Truck CACC Fuel Economy Testing: Initial Test Track Results

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TRB Vehicle-Highway Automation Committee Meeting

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Transport Canada Transports Canada

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ACKNOWLEDGEMENTS

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Environment and Climate Change Canada

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Outline

- Background
- CACC Control System Design
- Test Scenarios
- Test Procedures
- Test Results (Weighing Fuel Tanks)
- Alternate Analysis (without Weighing Tanks)
- Conclusions

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Project Background

- **Cooperative Truck Platooning**
  - **The prototype system tested is based on Cooperative Adaptive Cruise Control (CACC) technology**
  - **Multiple vehicles using 5.9 GHz DSRC based V2V communications and forward sensors to help maintain a constant distance between vehicles**
- **Potential Benefits**
  - **Improved fuel economy**
  - **Reduced emissions**
  - **Improved road-use efficiency**
  - **Reduce driver workload**

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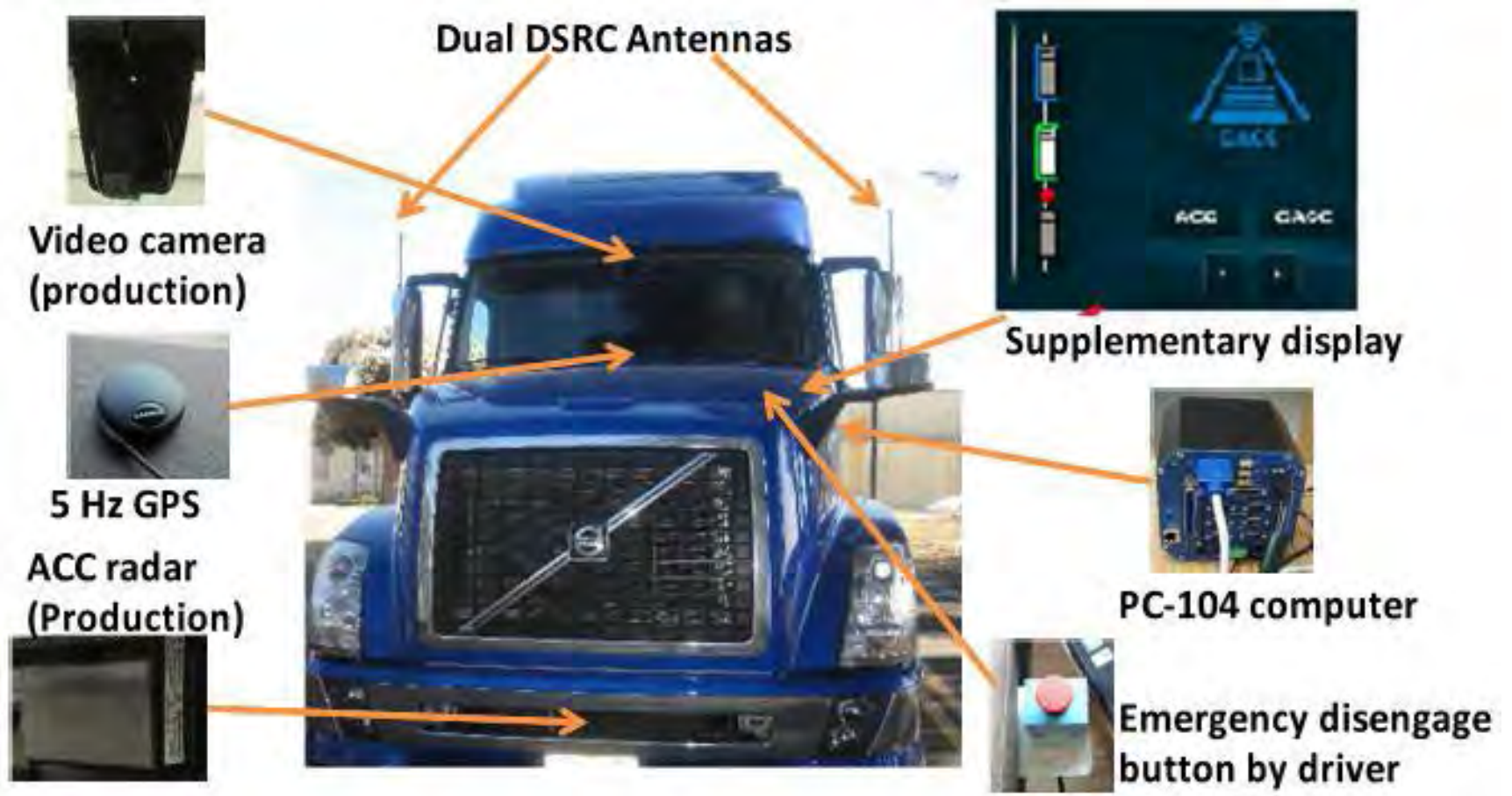
CACC Control System Design – System Structure



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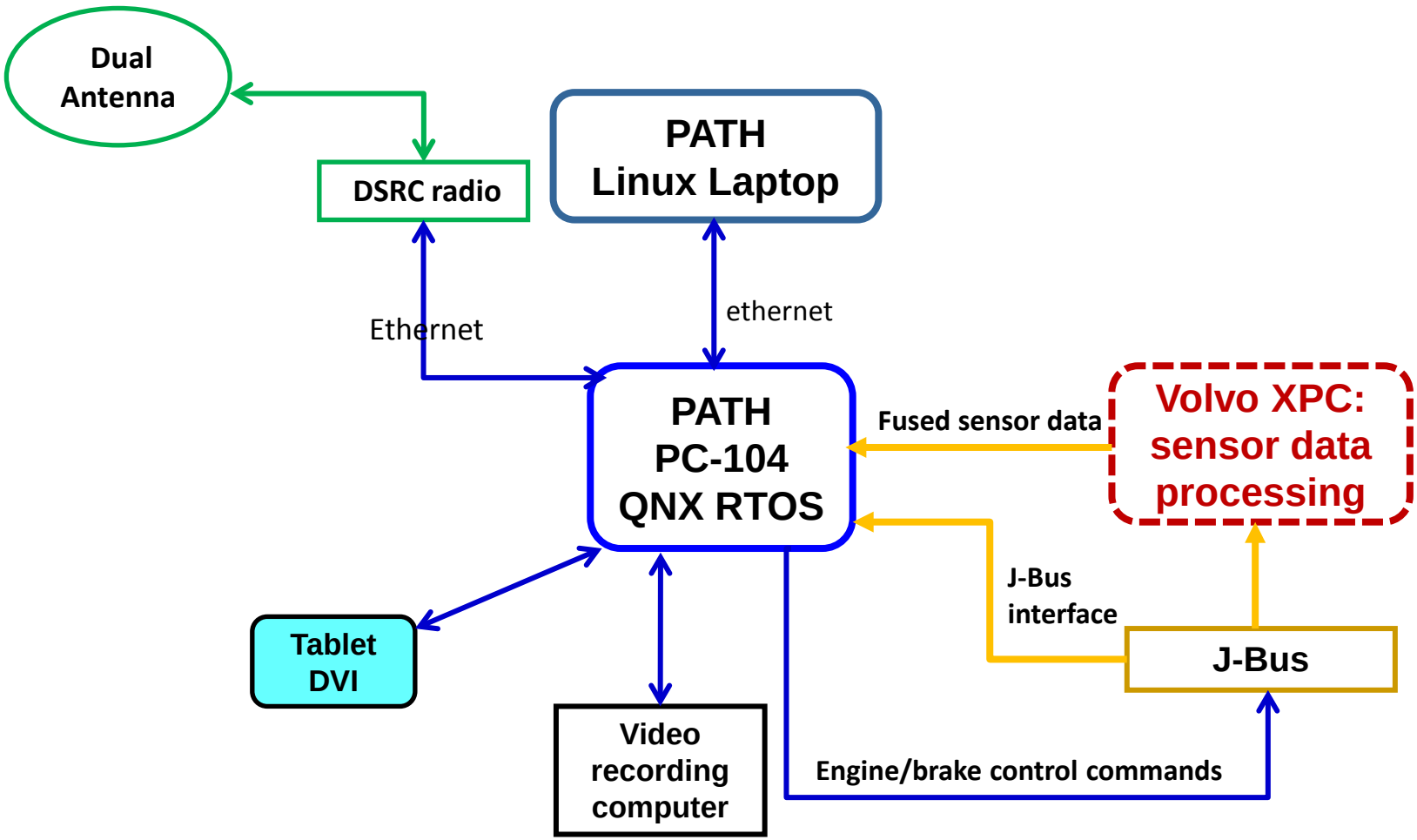
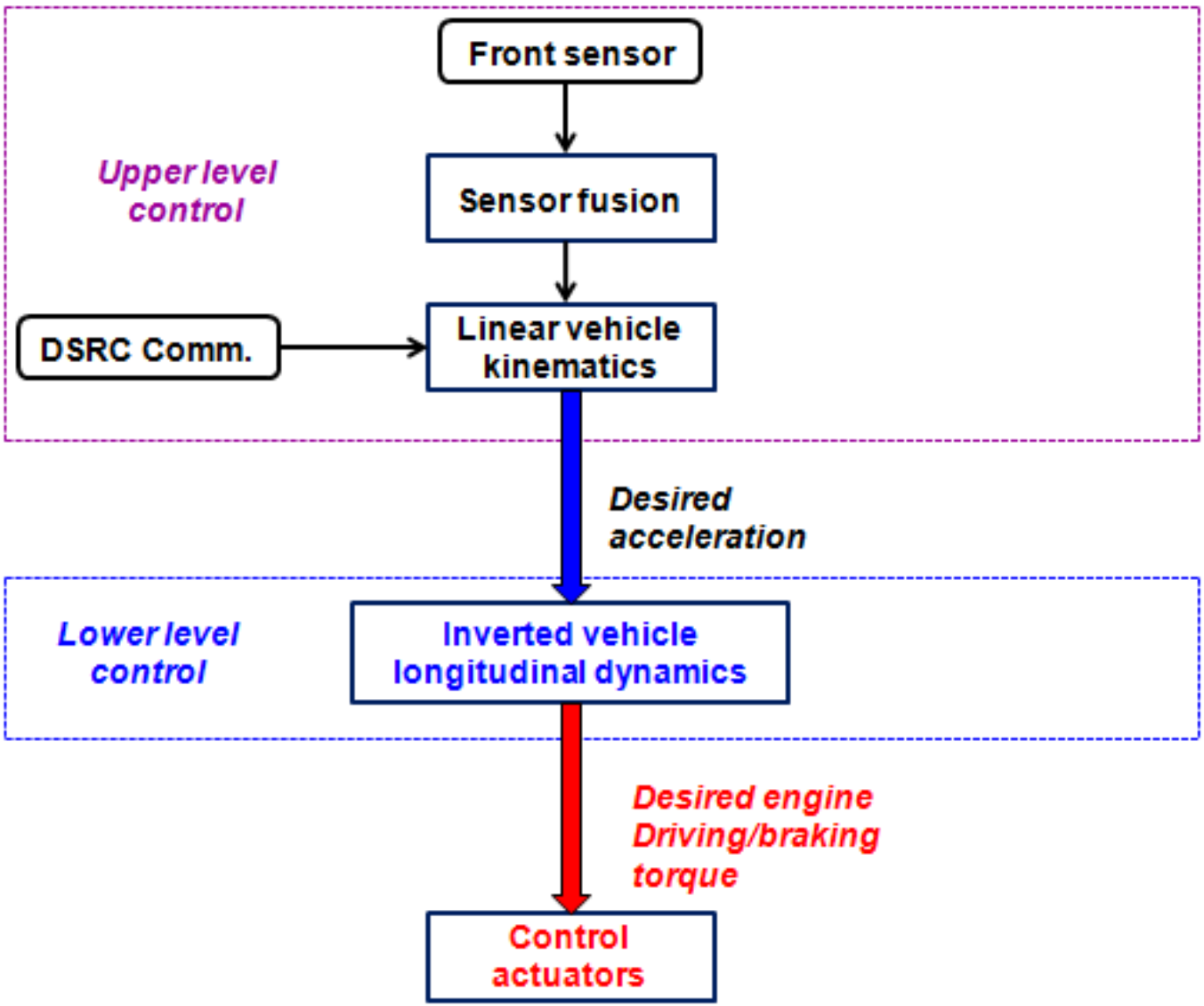
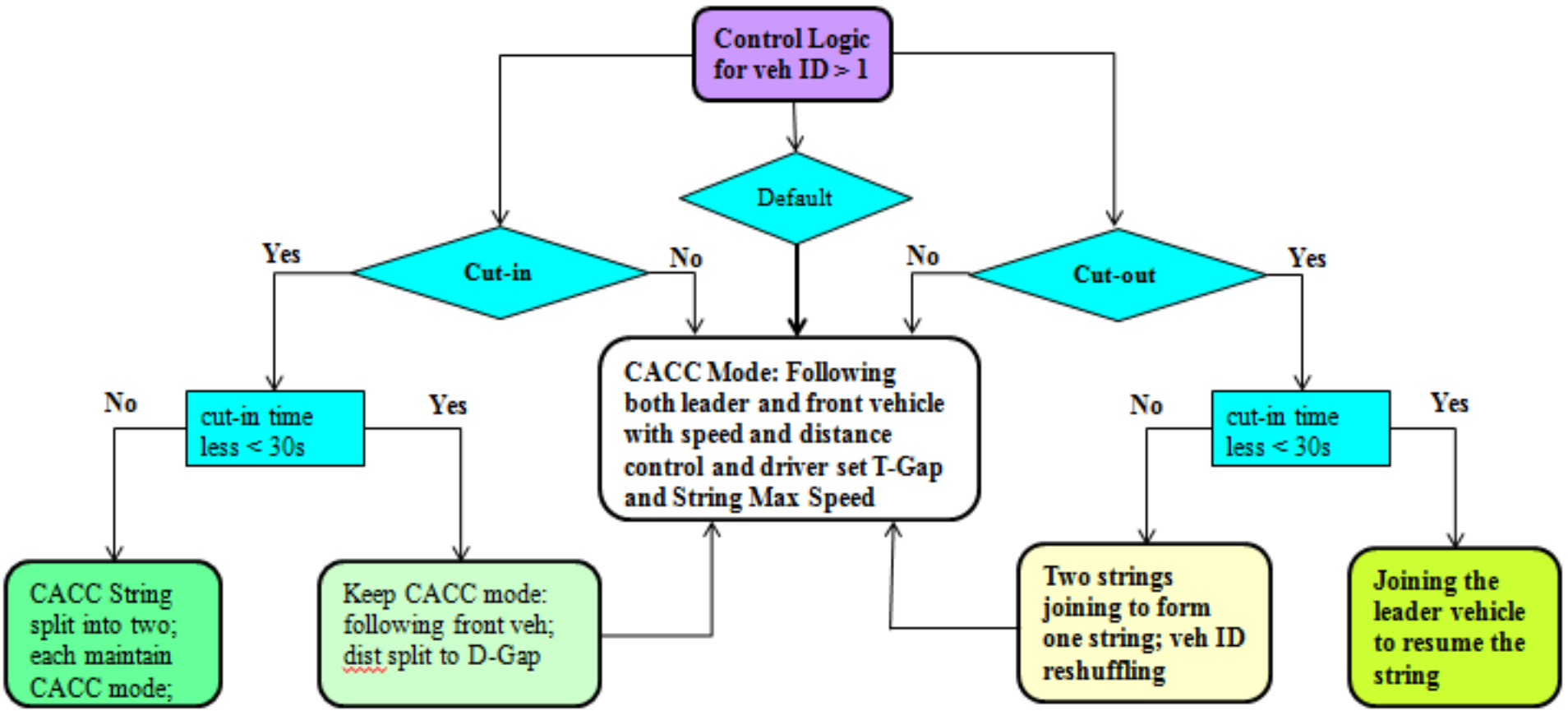
CACC Control System Design – System Structure



CACC Control System Design – Control System



CACC Control System Design – CACC



Truck CACC Test Scenarios

- **Fuel consumption measurements based on SAE J1321**
  - **Time Gap (T-Gap):**
    - **1.5s, 1.2s, 0.9s, 0.6s**
  - **Standard trailer vs. aerodynamic trailer**
    - **Boat tails & Side skirts**
  - **With/without ballast (rolling resistance)**
    - **65,000lbs & 29,000 lbs**
  - **Maximum speed:**
    - **65mph vs. 55mph**

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Test Procedures

- **Synchronized operation of 3 trucks using CACC**
- **A manually driven control truck followed 2 miles behind (as baseline for variations in ambient conditions)**
- **Single truck constant speed reference runs, 4 trucks drove 1 mile apart**
- **Weighed auxiliary fuel tanks of all trucks after each run (64 miles)**
- **Each condition repeated 4 times to produce average fuel consumption estimates**

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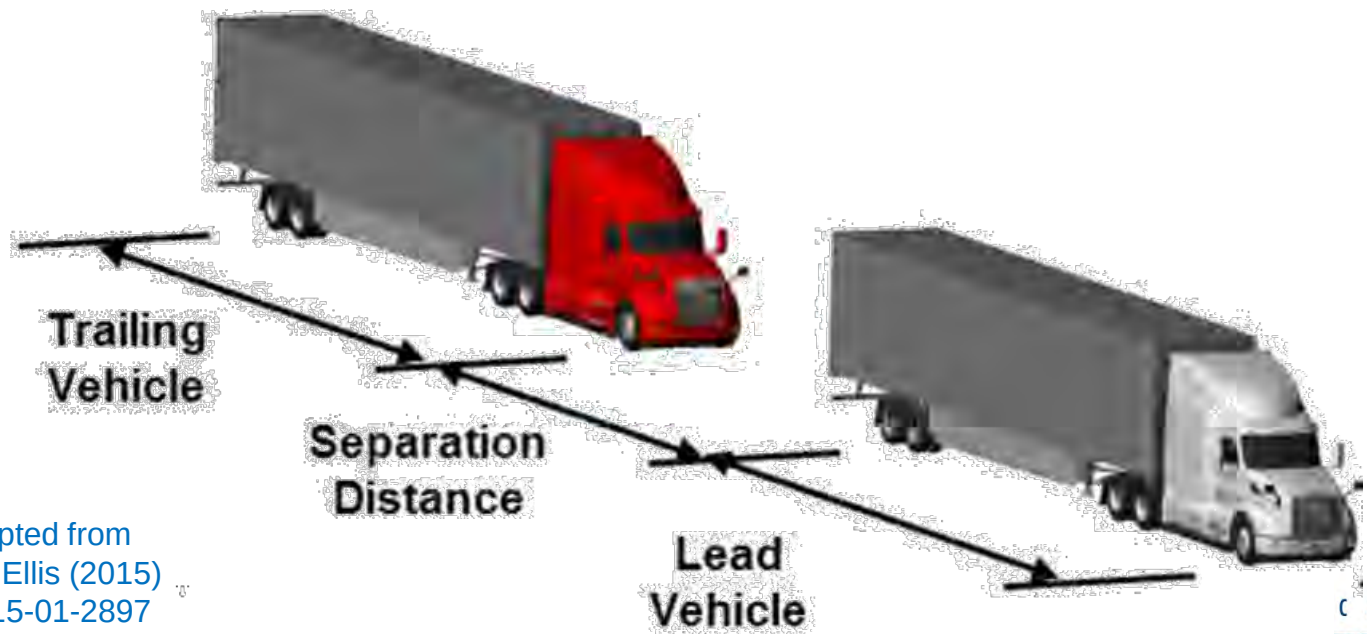
Aerodynamics of Cooperative Truck Platooning

- **As vehicles approach, they influence the flow-field around each other**



Schematic adapted from
Mihelic, Smith, Ellis (2015)
SAE Paper 2015-01-2897

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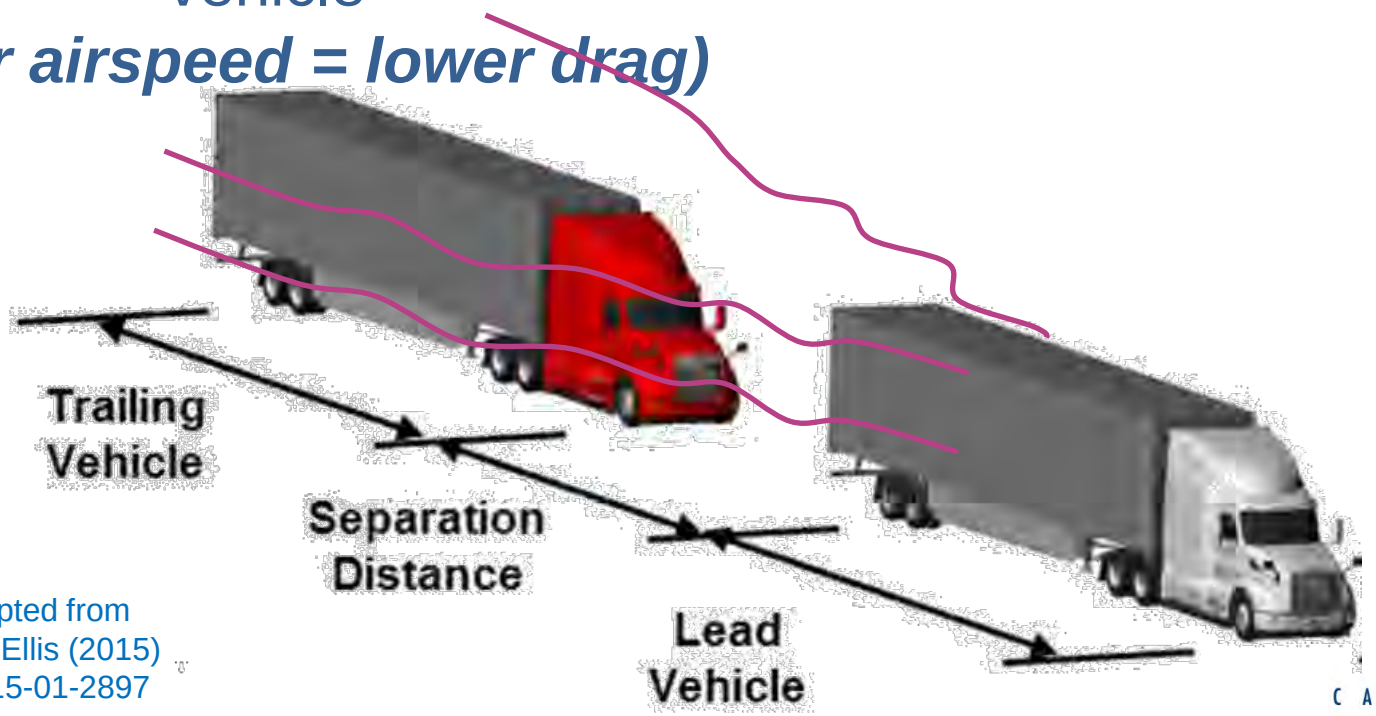
Aerodynamics of Cooperative Truck Platooning

- **As vehicles approach, they influence the flow-field around each other**

Low-speed air-wake of lead vehicle influences trailing vehicle

(lower airspeed = lower drag)



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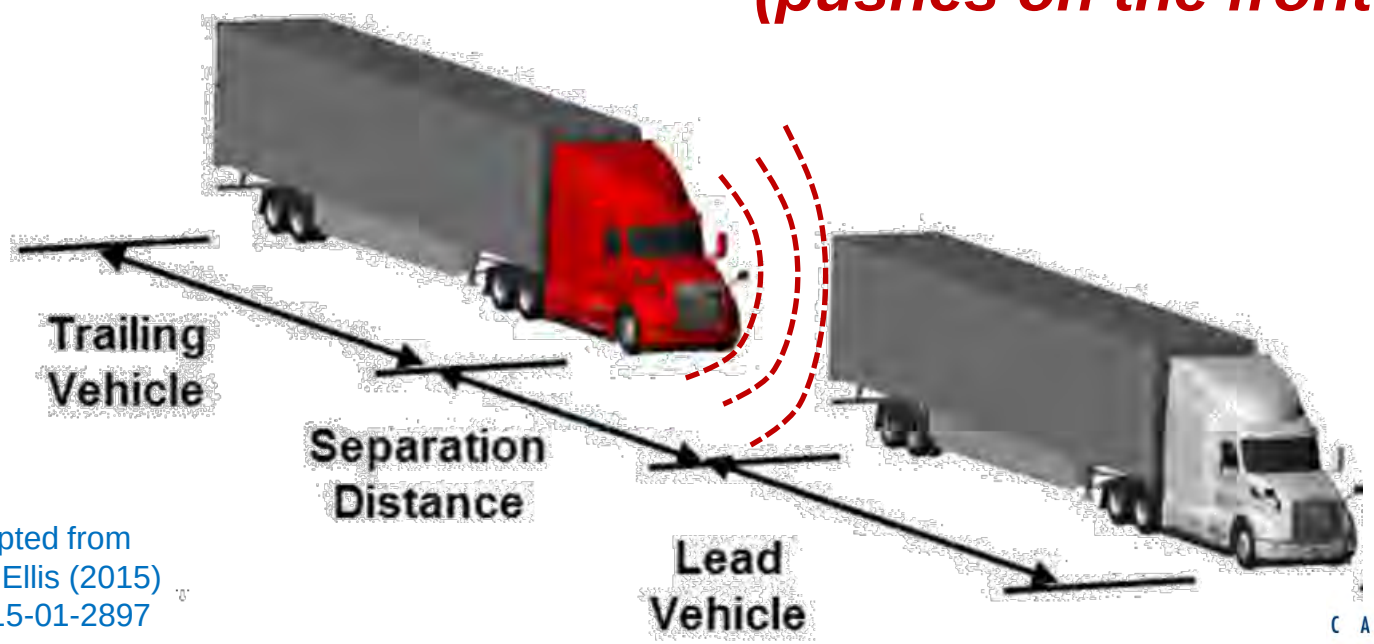
Aerodynamics of Cooperative Truck Platooning

- **As vehicles approach, they influence the flow-field around each other**

High-pressure zone in front of trailing vehicle influences lead vehicle
(pushes on the front vehicle)



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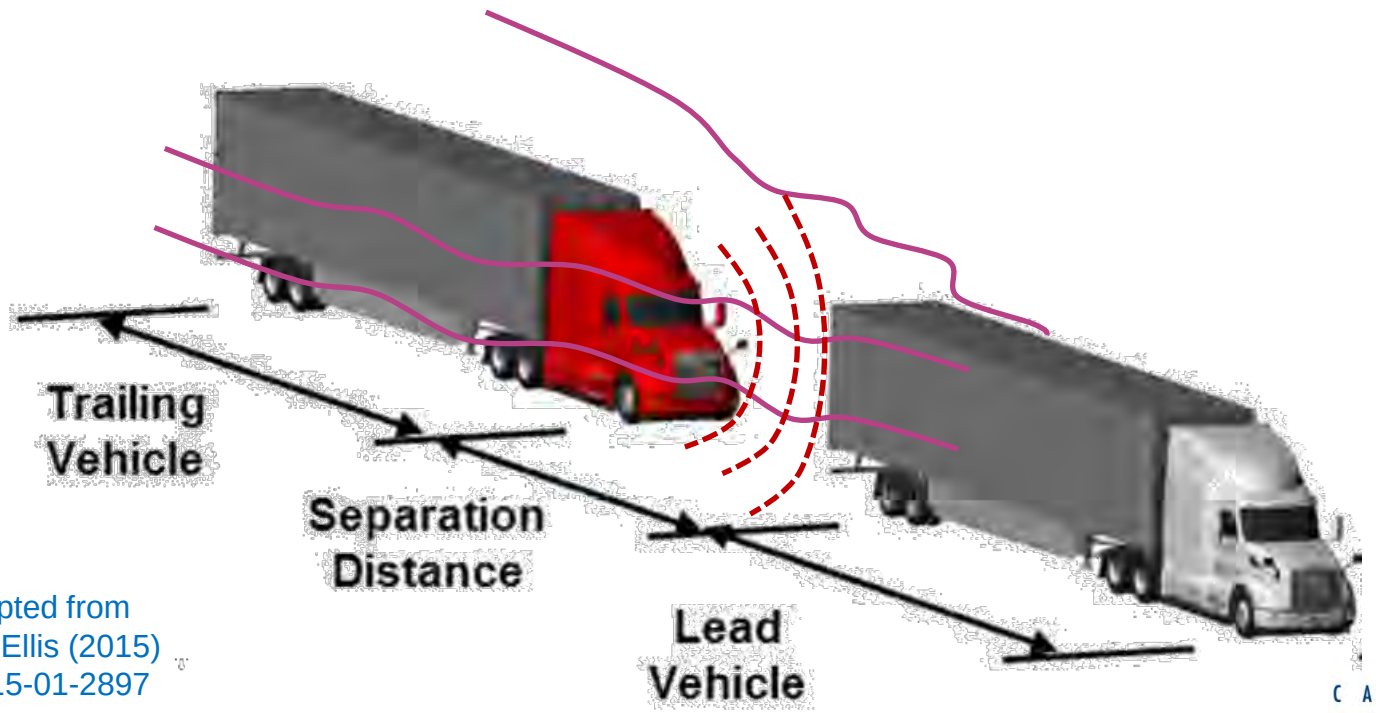
Aerodynamics of Cooperative Truck Platooning

- **As vehicles approach, they influence the flow-field around each other**

Magnitude of each effect is dependent on separation distance!



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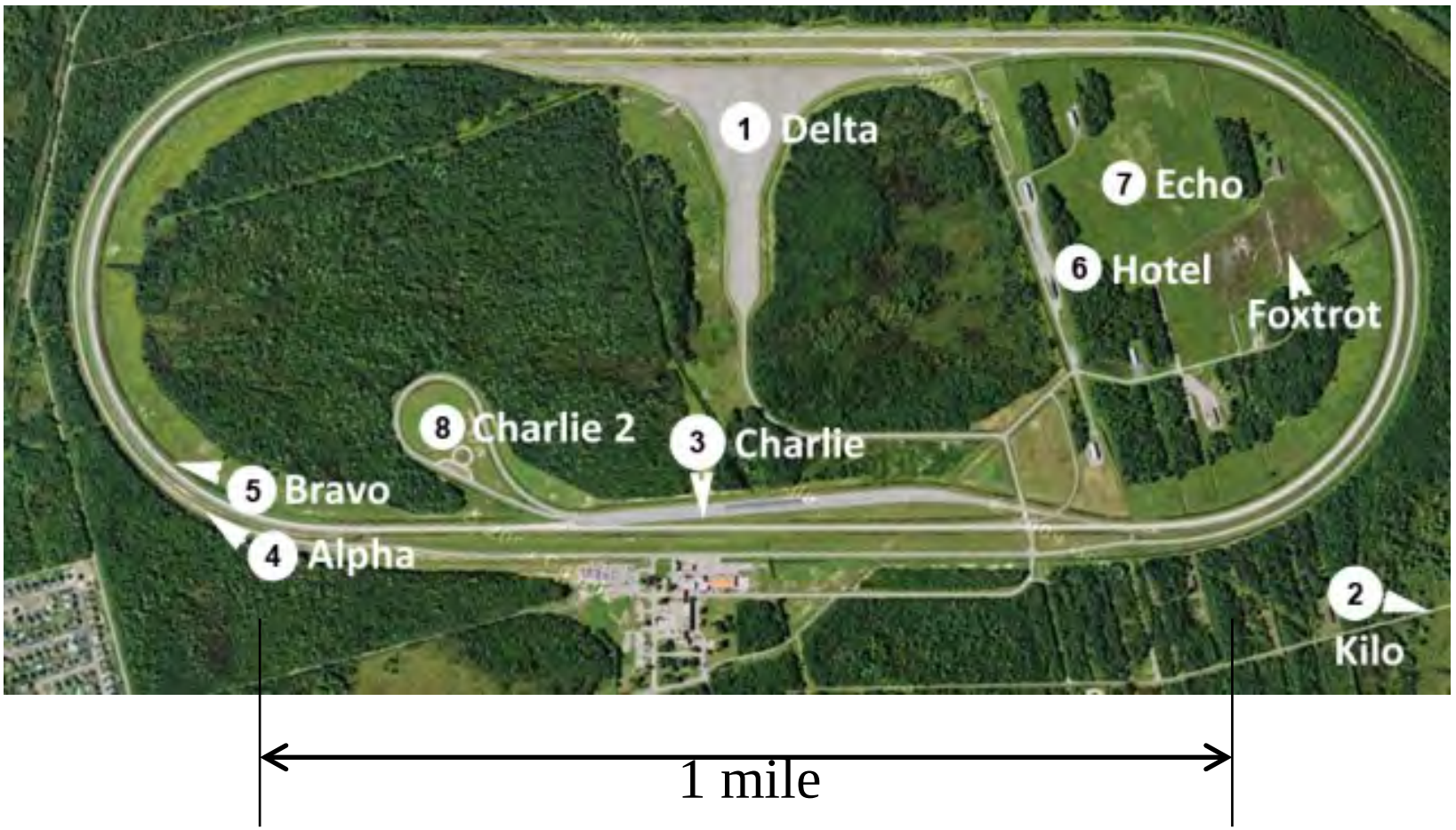
Transport Canada's Motor Vehicle Test Centre, Blainville, Québec



- Northern suburb of Montreal

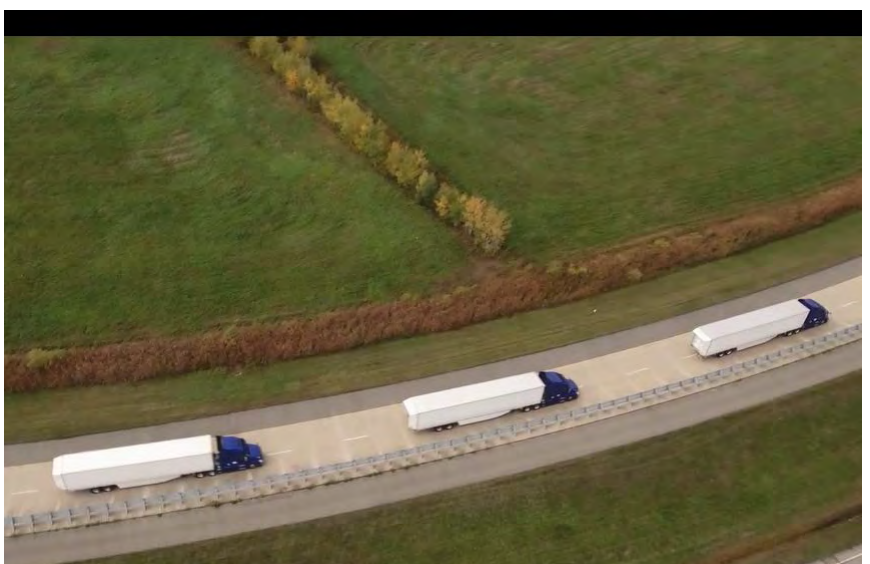
Boat Tail and Side Skirts

Fuel Tank Removal/Mounting

Load cell on fork lift for tank weighing

CACC 0.6s Gap @ 65 mph

CACC 0.6s Gap @ 65 mph



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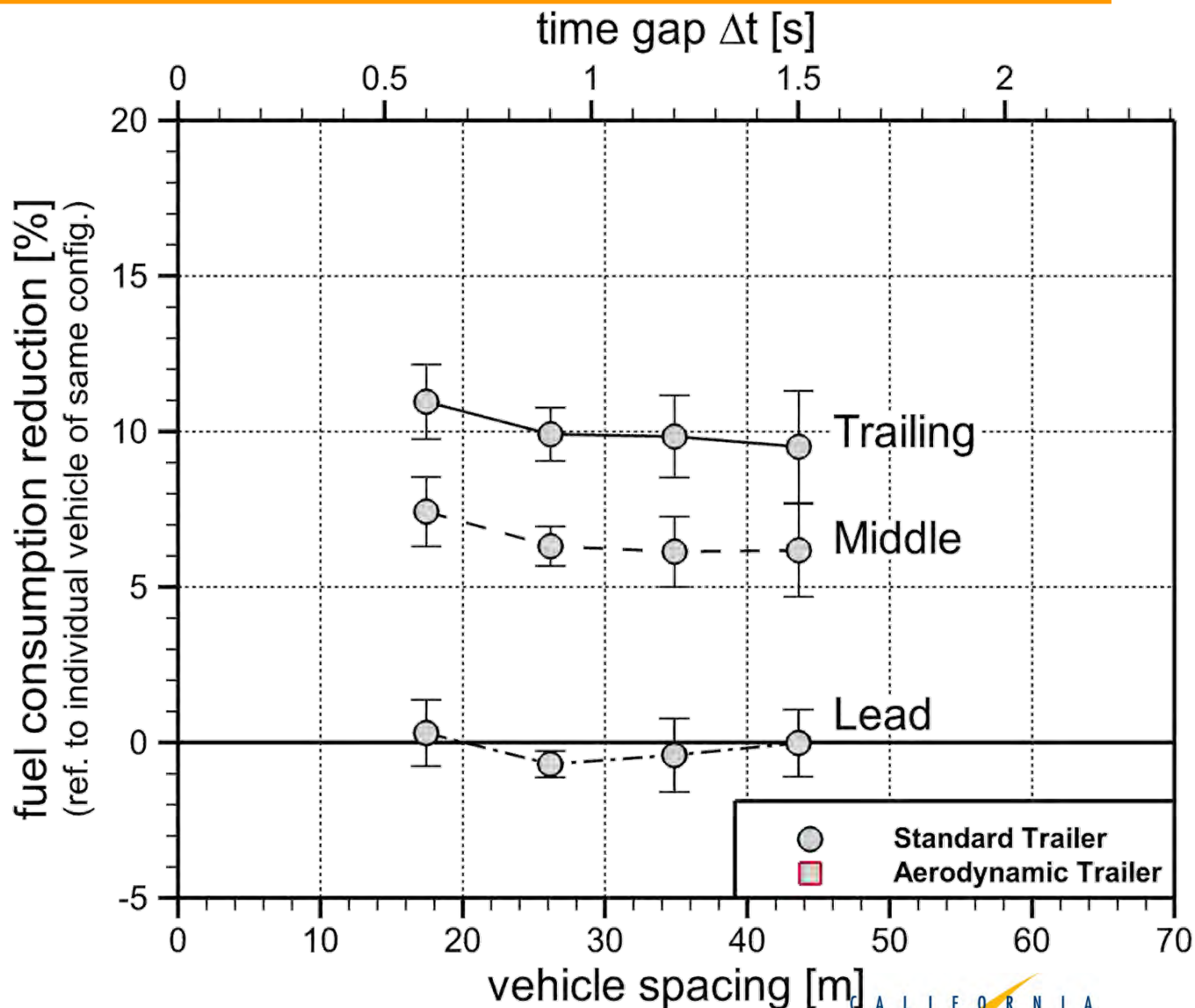
Test Results - NRC Canada Fuel Saving Estimates (65 mph + 65,000 lbs)

Fuel Savings for Individual Trucks



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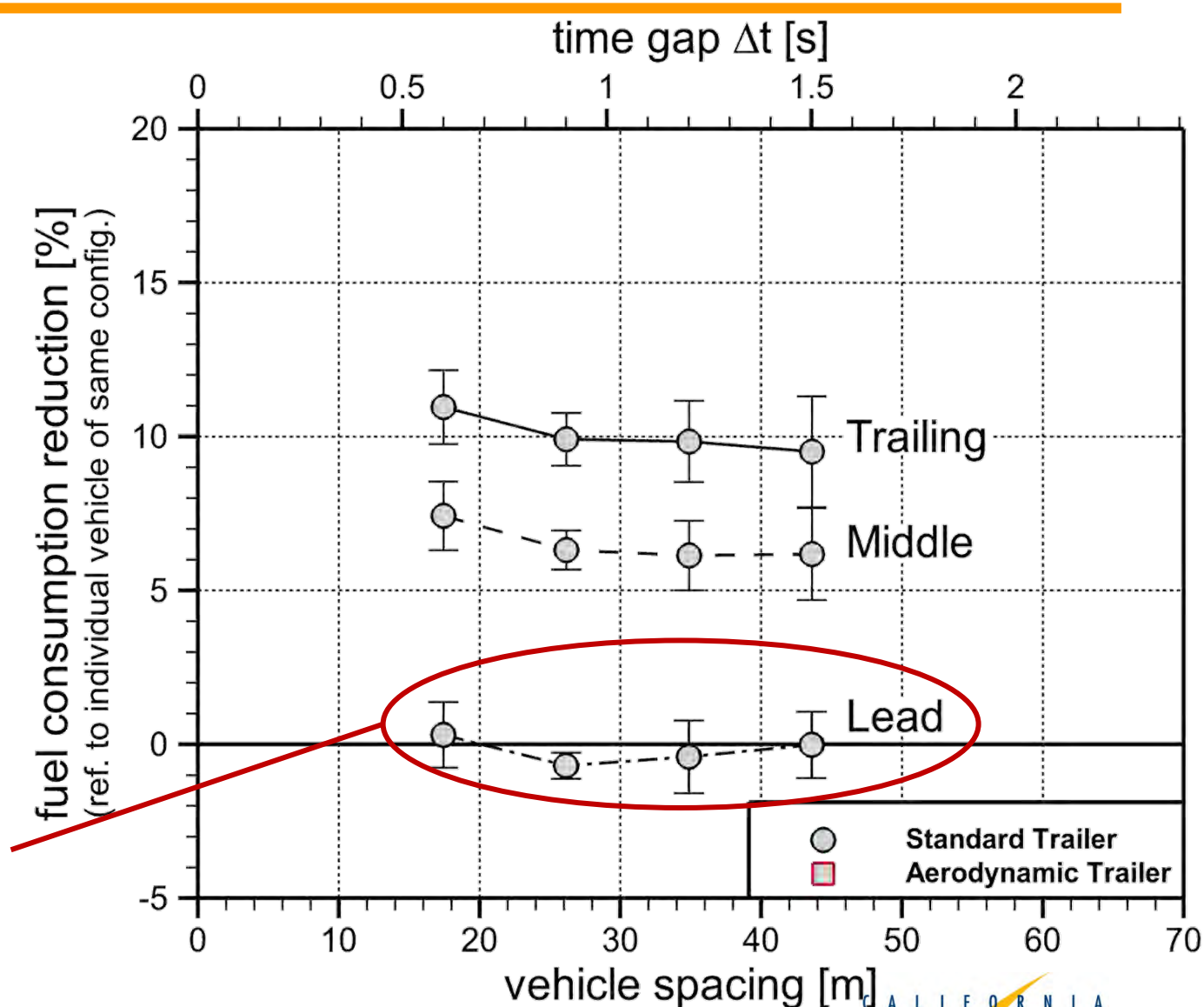
Test Results - NRC Canada Fuel Saving Estimates (65 mph + 65,000 lbs)

Fuel Savings for Individual Trucks



Negligible savings for lead vehicle observed

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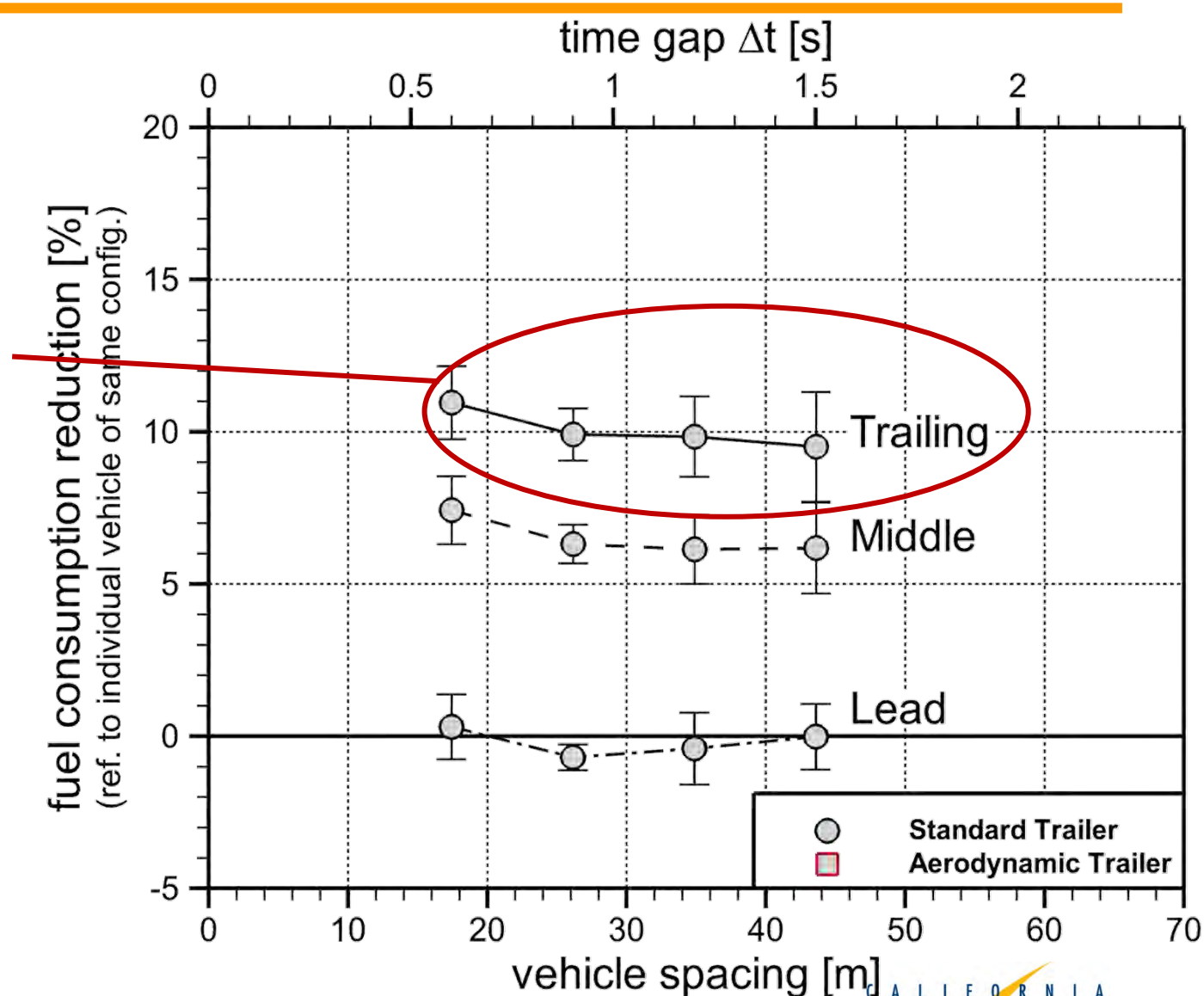
Test Results - NRC Canada Fuel Saving Estimates (65 mph + 65,000 lbs)

Fuel Savings for Individual Trucks

trailing vehicle shows highest savings



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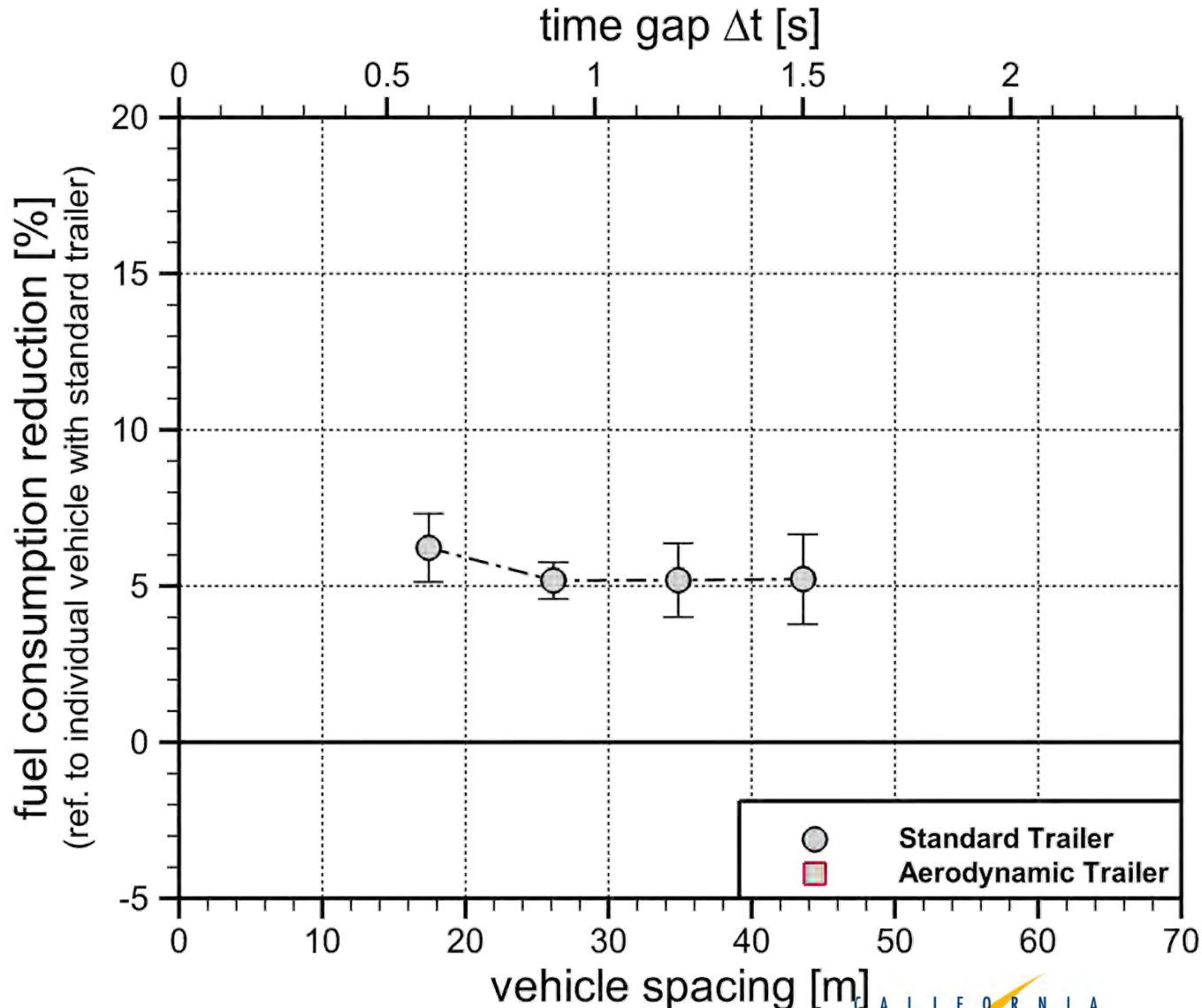
Test Results - NRC Canada Fuel Saving Estimates (65 mph + 65,000 lbs)

Total Fuel Savings for 3-Truck Platoon
(ref. standard truck)



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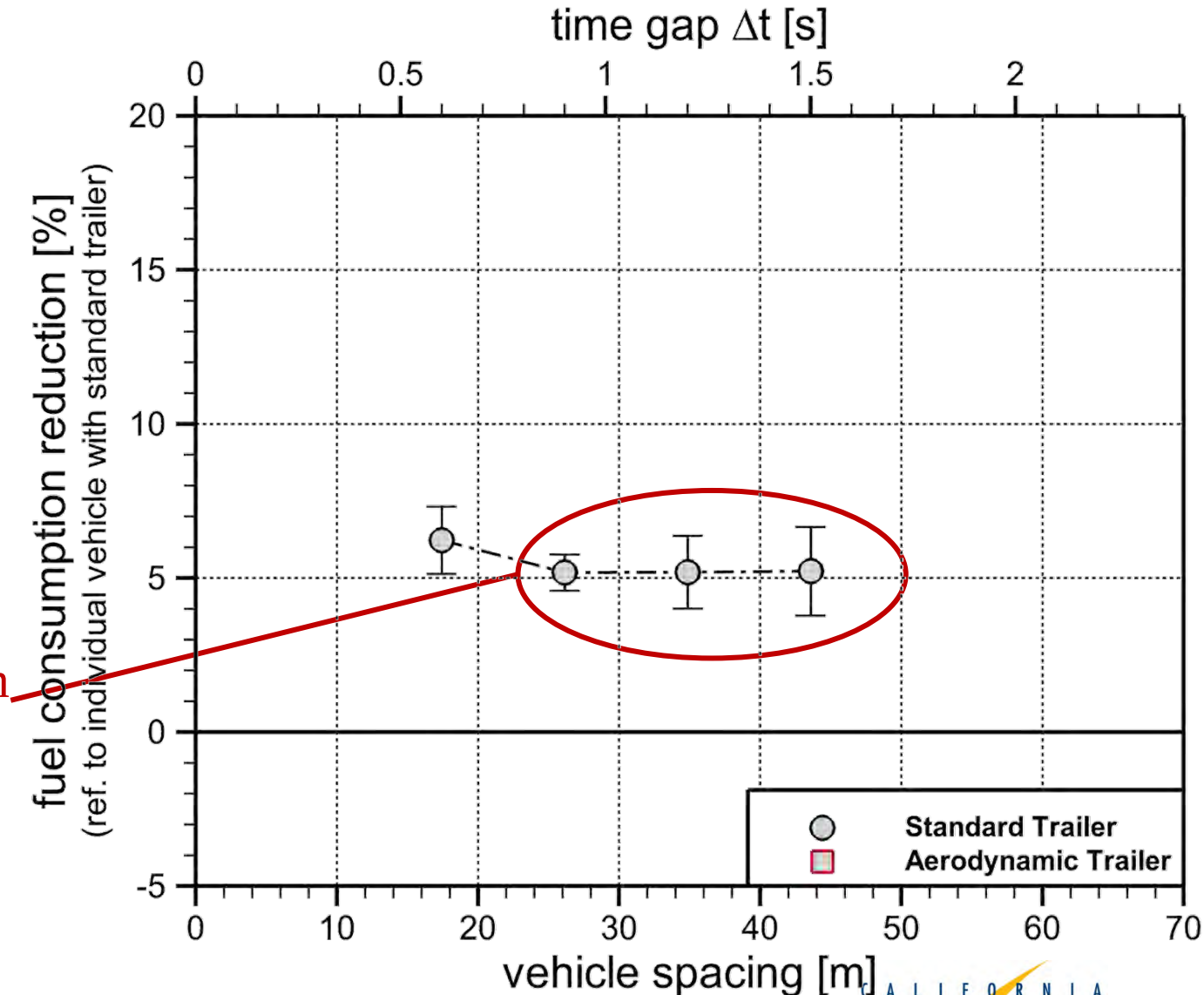
Test Results - NRC Canada Fuel Saving Estimates (65 mph + 65,000 lbs)

Total Fuel Savings for 3-Truck Platoon
(ref. standard truck)

no change beyond 22 m
for standard trailers



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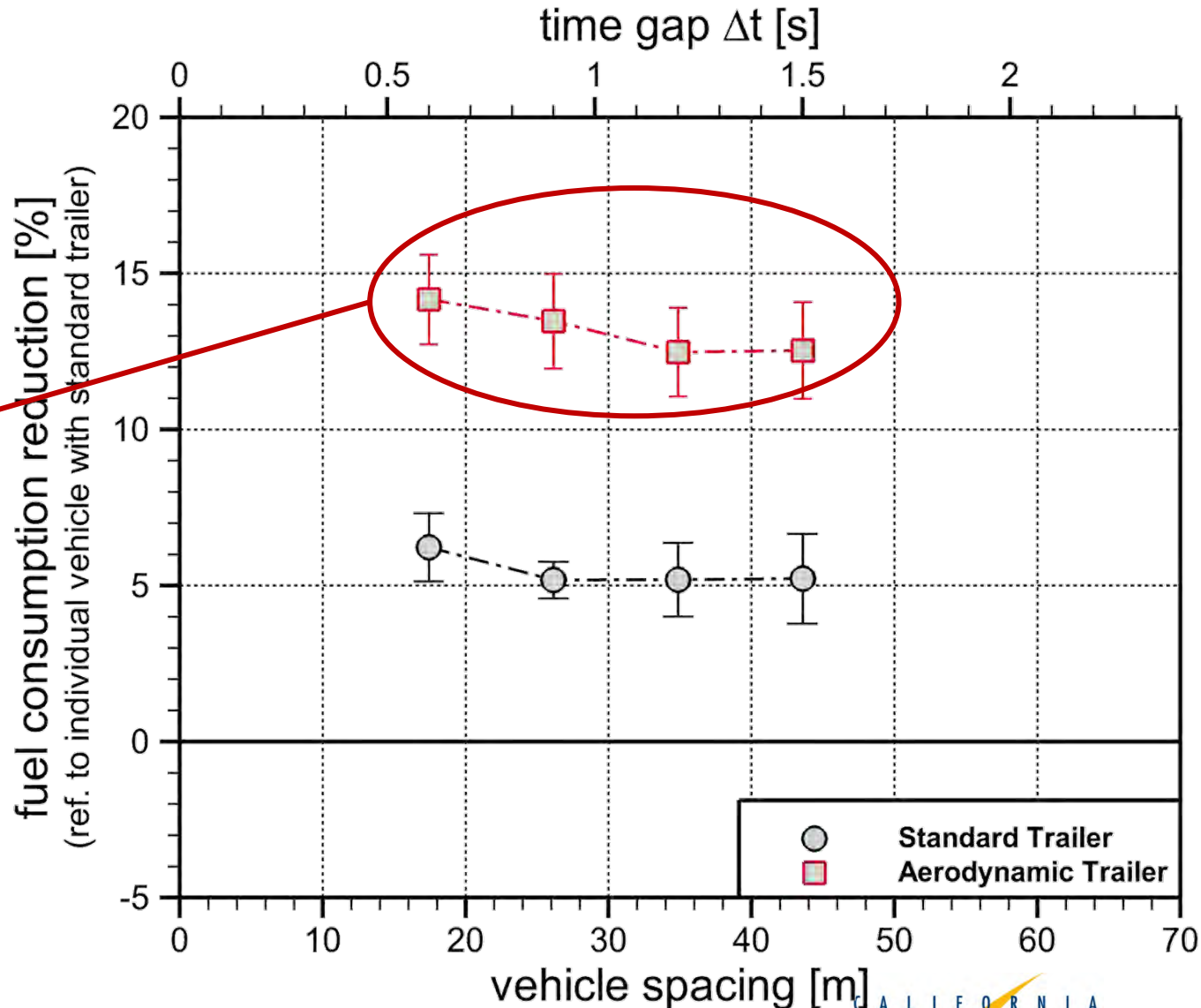
Test Results - NRC Canada Fuel Saving Estimates (65 mph + 65,000 lbs)

Total Fuel Savings for 3-Truck Platoon
(ref. standard truck)

Up to 14% fuel savings when combining aero devices with platooning

no change beyond 22 m for standard trailers



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Alternate Analysis – without Weighing Tanks

- **Data used:**
  - **Trailers with side skirts and rear end flaps**
  - **Only in reasonably good weather conditions**
- **Based on vehicle measurement**
  - **Cumulative distance from J-1939 Bus speed**
  - **Cumulative fuel consumption of fuel rate from J-1939 Bus**
  - **Average Fuel Rate:**

$$\text{Ave Fuel Rate} = \frac{\text{Cumulative fuel Consumption}}{\text{Cumulative Distance}}$$

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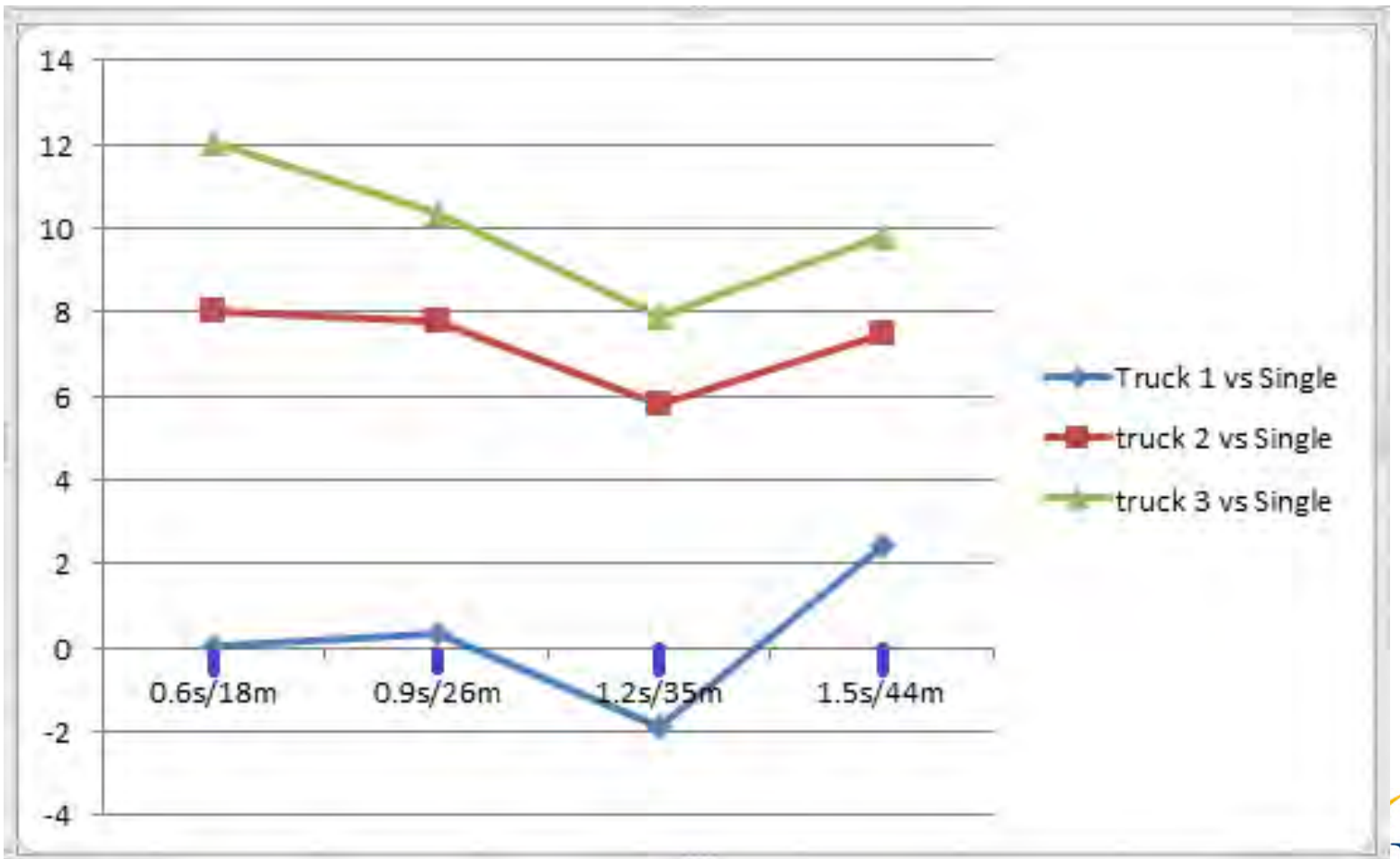
Alternate Analysis (65 mph + 65,000 lbs)

- **What's happening at 1.2s might be due to weather (e.g. windy), which we will work on further.**



Conclusions

- **Collaboration among multiple project partners conserved resources, close cooperation promoted mutual learning**
- **Truck CACC showed significant energy savings for followers, but not for leader, for selected range of gaps**
- **Consistent with findings from other research projects**
- **Test drivers were professionals and enthusiastic about use of the system**
- **Additional experiments needed for other conditions to show wider range of trends**

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