2020 DOE Vehicle Technologies Annual Merit Review
June 2020

Argonne NATIONAL LABORATORY

Simulation Tool for Energy-Efficient Connected and Automated Vehicle Control Development (EEMS 086)

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Project Overview

Timeline

- Project start: Oct. 2019
- Project end: Sep. 2021
- Percent complete: 15%

Budget

- Total Funding (2 years): $600,000
- FY20 Funding: $300,000
- FY21 Funding: $300,000

Partners

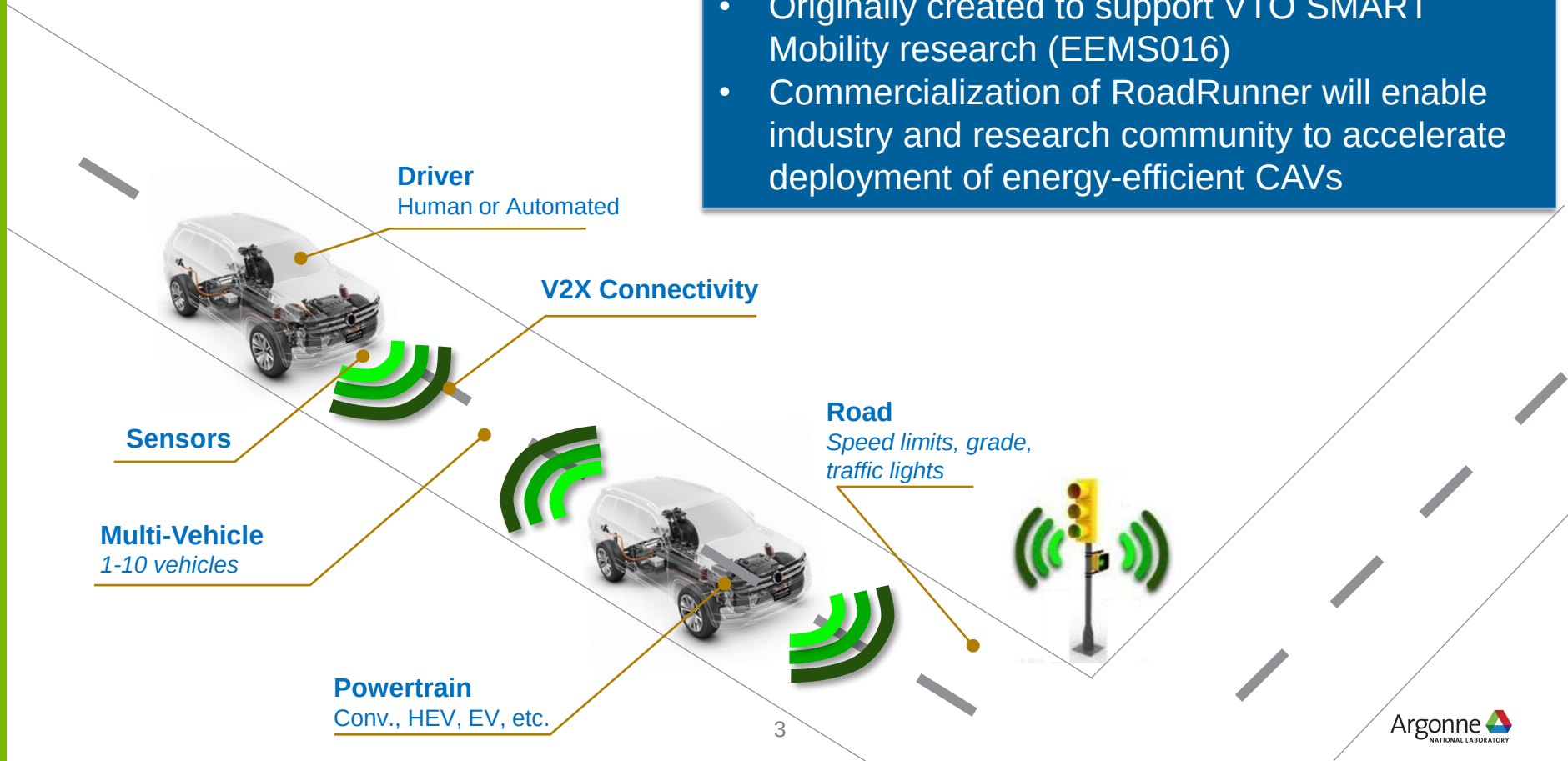
- **Argonne**: lead
- **Hyundai America Technical Center Inc. (HATCI)**: industry partner

Barriers

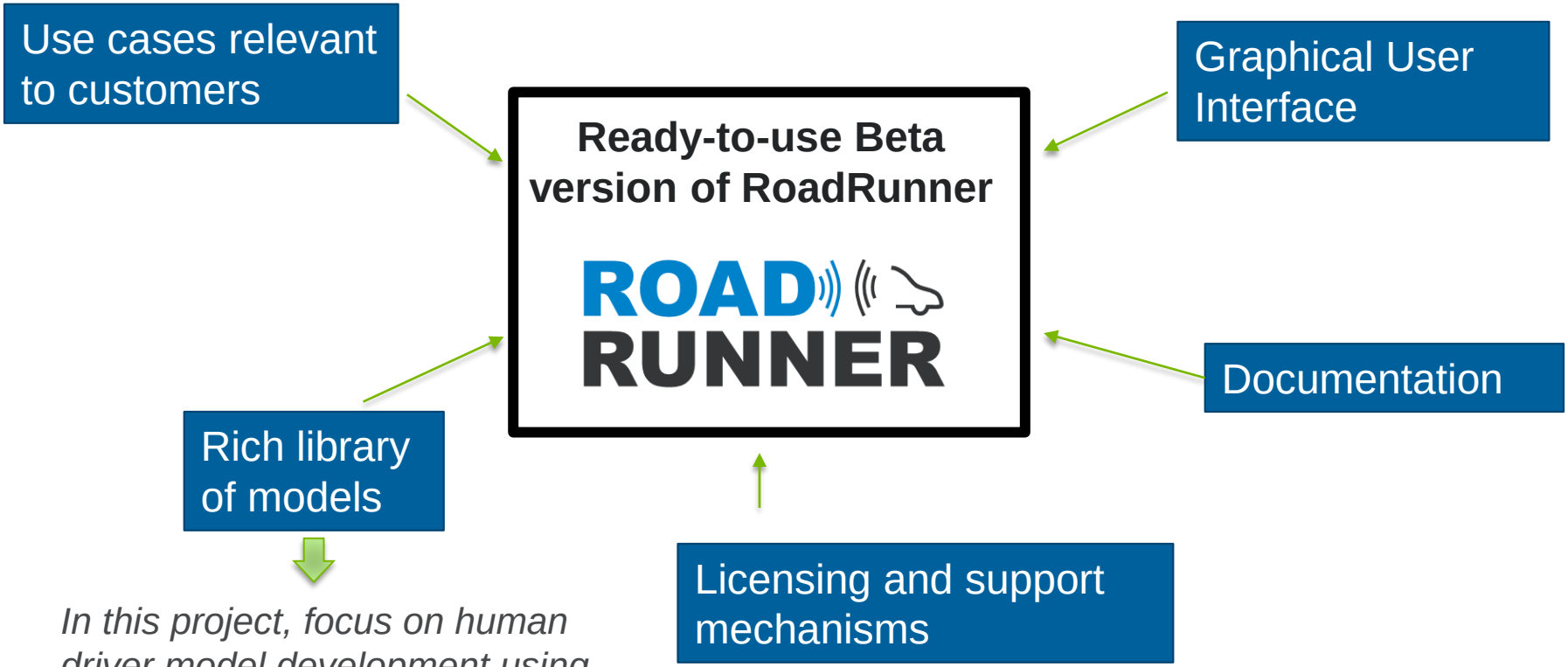
- Lack of tools dedicated to research energy efficiency in the context of powertrain, connectivity, and automation
- User interface and usability critical for deployment of new software/models
- Real-world data for model calibration is hard to come by

Relevance

- RoadRunner is a tool that helps integrate energy-efficiency in the design of CAV controls.
- Originally created to support VTO SMART Mobility research (EEMS016)
- Commercialization of RoadRunner will enable industry and research community to accelerate deployment of energy-efficient CAVs



Objectives

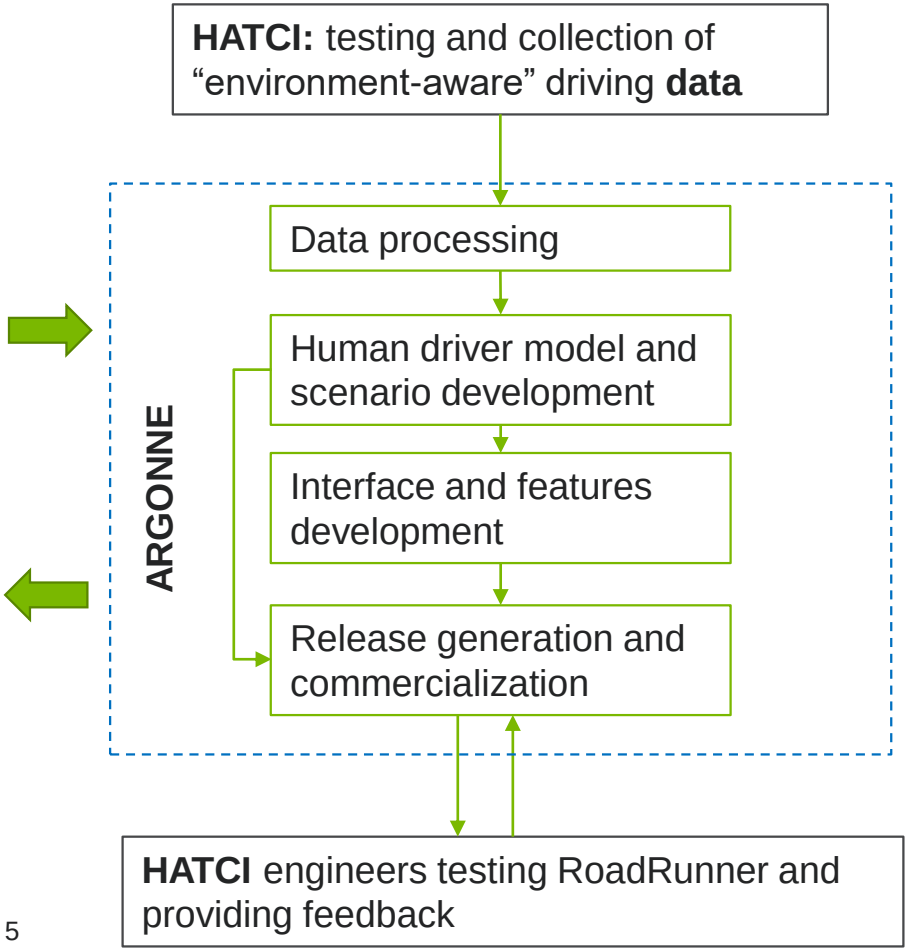


In this project, focus on human driver model development using driving data from Hyundai

Approach

Currently: a research tool
- Automated scenario generation
- Limited number of models and scenarios
- Limited/no GUI, mostly command line
- Human driver model with limited validation

Objective: a commercial and professional tool
- Validated state-of-the-art human driver model
- Graphical user interface
- Use cases relevant to automotive R&D engineers

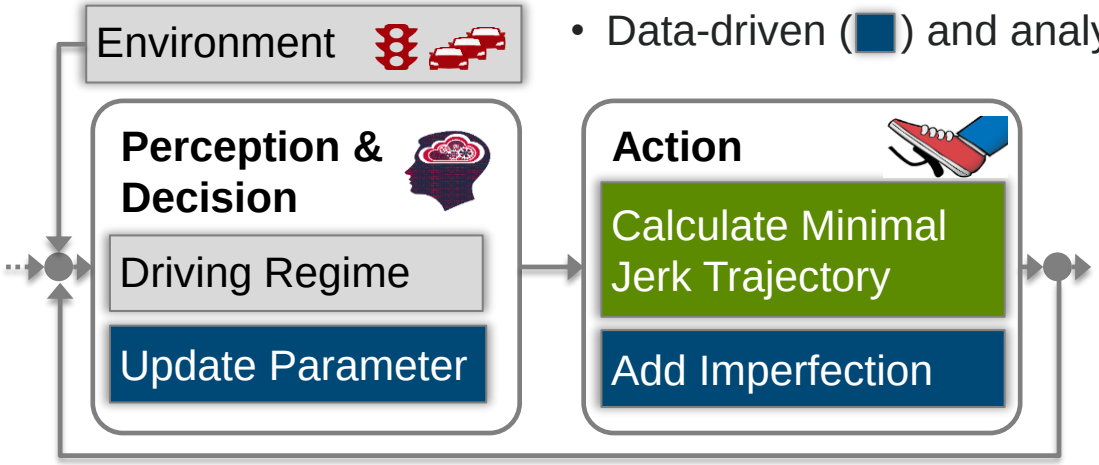


Milestones

Milestone Name/Description	Due Date
Alpha release of RoadRunner delivered to HATCI	07-2020
Preliminary analysis report on driving data from HATCI	10-2020
RoadRunner human driver model validated with test data from HATCI	01-2021
Beta release of RoadRunner to HATCI – a version close to final version, including a library of default CAV scenarios	07-2021
Final release of RoadRunner	10-2021

ACCOMPLISHMENTS
1 – HUMAN DRIVER MODEL DEVELOPMENT

Human Driver Model Overview



- Data-driven ( ) and analytical approach ( )

- *Action model initially developed in SMART (EEMS016)*
- *Hyundai data enables further development of Perception & Decision model*

Perception & Decision (P&D) model to capture the cognitive process of human brain

- *Determine driving regimes and their parameters*
- *e.g., determine the acceleration time and distance after a vehicle launches from a stop*

Action model to capture human driving behaviors impacting the state of the vehicle

- *Generate vehicle state trajectories*
- *e.g., using P&D parameters, compute vehicle state trajectories for an acceleration regime*

Completing Human Driver Model Using Real-World Data

Driving Data Provided by Hyundai

Source			Customer	Test
Data amount			Unlimited	Limited
Data variety	Scenarios		Unlimited	Limited
	# of vehicles		200+	1
	# of drivers		100+	1+
	# of vehicle class/type		10+	1
Data quality	Sampling rate		1Hz	10Hz+
	Collected signals	Motion	O	O
		Powertrain	O	O
		PV	O	O
		GPS	X	O
		Video	X	O

PV: Preceding Vehicle, GPS: Global Positioning System

Model Development

1. Data Generation and Exploration
- Scenario categorization
- Design of test experiments
- Automatic data processing

2. Model Development
- Perception & Decision Model
- Action Model
- Development initiated in SMART Mobility (EEMS016)

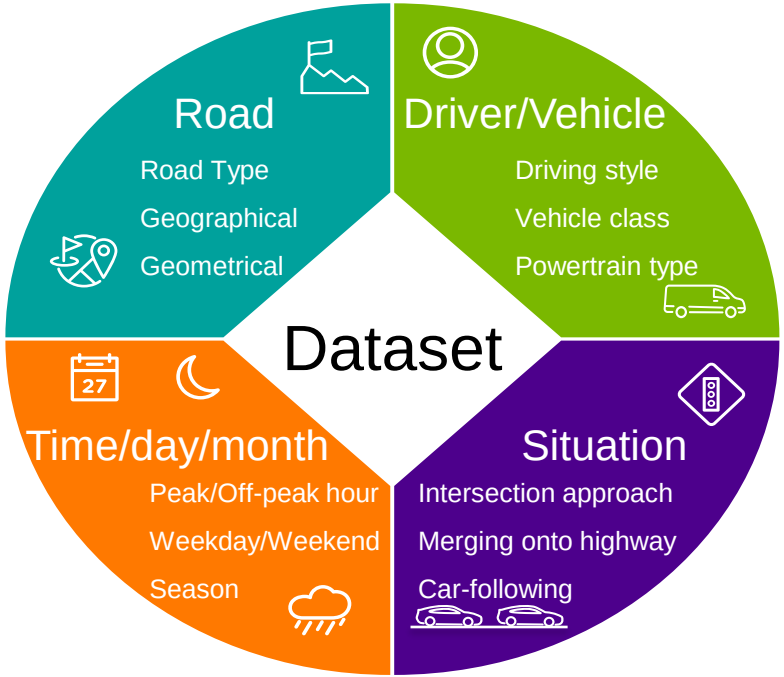
3. Model Calibration and Validation

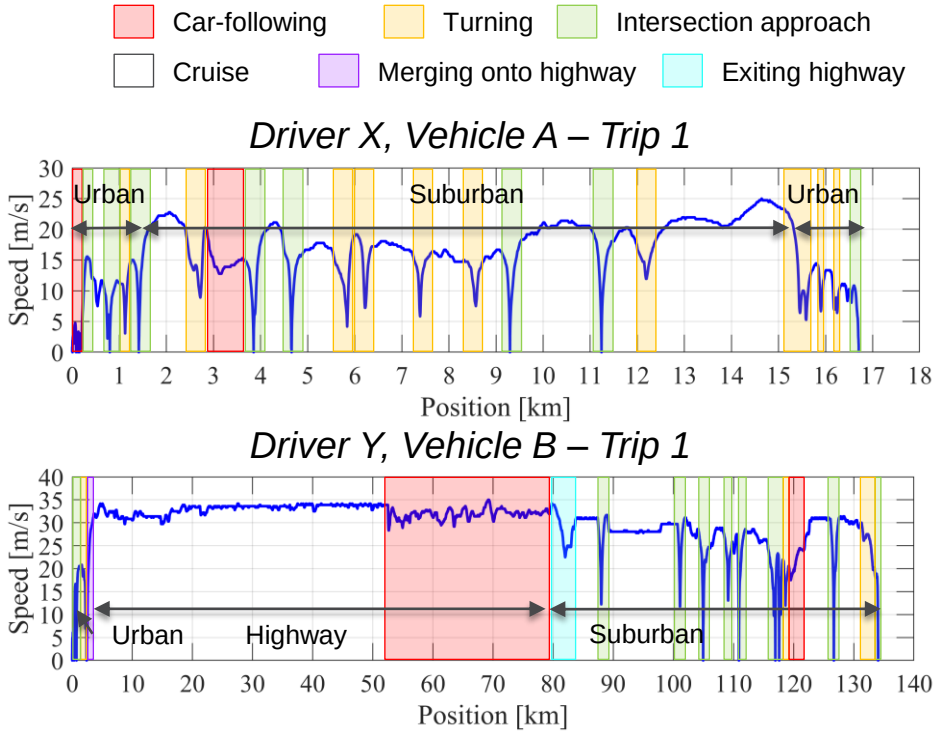
Outcome

✓ *High-fidelity dynamic driver model*

✓ *Good baseline for any CAV control development*

Customer Data Sample Provides a Large Variety of Situations





- Multiple factors influence driving behaviors (complex and interacting with each other)

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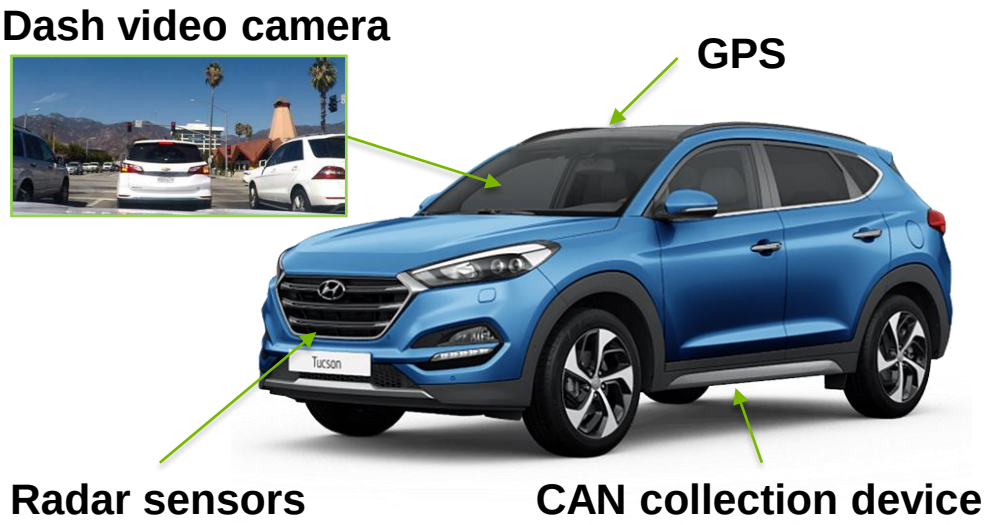
Dedicated Testing with Vehicle Provides More Information about Surrounding Environment

Customer Driving Data

- Dominant factor identification
- Scenarios categorization
- Target scenarios design

Design of Test Experiments

- 1 Hyundai vehicle, various drivers, in Michigan area
- 12-month collection period to start in 2020



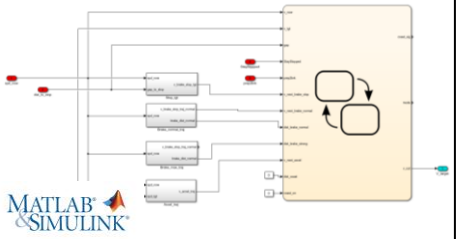
ACCOMPLISHMENTS
2 – INTERFACE DEVELOPMENT

Developing Use Cases Relevant to RoadRunner Users

1. User Defines Scenario and Selects Powertrain

- Route (from HERE maps or synthetic)
- Connectivity level of traffic signals
- Number of vehicles
- Vehicle class and powertrain (Autonomie)
- Connectivity level of vehicles
- Driving control (human, automated, eco-driving, etc.)

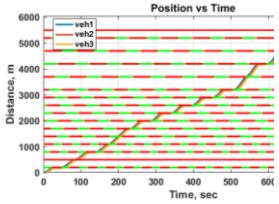
2. Simulink Model Building (Automated) and Simulation



3. Post-Processing & Quality Check (Automated)

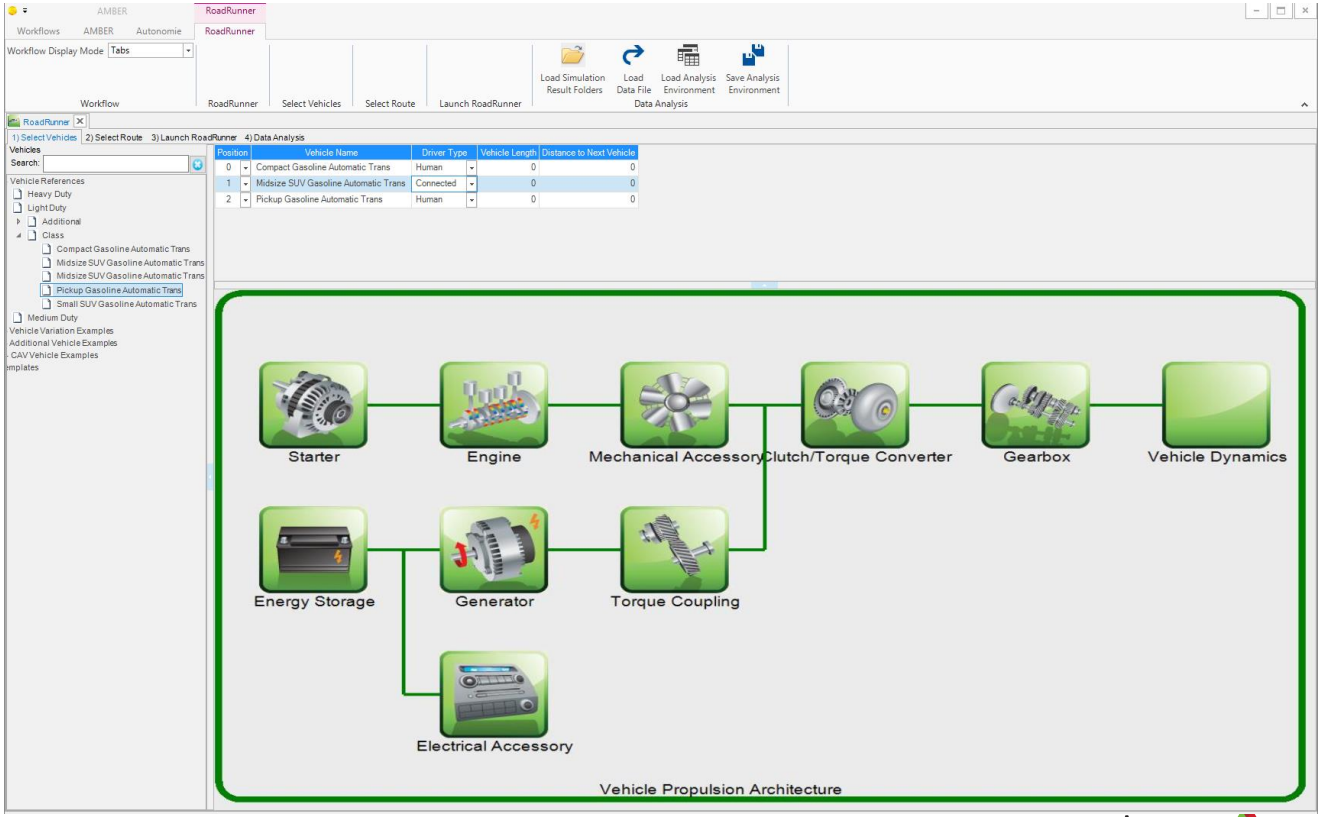
4. User Analyzes Simulation Results

- Energy consumption
- Powertrain operating conditions
- Space/time trajectories
- Intersection crossings
- Inter-vehicle gap



Building upon Argonne's Simulation Software

- Reusing many components of AMBER/Autonomie interface and backend code
- Graphical User Interface (GUI) will enable users to run RoadRunner simulation easily



CLOSING REMARKS

Response to Previous Year Reviewers' Comments

- Project has not been previously reviewed

Partnerships and Collaborations

CRADA partner

- Real-world driving data
- Tool use cases
- OEM perspective
- Beta testing

Lead

- Model development
- Tool development
- Tool deployment
- Builds upon SMART research (**EEMS016**)

Remaining Challenges and Barriers

- **On-road data collection** for human driver model development:
  - Challenge in getting a representative sample;
  - Duration (1 year) and sample of non-professional drivers should address this to some extent
- **Customer data processing** for human driver model development:
  - Challenge in identifying driving regimes, even though full context not available (No GPS, no road information, no video)
- **User interface** needs further development to accommodate more use cases.

Future Work

- Instrument and deploy vehicle for on-road testing (HATCI)
- Processing of HATCI data
- Human driver model calibration based on collected data
- Baseline driver and CAV model preparation for release
- User interface development & testing
- Commercialization

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

Summary

- Project aims to **commercialize RoadRunner**, a tool enabling development of energy-focused CAV controls
- A professional **graphical user interface** will ensure high level of usability
- In this project, model development focused on **human-driving model**
  - **Hyundai to provide large amount of real-world driving data**
  - Calibration of driver model from SMART project
- Development with OEM involvement will ensure tool meets the **needs of industry**
- RoadRunner improvements and maturation will help conduct other DOE-funded research activities

TECHNICAL BACK-UP SLIDES

Recreating Vehicle Contextual Information

Developing workflow to process large amounts of data

Raw "Rich" on-road data

- Geolocation
- Video
- Radar
- Powertrain (CAN)

Visualization

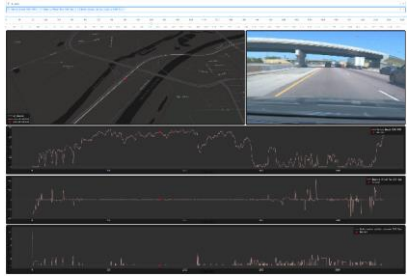
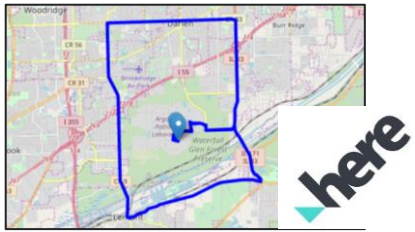


Image Recognition (Deep learning)

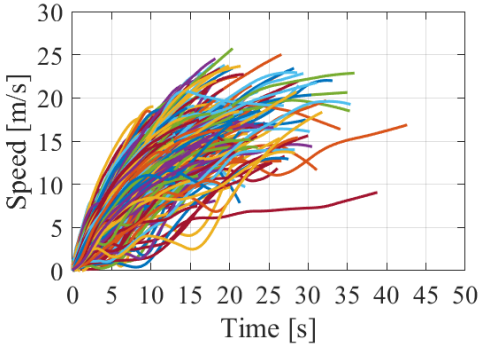
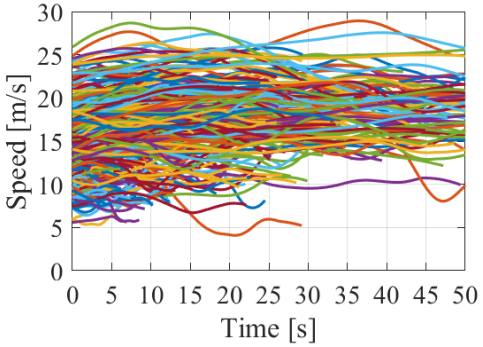
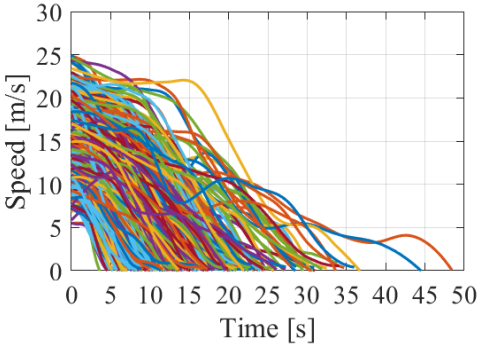
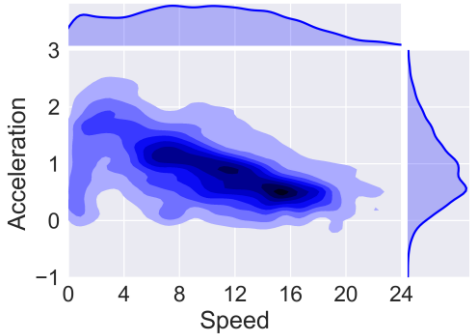
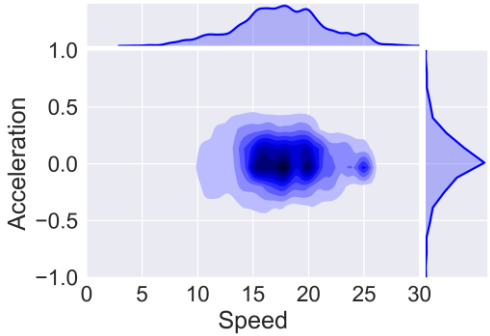
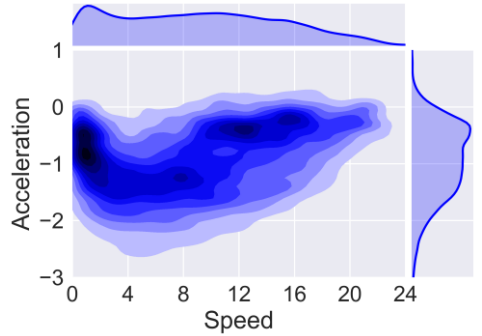
Map-Matching



Driving Context

- Road type and speed limit
- Intersections
- Surrounding Vehicles

Segmenting Data into Driving Regimes for Driver Model Calibration

	Acceleration	Cruise	Stop
Trajectories			
Distribution			

2D Kernel Density Plots

Example of Calibration Based on Real-World Data

3 step data process

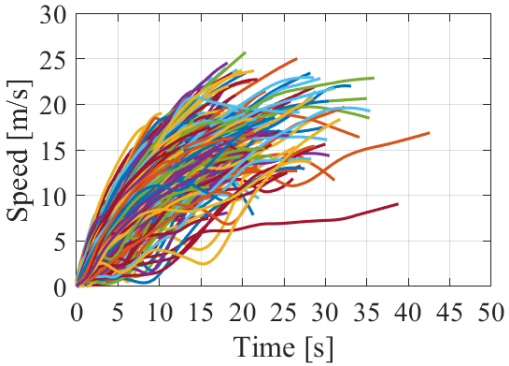
01 Data Exploration
- Handle big data
- Recreate contextual Info

02 Trip segmentation
- Categorize scenario
- e.g., urban, highway

03 Driving Regimes Isolation
- Identify driving regimes
- e.g., acceleration, cruise

Parameter extraction

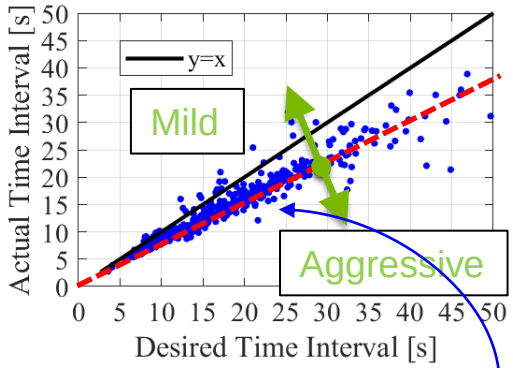
Acceleration regime



- Isolated driving regimes
- Extracted parameters
  - Boundary conditions (BC)

Parameter calibration

Acceleration style



- Compressed BC info. into
  - Based on kinematics
- Calibrated parameters (slope)
  - To be normal driving