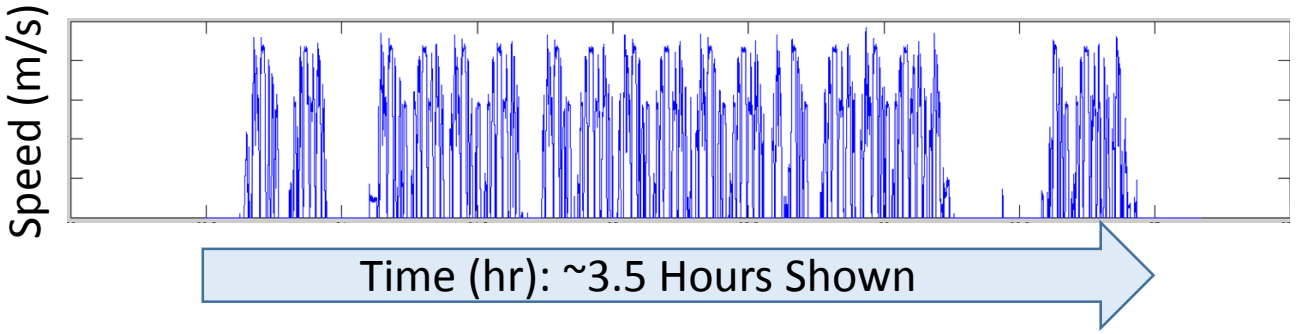




ACCOMPLISHMENTS – Automated Shuttle Data Collection: Data Dissemination and Processing

- **SMART Mobility Data Sharing and Analysis**
  - NREL running speed trace data in FASTSim using basic vehicle parameters to help understand the likely relationship between constant loads (HVAC & computing) and tractive (drivetrain) loads
  - Daily energy consumption and speed trace data provided to SMART projects for several full days of operation
    - Urban Science "Automated Mobility Districts" task US 2.41
    - Advanced Fueling Infrastructure "Fuel selection in automated mobility districts" & "Dynamic Wireless Power Transfer Feasibility Analysis," task AFI 3





ACCOMPLISHMENTS – Automated Shuttle Set to Begin Operating on NREL's Campus

- Multiple approvals cleared, contract in place, EasyMile shuttle set to begin carrying passengers on campus early this summer
- Coordination with manufacturer and shuttle contractor for data collection

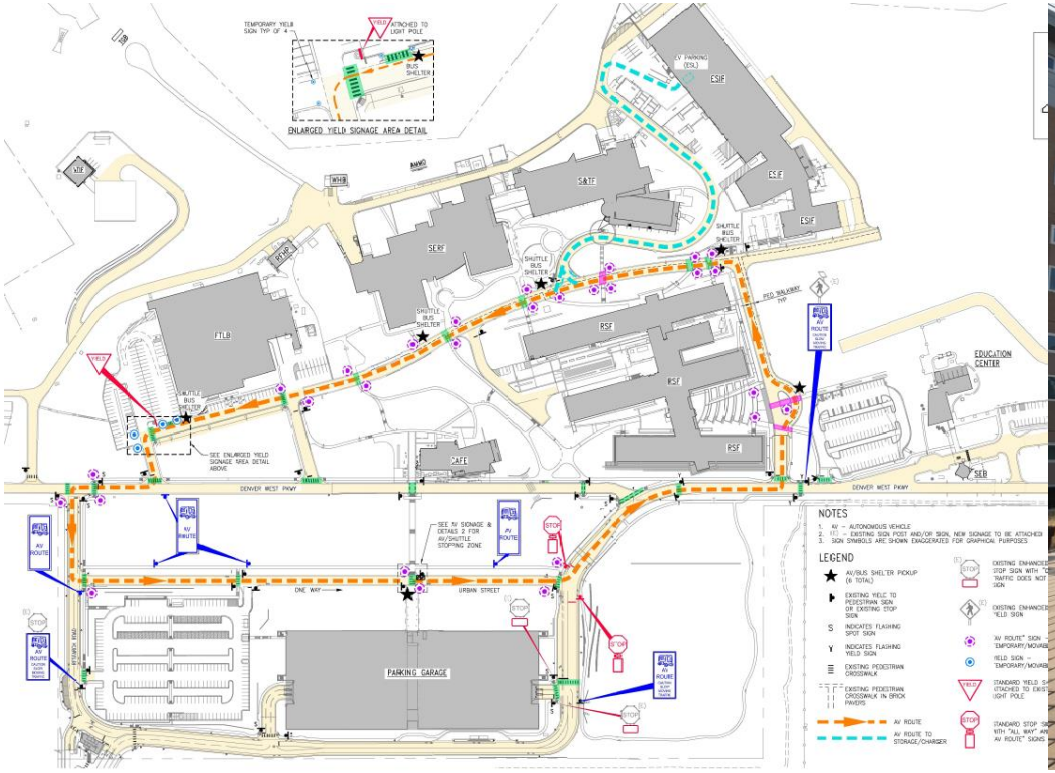


Photo by Dennis Schroeder, NREL 47297

COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS

DOE Vehicle and Mobility Modeling:

- Data & validation support for range of AV simulation/analysis efforts

DOE SMART - National Laboratory Partners:

- Primary Participants: ORNL, ANL, INL, LBNL, NREL
- Direct support for “Automated Mobility Districts”, “Fuel selection in automated mobility districts” & “Dynamic Wireless Power Transfer Feasibility Analysis” tasks

Industry Partners:

- FEV

University Partners:

- University of Michigan

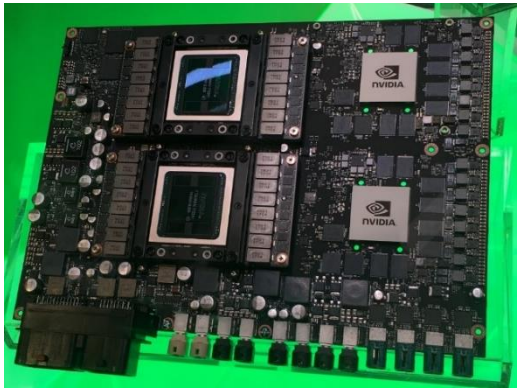
REMAINING CHALLENGES AND BARRIERS – Balancing Specific Insights with Predictions and Trends

Accessing state-of-the-art data is always challenging

- **AV loads (especially processing) evolving at an incredibly fast rate**

Get it working!

Integration



New Topologies and Hardware

- **New AV shuttles and mission profiles are constantly appearing (how to partner?)**

PROPOSED FUTURE RESEARCH
Subject to future funding

Highly Automated Vehicle Electrical Load Investigation

- Continued assessment of realistic processing loads and trends
- Emerging classes of AV-specific hardware and strategies
- Actuation loads for large (MD/HD/other) vehicle classes
- What else are we missing – redundancy, safety, cooling, data-management

Data Collection from Automated Shuttles

- More fleet partners including synergistic technologies (i.e. wireless, V2G)
- Automated busses and other large-scale automated transit/freight options
- Other unique forms of mobility driving additional needs and targets

Other Opportunities to Support SMART and Other DOE Needs

SUMMARY SLIDE

Relevance

- Components and new vehicle platforms associated with emerging forms of mobility will drive new sensitivities, duty cycles, and areas for research
  - Data-driven insights and opportunities are key to helping validate assumptions, identify research gaps, and track technology trends

Approach

- Real-world snapshot of automated driving electrical loads and impacts
- In-field data collection of automated shuttle deployments

Highlighted Accomplishments

- Snapshot of current AV loads within the context of overall system
- Highlighted actuation and sensor loads with real components/usage
- Emerging operational and charging insights for AV shuttles
- More automated shuttle partners and location to come…

QUESTIONS?