Advanced GNSS Positioning for Cooperative Adaptive Cruise Control (CACC) Truck Platooning

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Outline

- Background and Motivation
- CACC System
  - Hardware Setup
  - DSRC radio communication
  - CACC algorithms and software
- Testing and Demonstrations
  - Phase II
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- Conclusions and Future Work

Background and Motivation

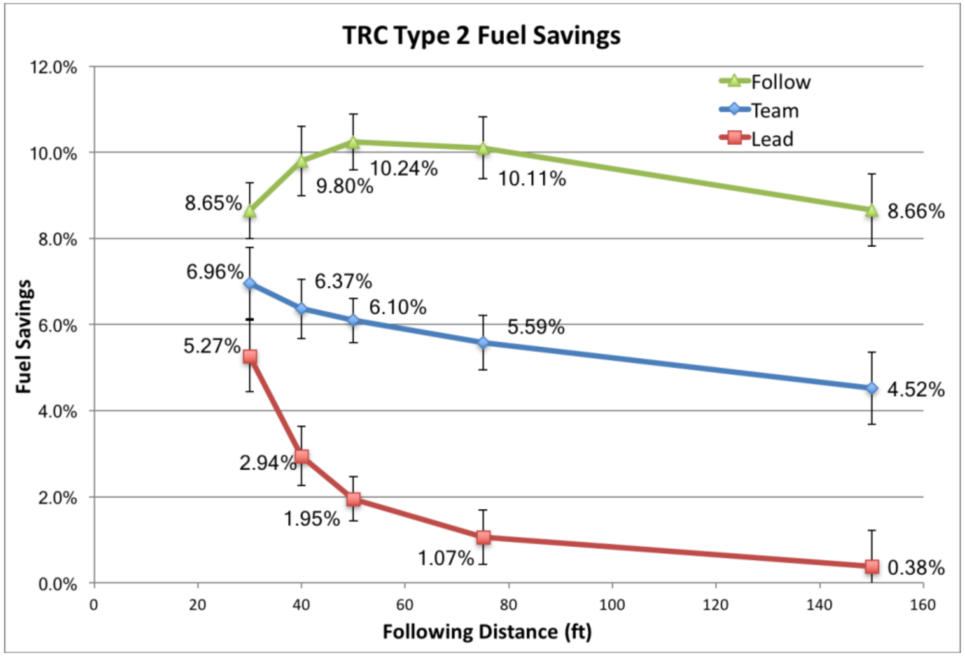
Background/Motivation

- Although combination trucks account for ~1% of all motor vehicles on US roads, these vehicles drive approximately 50,000 more miles than the next vehicle type [1]

- Decline of truck drivers, e.g. in the Canadian forestry industry [2]

Background/Motivation Cont.

- ATRI showed highest operational cost for truck fleets of all sectors was fuel usage, coming in at 38% of the total marginal operating cost [3]
- 36% of all freeway accidents occurred on entrance ramps [4]

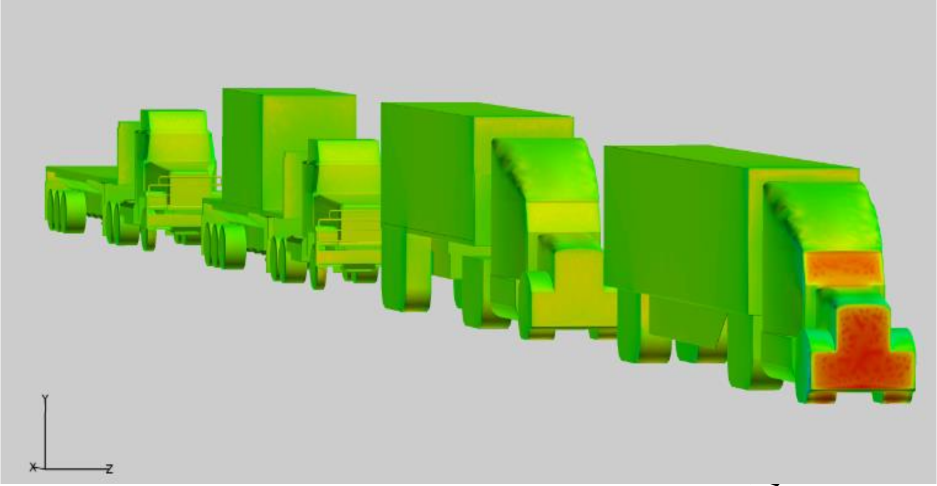


[5]

CACC System

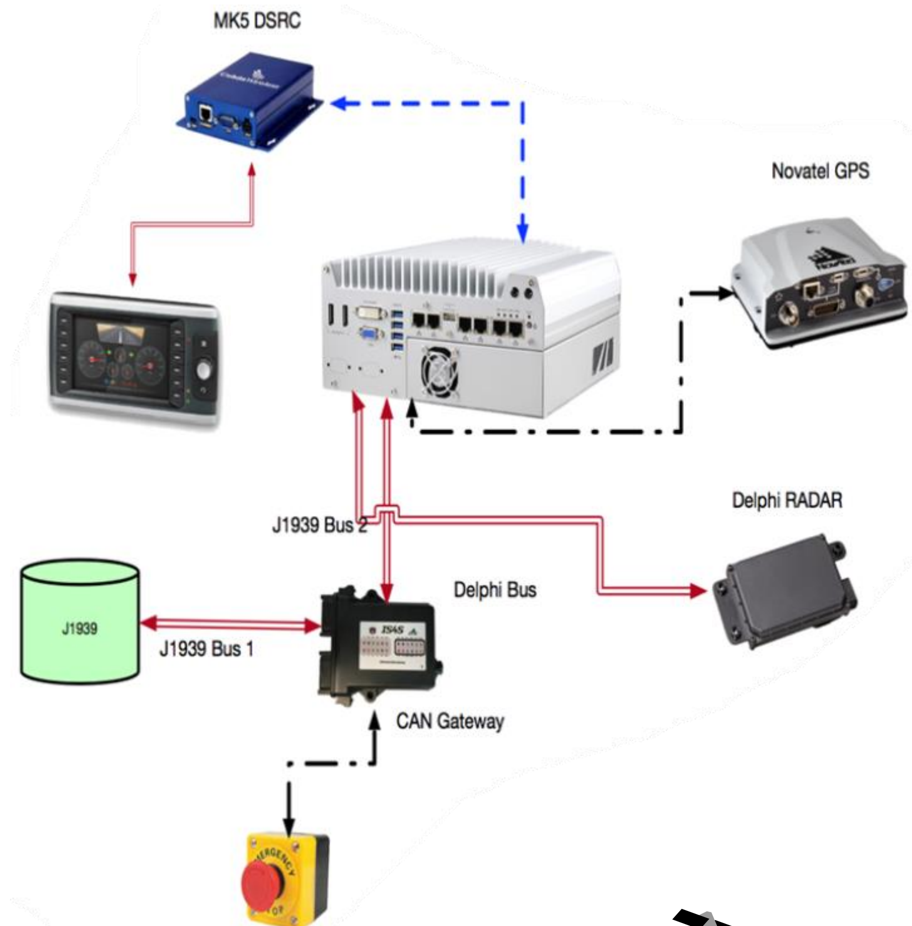
CACC Overview

- Cooperative Adaptive Cruise Control
- Extension of Adaptive Cruise Control (ACC)
- V2V network to share information
- Auburn's CACC system
  - Level 1 Autonomy
  - Longitudinal (throttle and braking) control
  - Manual steering



Hardware Setup

- System components
  - PC for vehicle interface and algorithms
  - DSRC radio
  - GPS receiver
  - Automotive radar
  - By-wire kill switch for disconnect from CAN bus
  - GUI Display



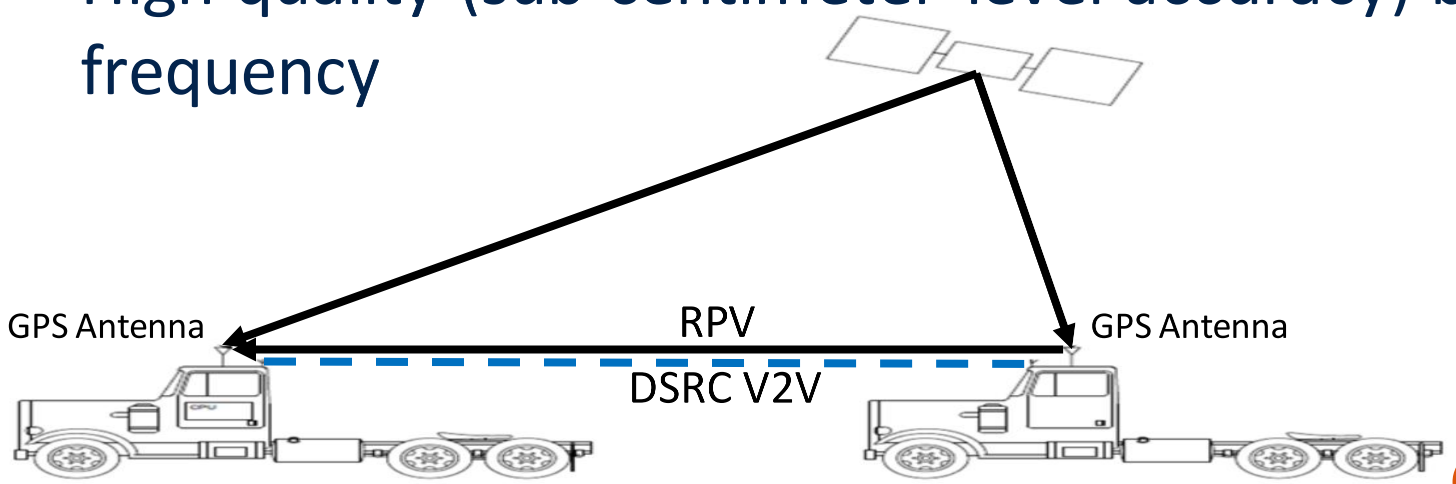
DSRC Radio Communication

- Dedicated Short Range Communication (DSRC)
- Current industry standard
- Developed two implementations
  - Denso
  - Cohda Wireless MK5
- Custom UDP data packet
  - Vehicle state information
  - Raw GPS observables

CACC Algorithms

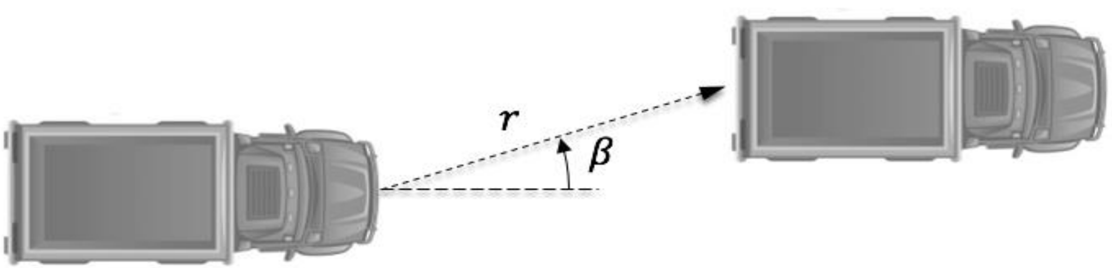
Range Estimation

- Dynamic-base Real Time Kinematic (DRTK) [6]
  - Differential GPS technique; extension of RTK
  - Uses GPS carrier phase measurements to calculate Relative Position Vector (RPV)
  - High quality (sub-centimeter level accuracy) but low frequency



CACC Algorithms

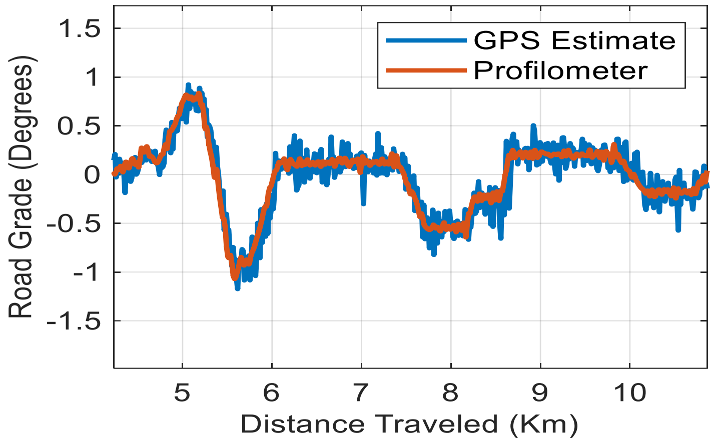
- Kalman Filter
  - Fuses complementary measurements of radar and DRTK
  - Produces reliable estimates of inter-vehicle range, range rate, and bearing
  - Track neighboring vehicles using radar and predict forward path for cut-in detection [7]

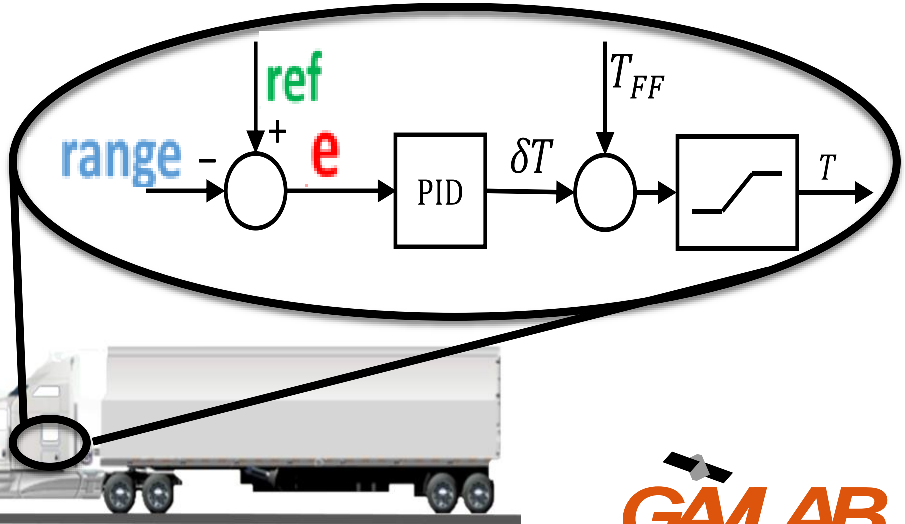


CACC Algorithms

Control System

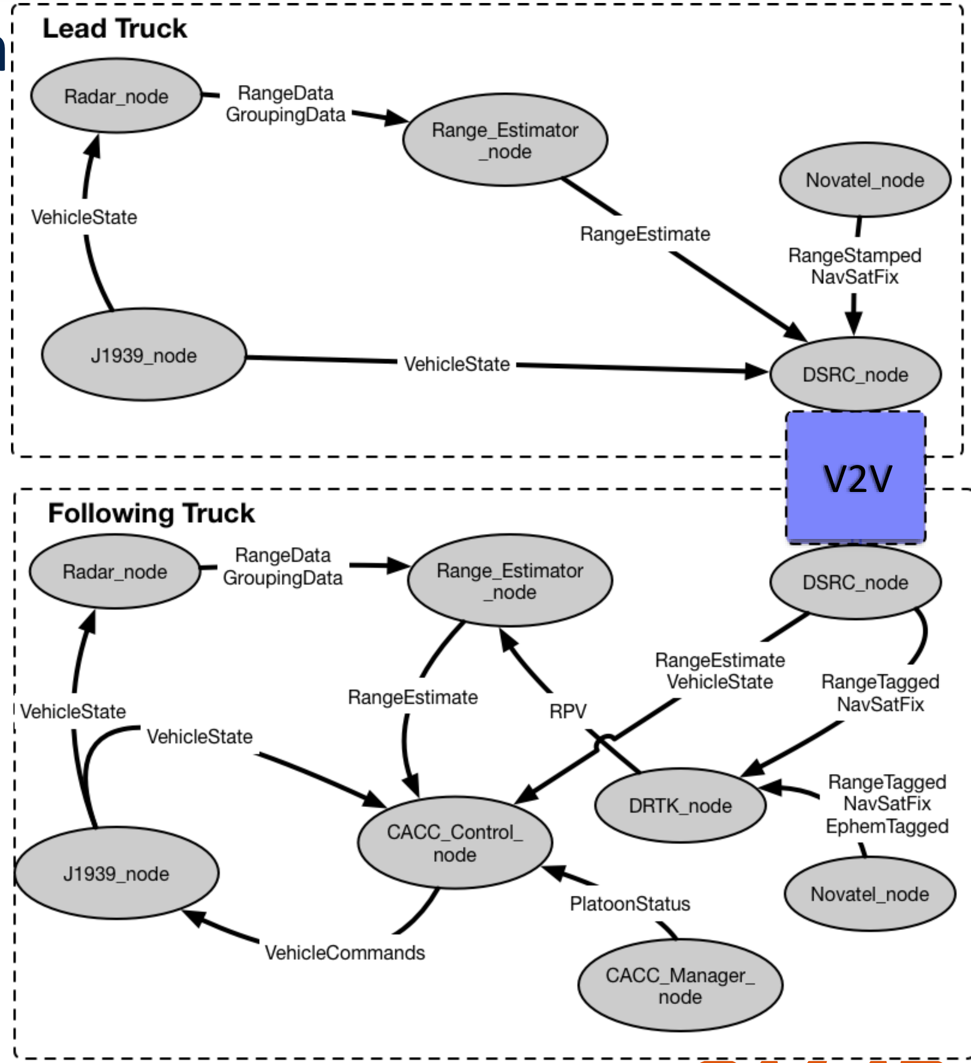
- Longitudinal headway, or gap, controller
- PID with feedforward control
- Feedforward $F_{RR}, F_{air\ drag}, F_{grade}$





CACC Software

- Real time implemented in ROS architecture [8]
  - Sensor/hardware Drivers
    - J1939 CAN
    - Delphi ESR Radar
    - Novatel GPS
    - DSRC V2V communications
  - Controller and Estimation
    - Range Estimation filter
    - DRTK RPV filter
    - CACC control Node
    - Convoy Manager



Testing and Demonstrations

Phase II

Phase IIC

- Blue Water Bridge Crossing
- October 5, 2017 in Port Huron, Michigan
- Convoy across bridge from USA to Canada and back for VIP event

Phase II Cont.

Phase IIB

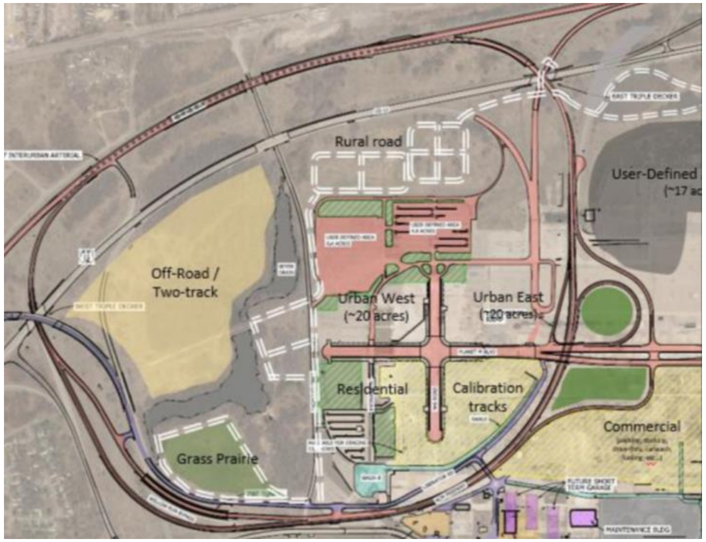
- Truck Platooning on highway I-69 in Michigan
- October 16-19, 2017
- Convoy tests for controller validation
  - Spacing: 50, 75, 100, and 200 ft.
  - Speed: 55 mph

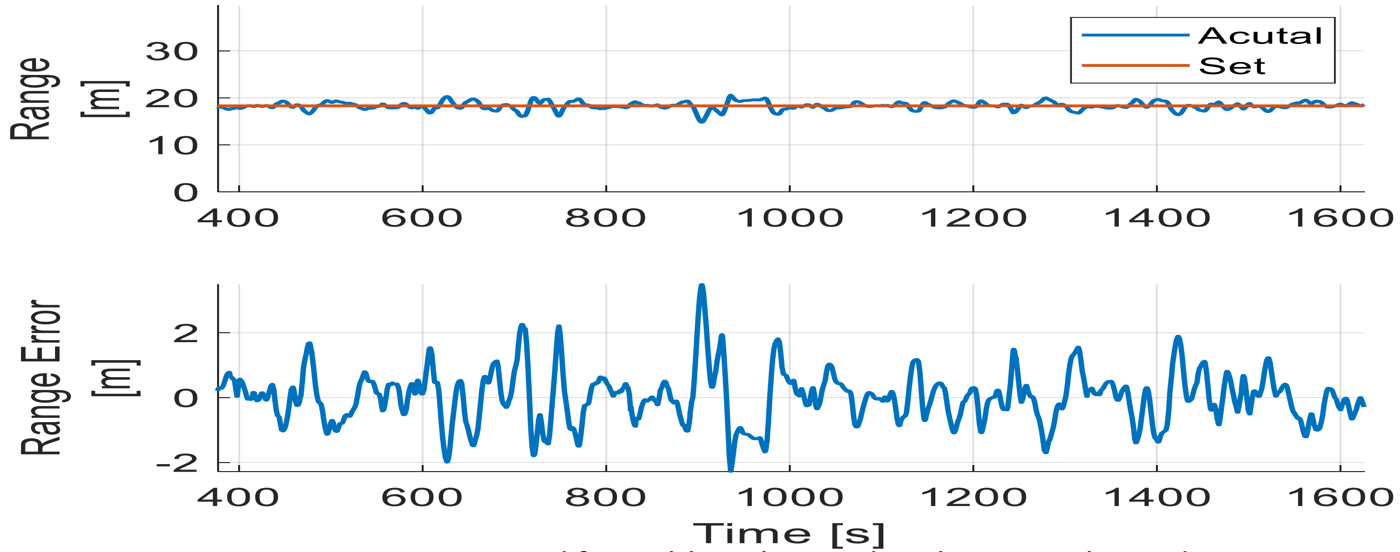
Phase II Cont.

- Demonstration totals during testing:
  - Operation time: ~3.5 hours
  - Distance: >170 miles

Phase III

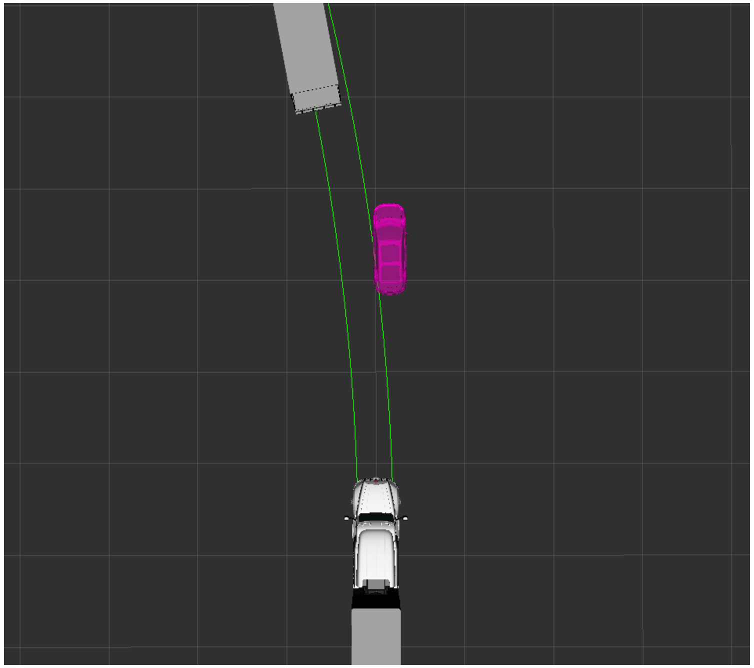
- October 22-27, 2018
- Four vehicle platoon
- Longitudinal control, vehicle cut-ins, and connected vehicle merging





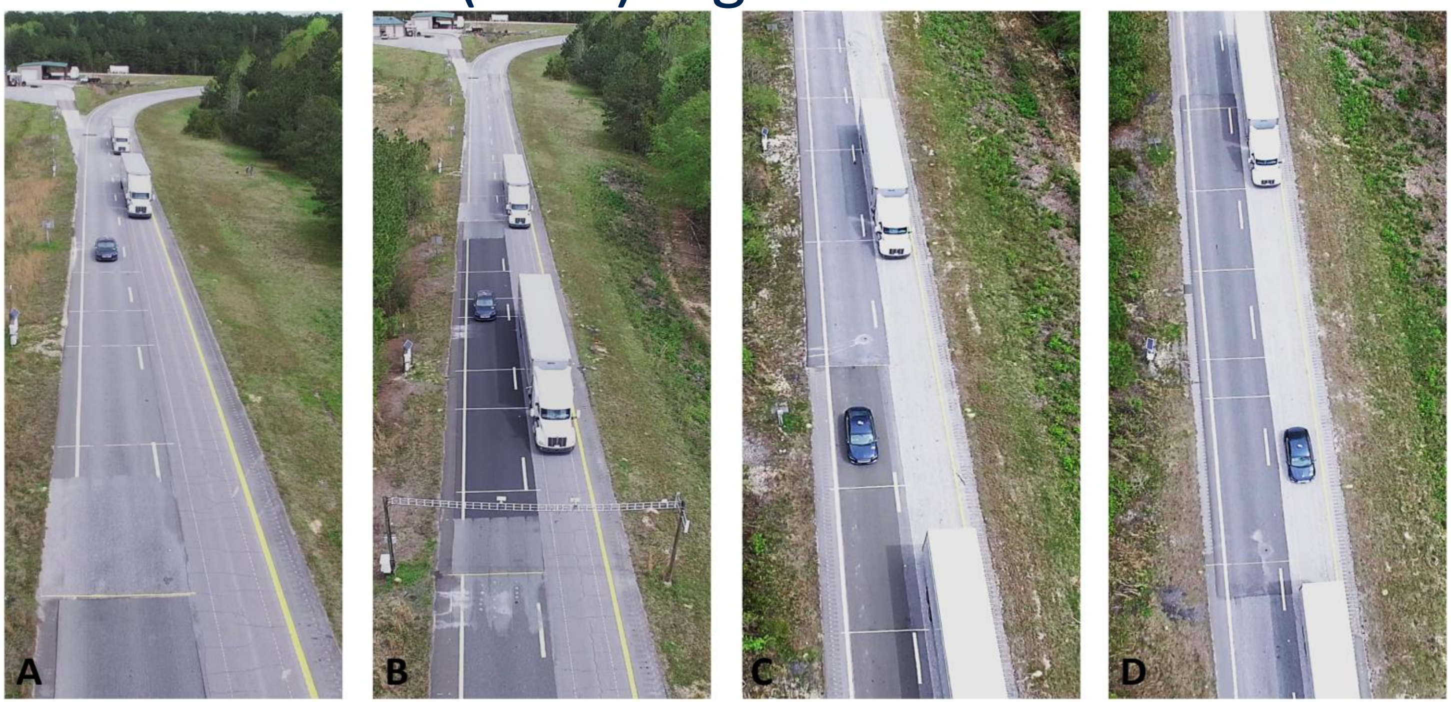
Phase III Cont.

- Cut-in detection
  - Track neighboring vehicles
  - Project forward path and determine if vehicle is inside
  - Fall back to safe distance
  - Range off cut-in; maintain DRTK to leader



Phase III Cont.

- Connected vehicle merging
  - GPS position/velocity, merge point/speed limit known
  - Estimate time to merge point
  - First In First Out (FIFO) logic



Phase III Cont.

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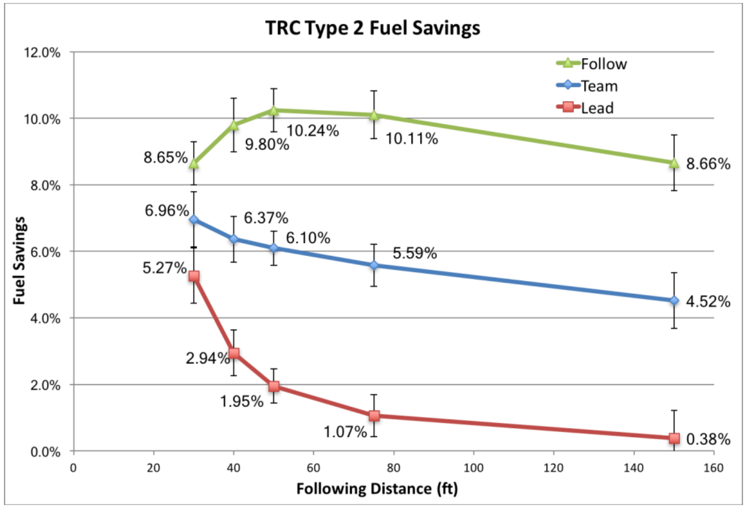
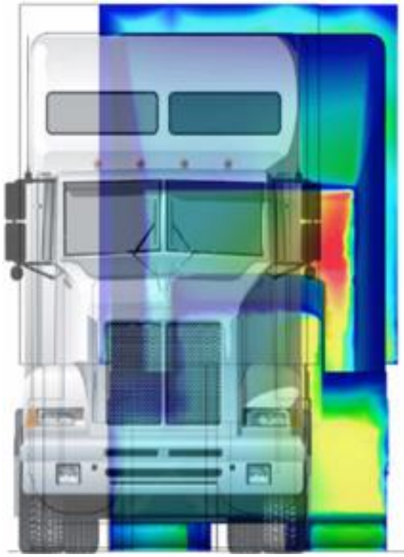
Conclusions and Future Work

Conclusions/Future Work

- Successfully developed and implemented a CACC system
- Demonstrated capabilities that have potential safety, fuel benefits
- Future work:
  - Level 2 Autonomy (lateral control)
  - Fuel testing
  - Optimal platoon configuration and terrain





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Acknowledgements

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Questions?

Thank You!

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