Energy-Efficient Adaptive Cruise Control Using Eco-Driving Algorithm

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What is Adaptive Cruise Control (ACC)?

- Enables "feet-off" driving
- Primarily leverages radar to track lead vehicle and objects
- Controls speed of the vehicle

ACC is starting to become a standard feature in production vehicles

Using ACC Could Decrease Fuel Efficiency

Report by Argonne National Lab

https://vms.taps.anl.gov/research-highlights/adaptive-cruise-control-real-world-energy-consumption/

Adaptive Cruise Control Real World Energy Consumption

The Argonne results offer multi-faceted understanding. On a trip-level scale, engaging ACC seemed to slightly increase fuel consumption (+0.26 l/100km or 2%) over the entirety of the fleet. A primary reason is that ACC uses more energy during cruising, which is where the majority of driving time is spent. Yet, in analysis of specific driving situations like acceleration or braking, ACC showed promise, particularly in the presence of a preceding vehicle.

The results offer new research direction and focus to further optimize ACC systems with energy efficiency in mind.

Fuel Efficiency Affected by Increased Tractive Effort

Study by Joint Research Centre of the European Commission and the University of Birmingham

He, Y., Makridis, M., Fontaras, G. et al. The energy impact of adaptive cruise control in real-world highway multiple-car-following scenarios. Eur. Transp. Res. Rev. 12, 17 (2020). https://doi.org/10.1186/s12544-020-00406-w

Penalty caused by string instability or amplification of lead vehicle speed variations

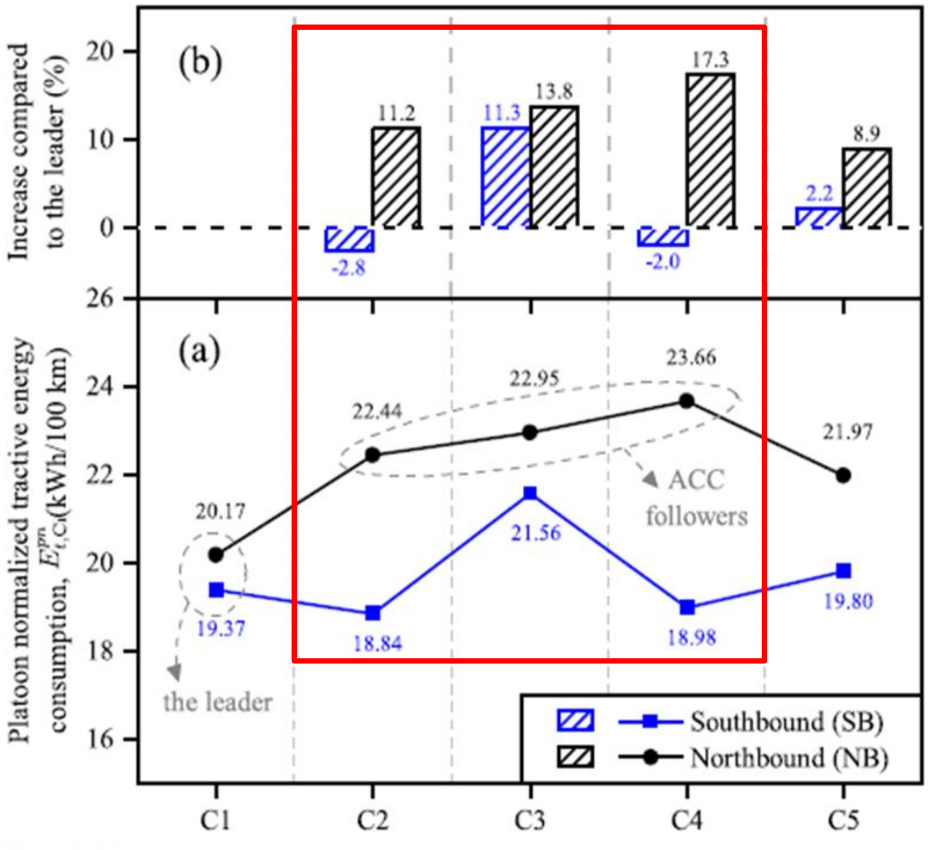


Fig. 8 ACC energy impact on the platoon level

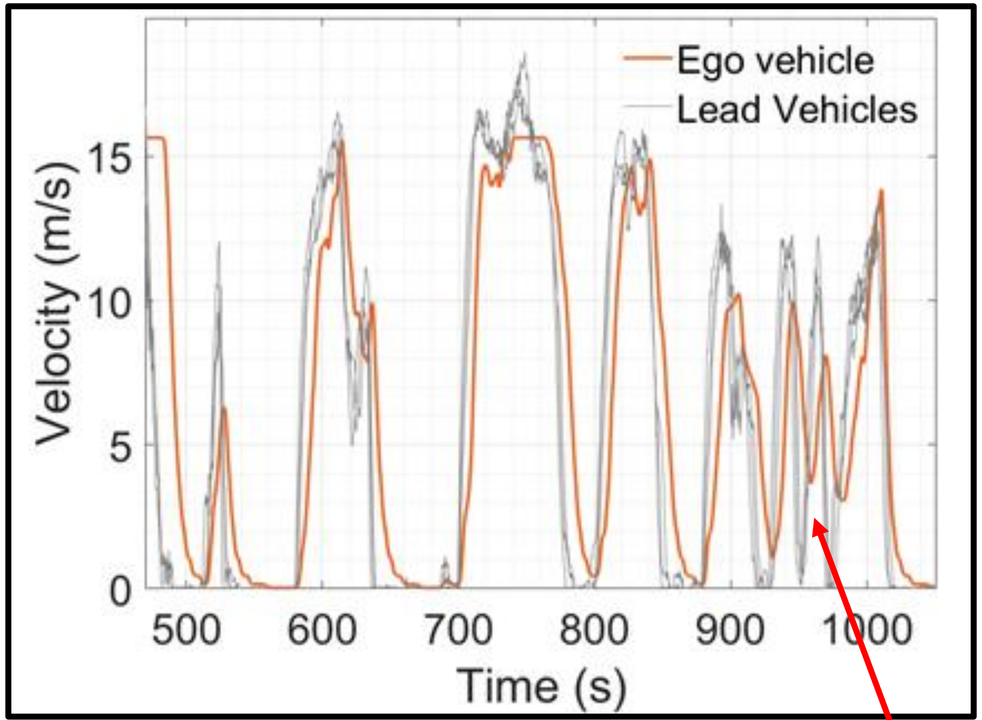
Overview

- **SwRI Eco-Driving Algorithm**
  - Objectives and Method
  - Required Information Streams and Velocity Profile Realization

- **Impact on Energy Consumption**
  - *Study 1 – NEXTCAR II*
    - Individual (ego/eco) vehicle on Blanco Road, San Antonio, TX
  - *Study 2 – DOE EEMS*
    - Entire Urban Corridor – N High Street, Columbus, OH

Algorithm Objectives and Intended Results

- **Objectives**
  - Track a desired speed
  - Minimize acceleration and deceleration
- **Method**
  - Solve an optimization problem in real-time
- **Intended Results**
  - Produce trajectories that don't impede traffic flow
  - Reduce required tractive work



Smoother velocity profile and fewer stops

SwRI Eco-Driving algorithm results in energy efficient velocity profiles

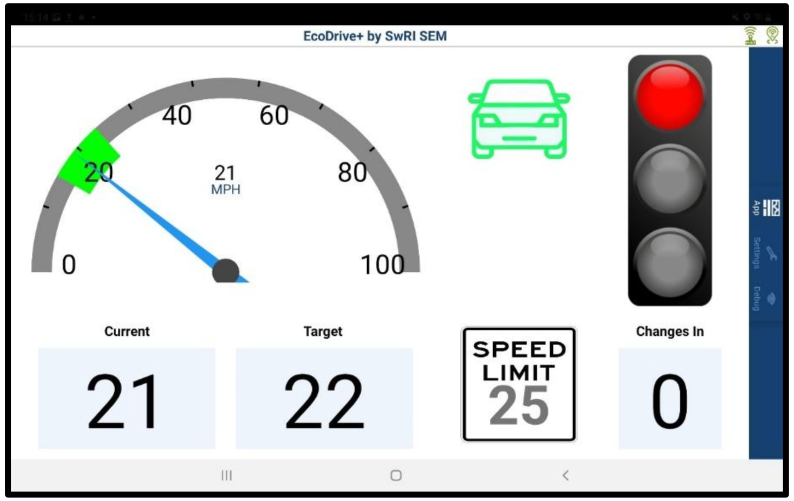
Implementation

1. Speed and location of nearby vehicles
2. Phase and timing of approaching traffic light

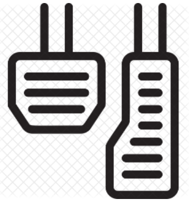
GPS	Location
Cellular Internet	Web Query
Vehicle CAN	Radar, Camera, Speed
C-V2X / DSRC	V2V, V2I

Eco-Driving Algorithm

User Interface



Pedal Control



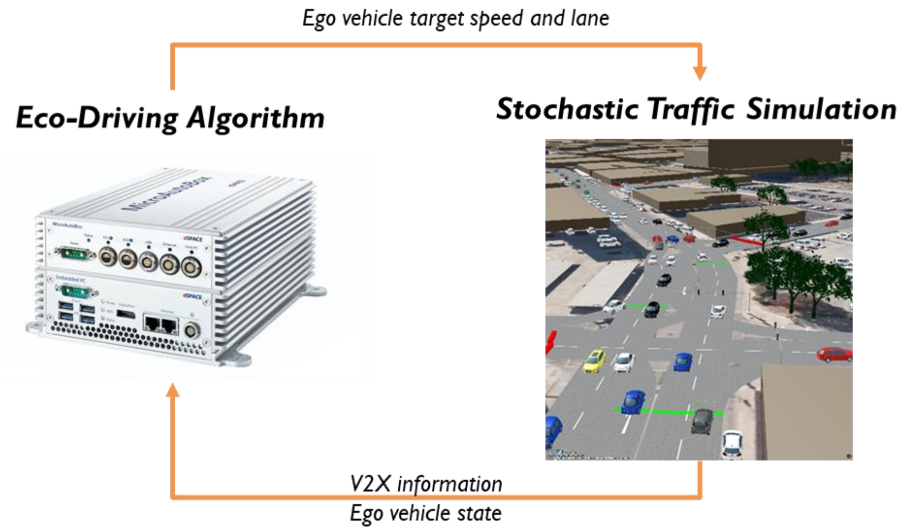
Algorithm can produce valuable results with partial information and various data sources.

Velocity profile can be realized by human (using UI) or drive-by-wire control

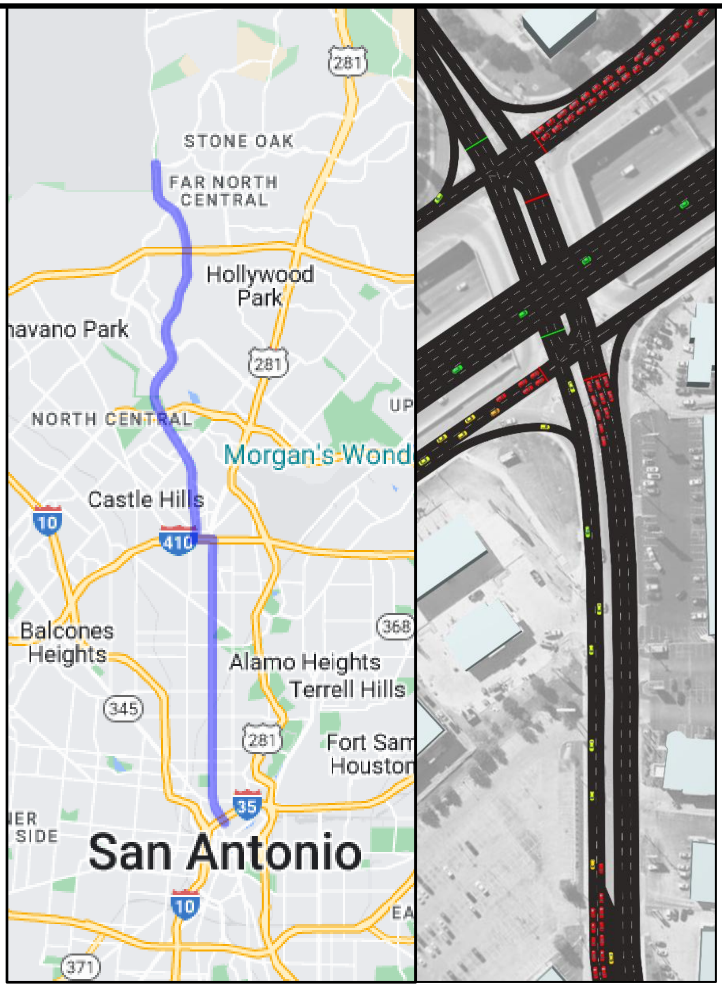
Study 1 – NEXTCAR II *Simulation Setup*

- **Phase II of ARPA-E funded NEXTCAR project**
  - Using Honda Clarity PHEV for demonstration
- **Software in loop setup**

Eco-Driving controller controls the ego vehicle state in a dynamic stochastic traffic simulation environment



25 km Corridor in San Antonio, TX

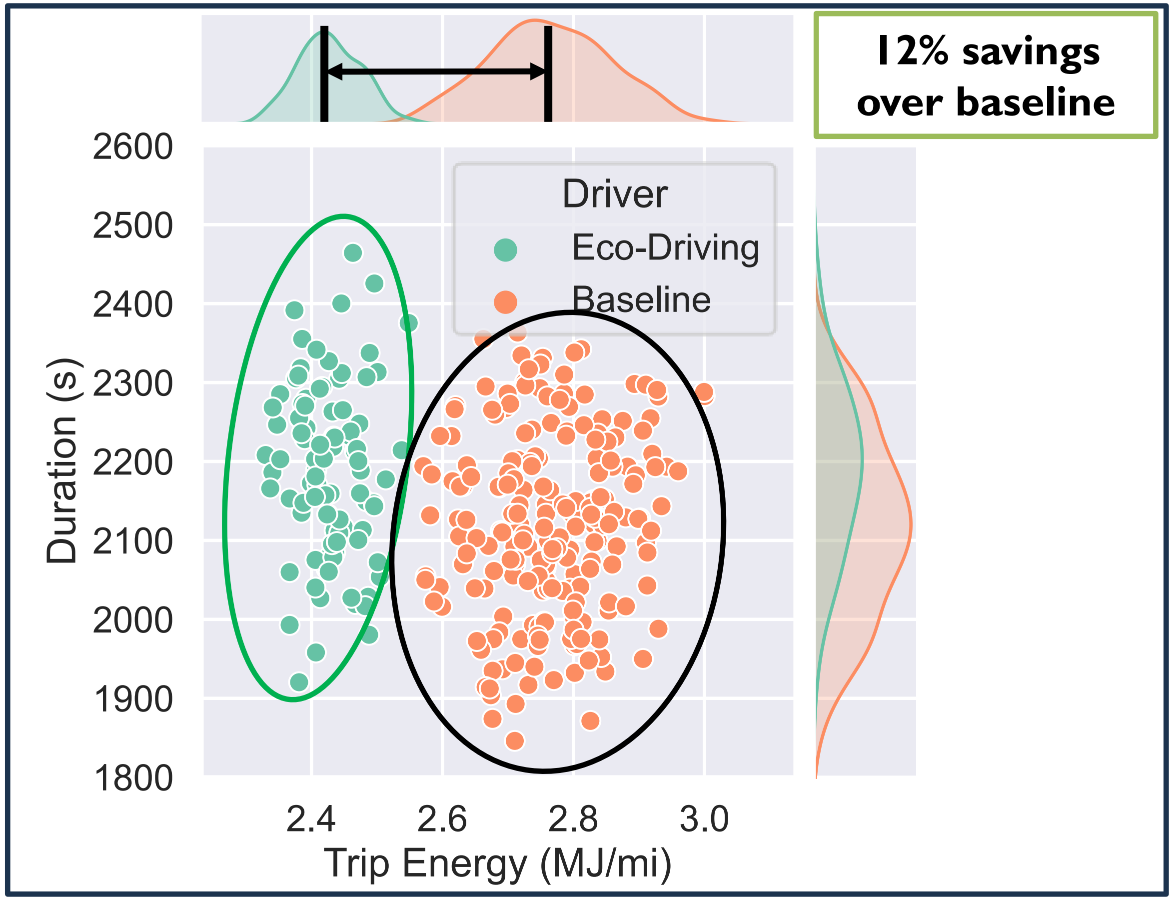


Study 1: Urban corridor in San Antonio, TX

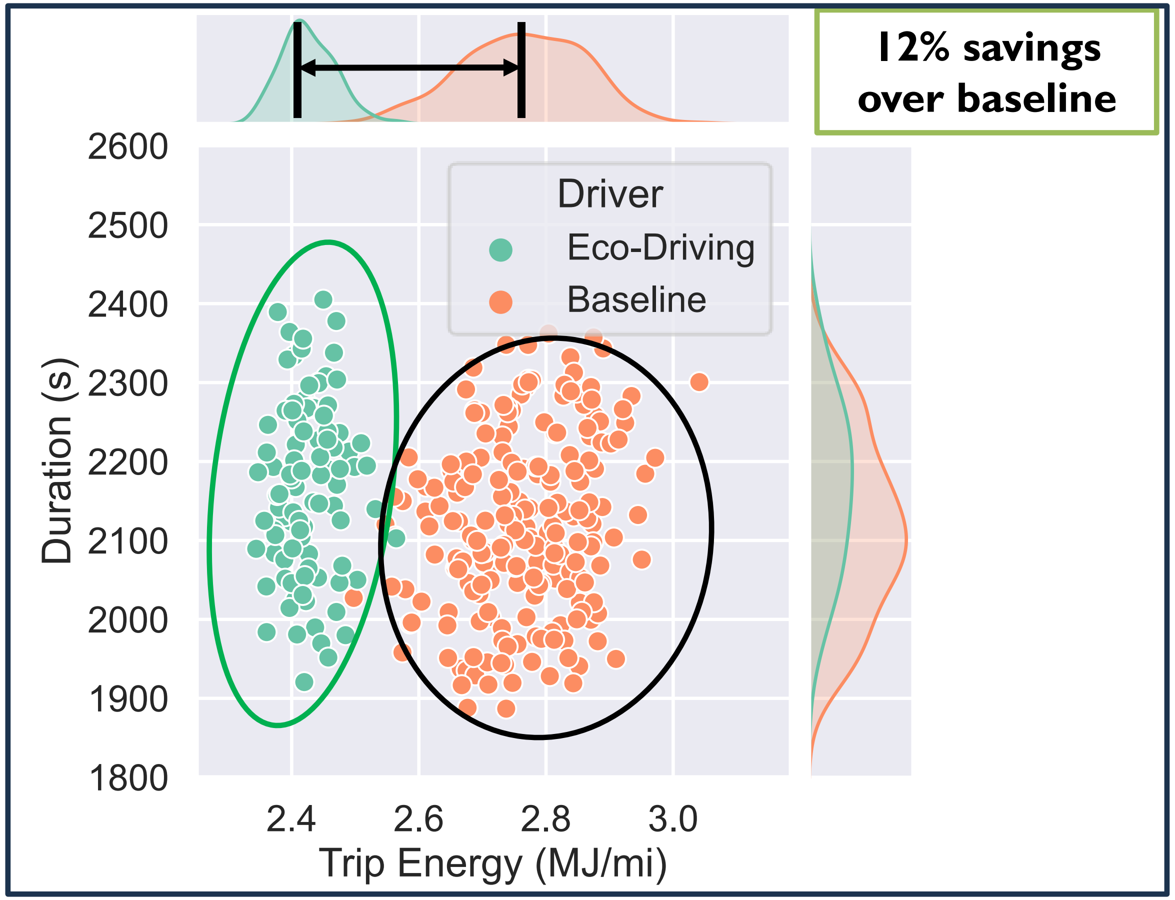
The information, data, or work presented herein was funded in part by the Advanced Research Projects Agency-Energy (ARPA-E), U.S. Department of Energy, under Award Number DE-AR0000837.

Study 1 – NEXTCAR II *Simulation Results*

Simulation Results ***[V2V + V2I]***



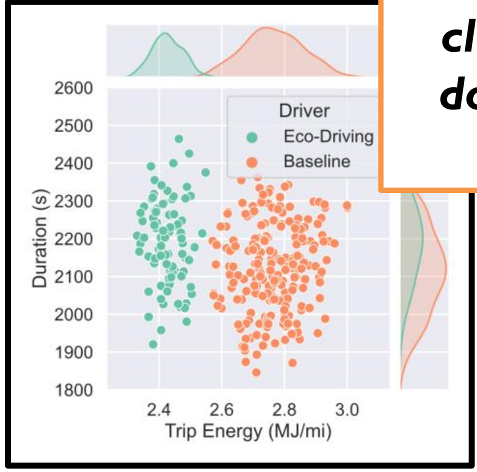
Simulation Results ***[Radar Only]***



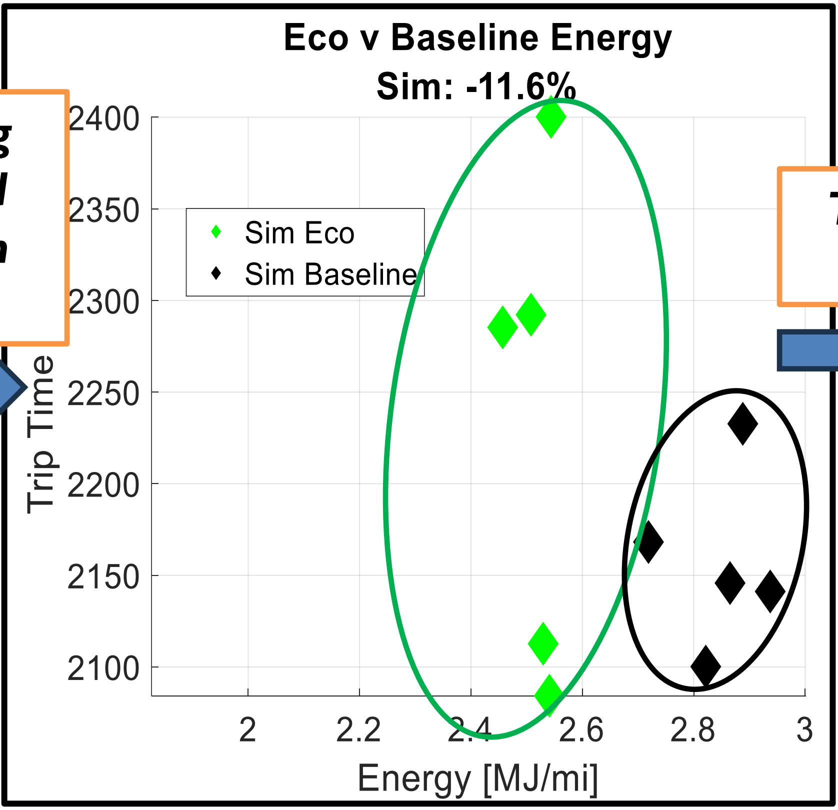
Radar only package can match "full" connectivity savings under certain scenarios

Study 1 – NEXTCAR II *Savings on Dyno*

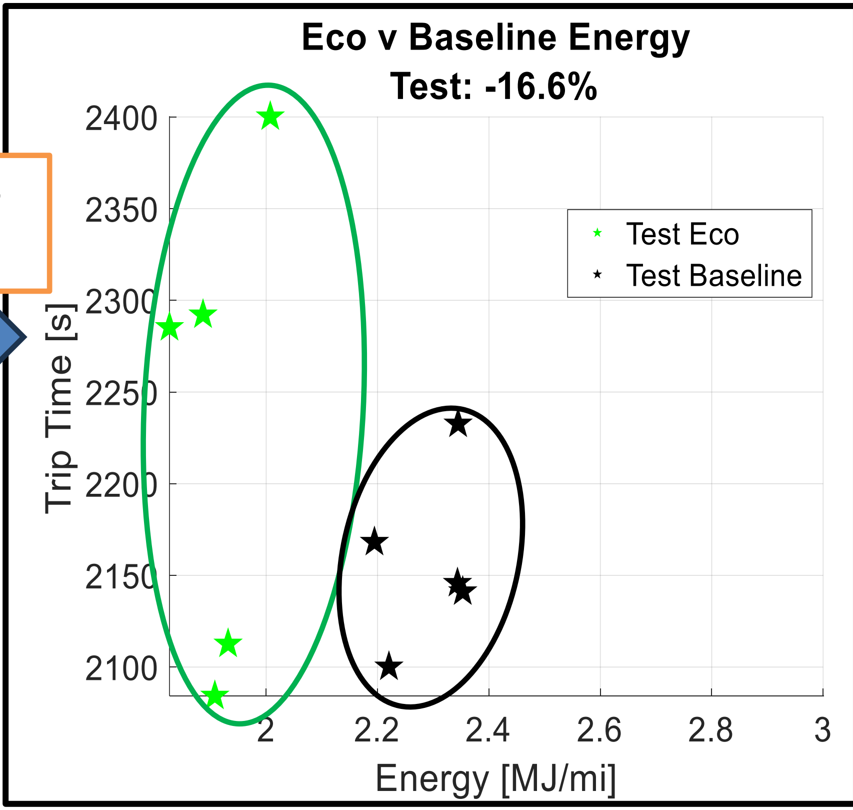
Downselected for Dyno Testing [V2V + V2I]



Sampled using clustering and downselection routine



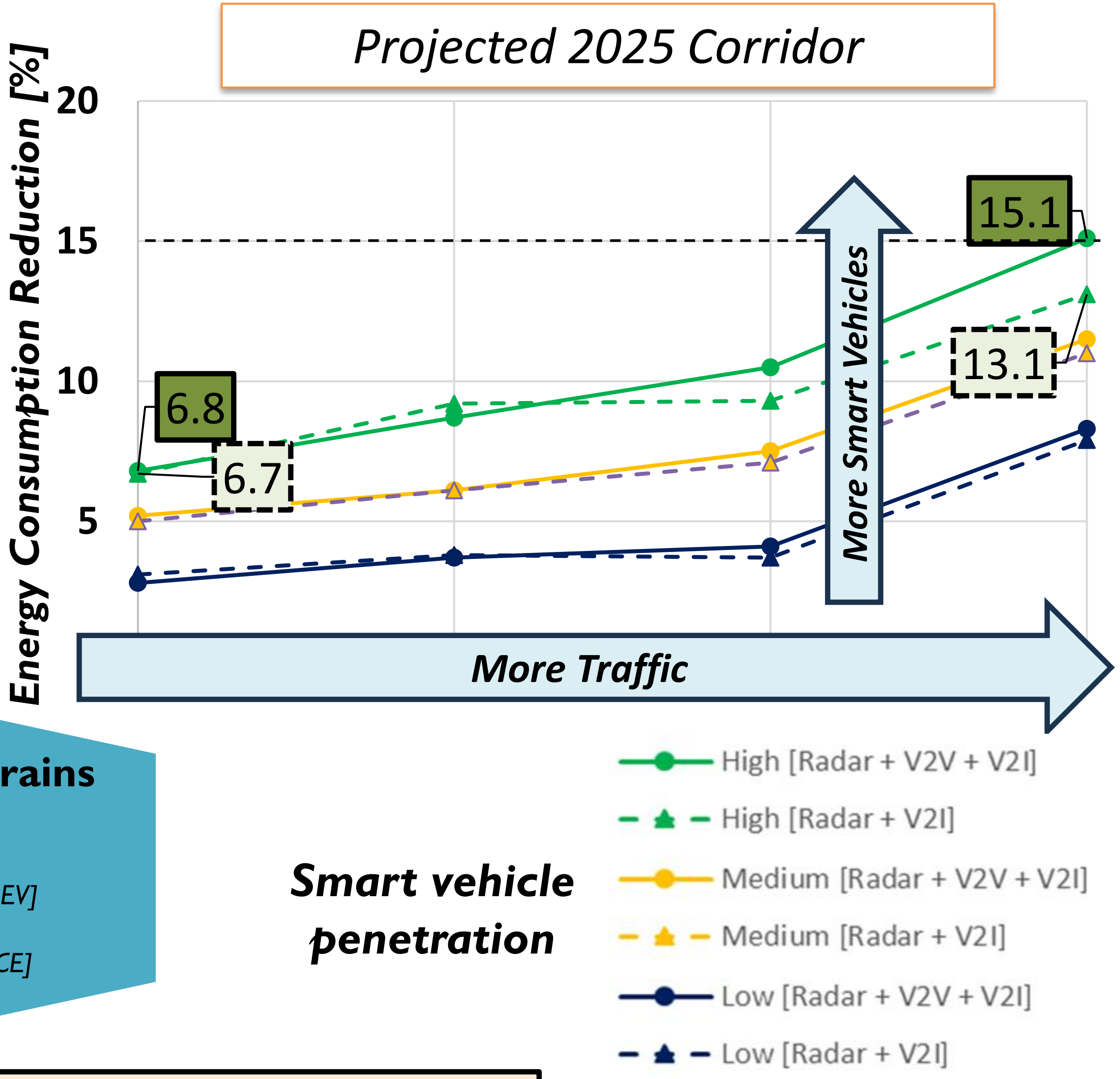
Test on Dyno



Savings for V2V and V2I case verified on dyno
Expect similar results for Radar only case

Study 2 – DOE EEMS *15% Savings at Corridor Level*

- **Funded by DOE VTO EEMS**
- **Consisted of doing traffic simulations like NEXTCAR**
  - *Difference*: Simulation Corridor from Columbus, Ohio
- **Performed ~92,000 powertrain simulation**



4 Levels of Smart Vehicle Penetration

2 Levels of Technology Penetration
- *V2V + V2I + Radar*
- *V2I + Radar*

4 Levels of Traffic Conditions

5 Powertrains
- *Model 3 [EV]*
- *Kia Soul [EV]*
- *Prius Prime [PHEV]*
- *Elantra [ICE]*
- *Chrysler 300 [ICE]*

Study 2: Different corridor, a few more vehicle types, and test cases

The information, data, or work presented herein was funded in part by the Vehicle Technology Office (VTO), U.S. Department of Energy, under Award Number DE-EE0008873.
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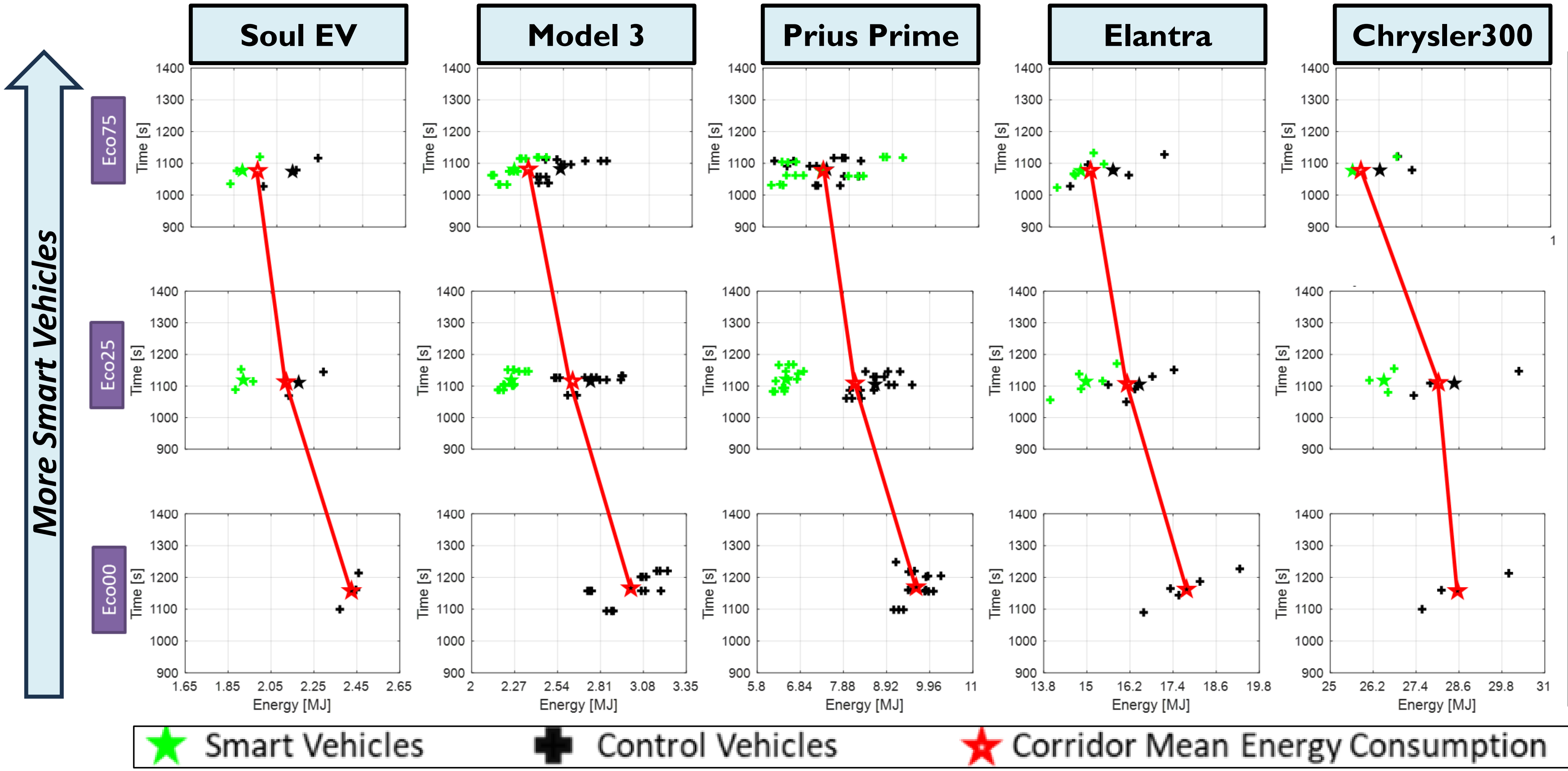
Study 2 – DOE EEMS

Positive Impact on Other Vehicles – Dyno Results



Smart vehicles are towards the left of baseline vehicles
→ More efficient

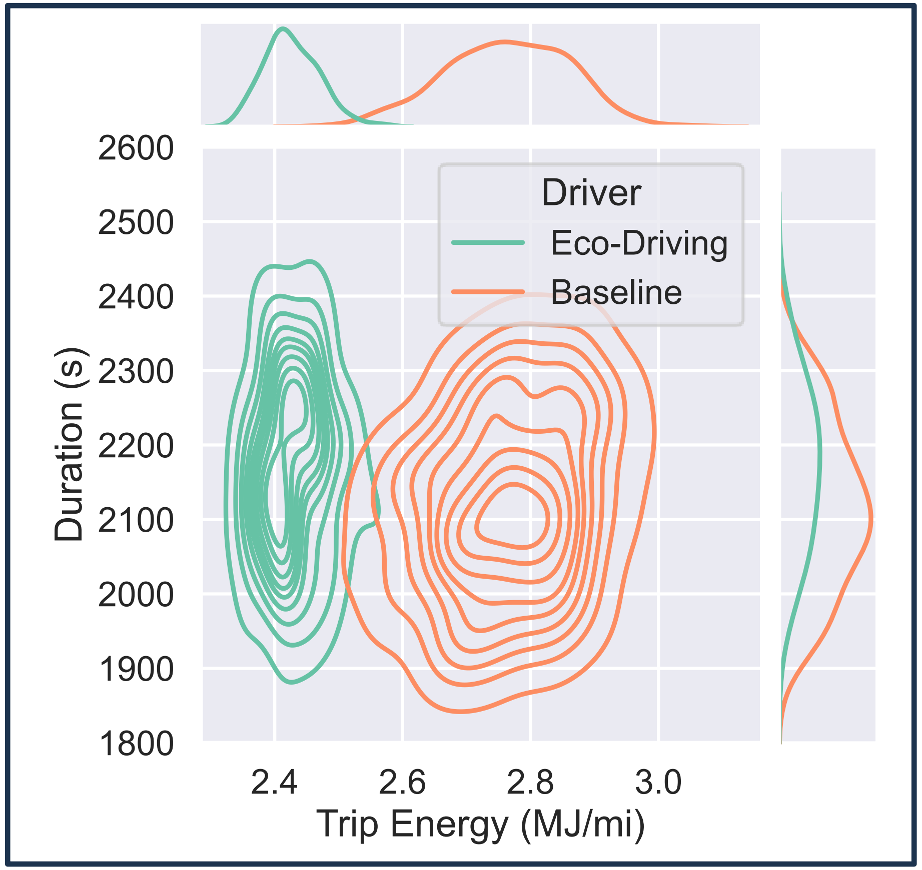
Black points move towards green points with more smart vehicles
→ All vehicles become more efficient

Summary

SwRI Eco-Driving Algorithm can enable appreciable energy savings

- **Potential for savings even cases with partial or no connectivity using**
  - Information available via current production sensor suite sufficient to enable savings
- **Verified savings on variety of powertrain types**
  - EV, HEV and ICE
- **Demonstrated savings on dyno**

Simulation Results
Study 1: Radar Only Case
12% Savings over baseline



Thank You!

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