TRUCK PLATOONING: AN EARLY APPLICATION OF COOPERATIVE VEHICLE AUTOMATION

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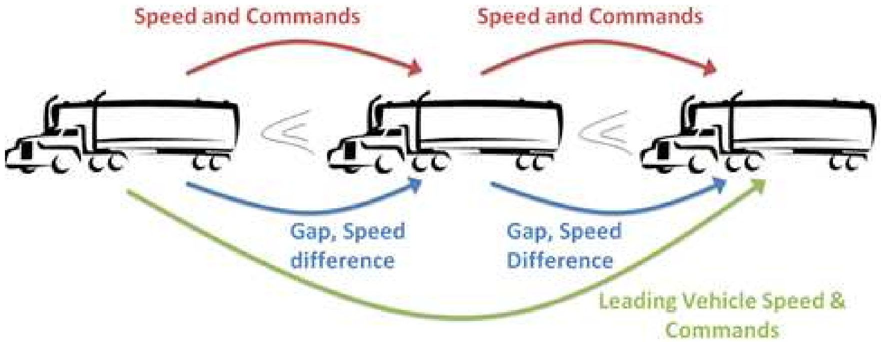
Truck Platooning - Overview

- What is it?
- SAE Levels of Automation
- Why V2V Cooperation is Essential
- Benefits to be gained
- Importance of energy savings
- Cooperative adaptive cruise control system
- Test trucks in action
- Energy saving results
- Main Findings

What is truck platooning?

Operating trucks in close formation under automatic speed control using V2V communication to coordinate their speeds

- **Cooperative adaptive cruise control (CACC)**
  - **Ad-hoc combination of trucks**
  - **Drivers can join or depart at will**
  - **Constant time-gap separation**



- **Tightly-coupled platoon**
  - **First truck (or driver) supervises operations**
  - **Joining and departing authorized by leader**
  - **Constant clearance-gap (distance) separation**
  - **Generally enables shorter gaps**

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SAE Levels of Automation (standards.sae.org/j3016_201609/)

Driving automation systems **are categorized into levels based on:**

1. **Whether the driving automation system performs *either* longitudinal *or* lateral vehicle motion control → L1**
2. **Whether the driving automation system performs *both* longitudinal and lateral vehicle motion control → L2+**
3. **Whether the driving automation system *also* performs object and event detection and recognition → L3+**
4. **Whether the driving automation system *also* performs dynamic driving task fallback → L4+**
5. **Whether the driving automation system is limited by an operational design domain (ODD) → below L5**

Example Systems at Each Automation Level

Level	Example Systems	Driver Roles
1	Adaptive Cruise Control OR Lane Keeping Assistance	Must drive other function and monitor driving environment
2	Adaptive Cruise Control AND Lane Keeping Assistance Traffic Jam Assist (Mercedes, Tesla, Infiniti, Volvo…) Parking with external supervision	Must monitor driving environment (system nags driver to try to ensure it)
3	Traffic Jam Pilot	May read a book, text, or web surf, but be prepared to intervene when needed
4	Highway driving pilot “Driverless” following truck in platoon “Driverless” valet parking	May sleep, and system can revert to minimum risk condition if needed
5	Ubiquitous automated taxi Ubiquitous automated truck	No drivers needed

Communication-Based Cooperation is Essential

- **Providing advance information about traffic condition changes and hazards (including beyond sensor line of sight)**
- **Enabling coordination of vehicle actions for safety, smoothness and traffic flow stability**
  - **Implications for congestion, travel time, energy, emissions…**
  - **Shorter gaps for aerodynamic "drafting"**
- **Supporting broader traffic management functions (speed advisories, rerouting, weather alerts,…)**
- **Information to support eco-driving (adjusting speed profiles based on upcoming traffic signal changes)**

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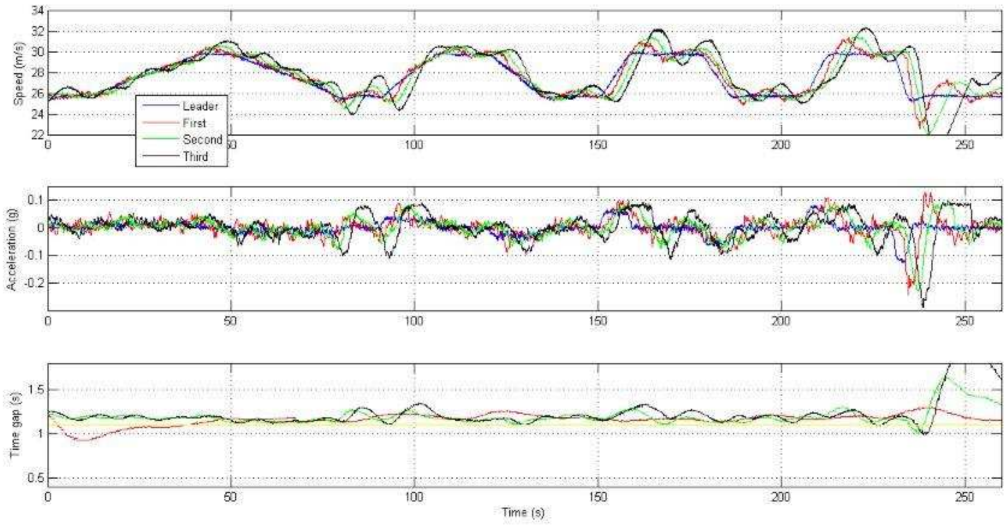
Automotive Example: Adaptive Cruise Control with and without V2V Cooperation

Autonomous (no communication)

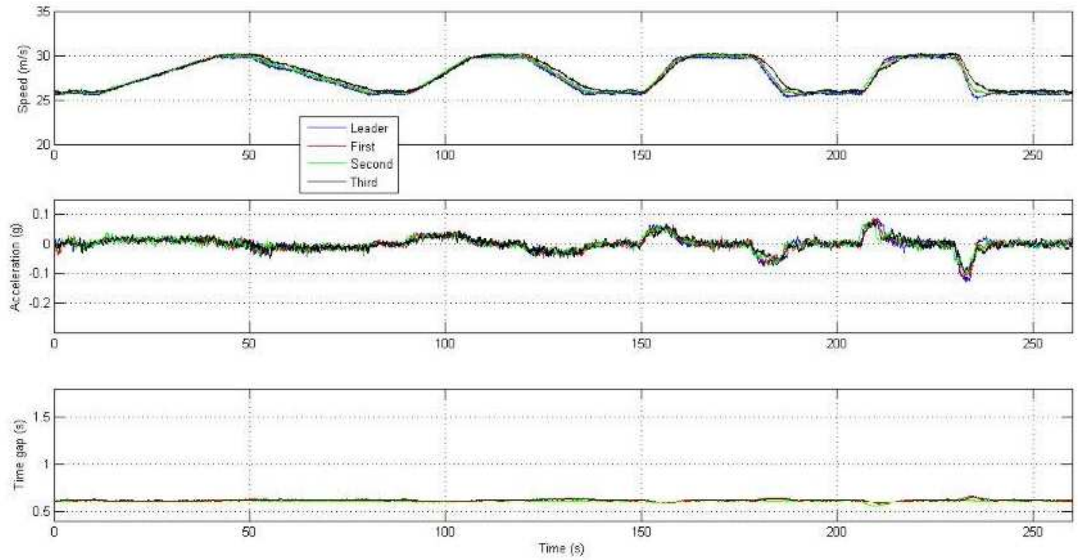
Cooperative (with V2V communication)

Comparison of Performance

Autonomous (no communication)



Cooperative (with V2V communication)



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Benefits to be Gained at Each Automation Level (assuming use of communication for cooperation)

- **Level 1:**
  - Some comfort and convenience
  - Substantial energy savings (drafting and smoothing speeds)
  - Safety (from collision warnings)
- **Level 2:**
  - Some additional comfort and convenience
  - Additional energy savings if shorter gaps are enabled
  - (Possible reduction in safety, if misused by driver)
- **Level 3:**
  - Potential for driver to do other non-driving tasks
  - (Possible reduction in safety if driver loses vigilance)

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Benefits to be Gained at Each Automation Level (assuming use of communication for cooperation)

- **Level 4:**
  - Significant improvement in driver quality of life, stress reduction
  - Hours of service reforms based on ability for driver to sleep on part of long-haul runs
  - Possibility of driverless platoon followers, saving labor costs
  - Enhanced safety based on system fallback capability
- **Level 5 (remote future):**
  - No need for drivers

Importance of Heavy Truck Energy Savings

- **Heavy trucks consume 20% of U.S. transportation energy**
- **Heavy trucks consume 14% of all U.S. petroleum**
- **Fuel represents 39% of long-haul heavy truck operating costs**

- **Annual saving of 10% in fuel costs for a typical long-haul truck represents $6000 per year (worth $60,000 over the life of the truck)**

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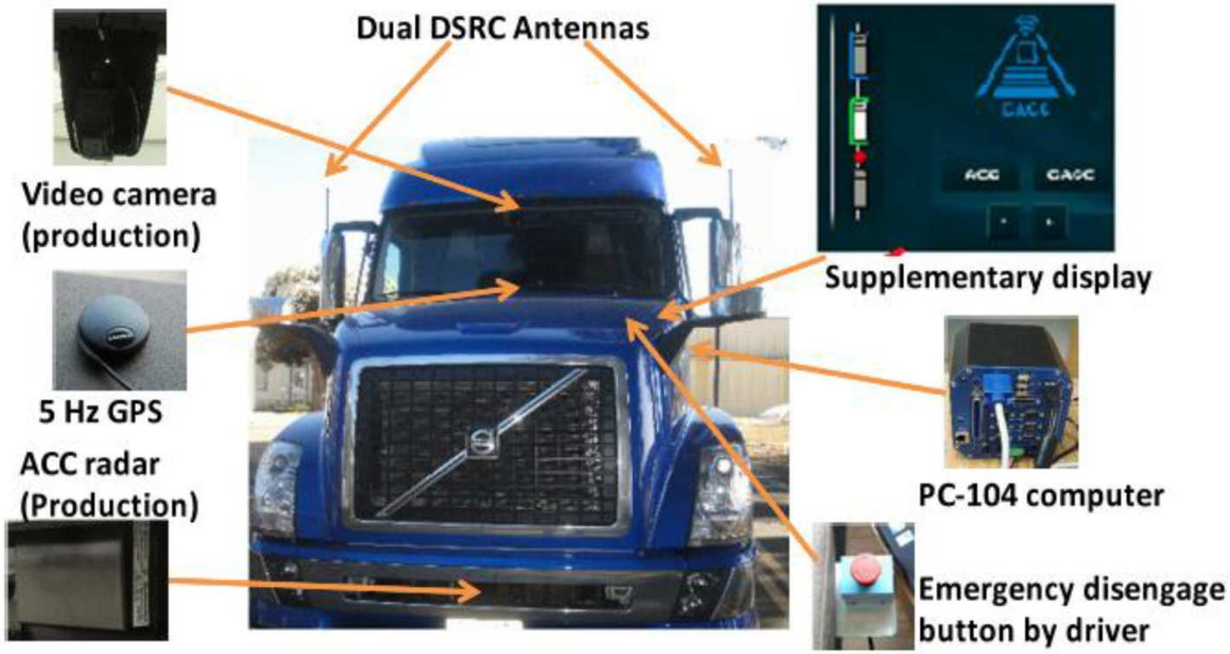
Development and Testing of Truck Cooperative ACC System

- **Project sponsored by Federal Highway Administration, Exploratory Advanced Research Program (EARP), with cost sharing from California Department of Transportation**

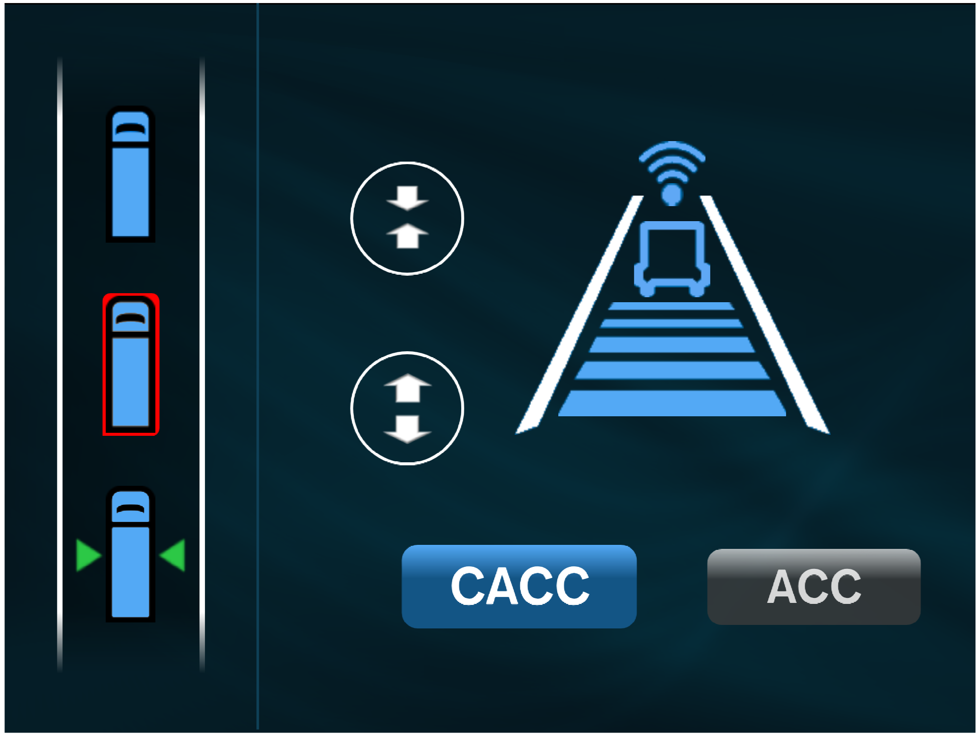
- **Measuring energy saving potential and driver preferences for different gap settings**
- **Simulating impacts on traffic and energy use in a high-volume freight corridor**

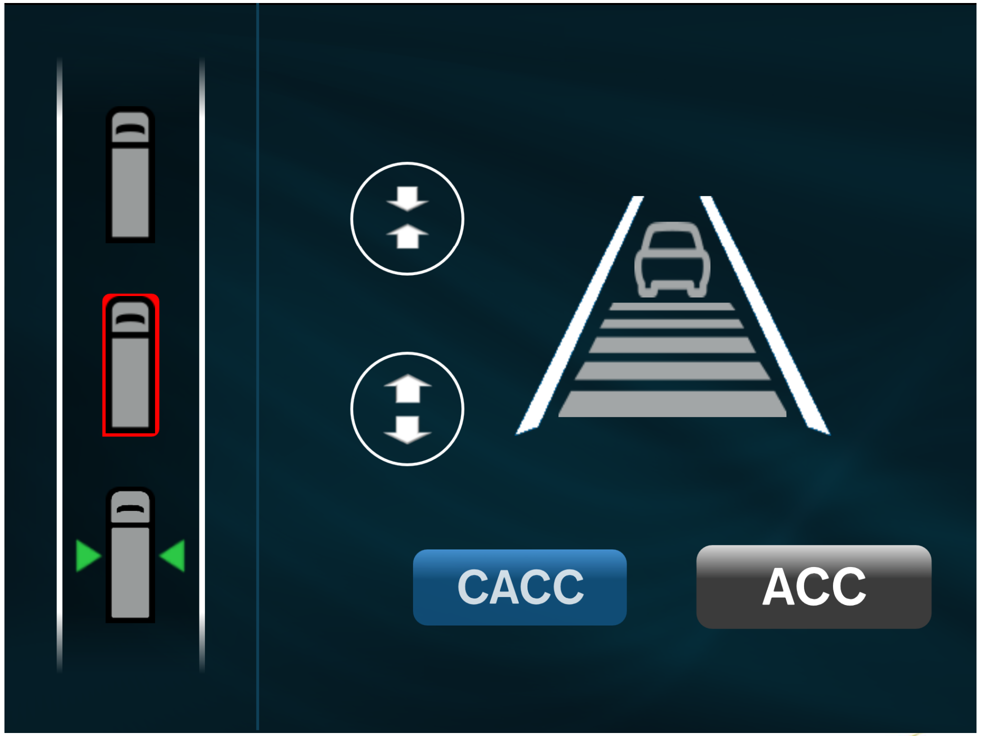
Cooperative Adaptive Cruise Control System

- Build on production Volvo ACC system
- Add V2V communication by 5.9 GHz DSRC
  - Vehicle location
  - Speed, acceleration, braking, commands
- Short gap settings enabled:
  - 0.6, 0.9, 1.2, 1.5 s
  - 57, 86, 114, 143 ft @ 65 mph
- Coordinated braking



Supplementary Display for Driver





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Testing to Measure Energy Consumption

- **International collaboration with Transport Canada and National Research Council of Canada**

Transport Canada Transports Canada

Environment and Climate Change Canada Environnement et Changement climatique Canada

PMG www.pmgtest.com

PIT Group by FPInnovations

cftr

NRC·CNRC

- **Testing in Blainville, Quebec on 4-mile oval track**
  - **SAE standard test procedure**
  - **64-mile continuous drive per run**
  - **3 runs repeated and averaged**
  - **Auxiliary fuel tanks weighed on each run**

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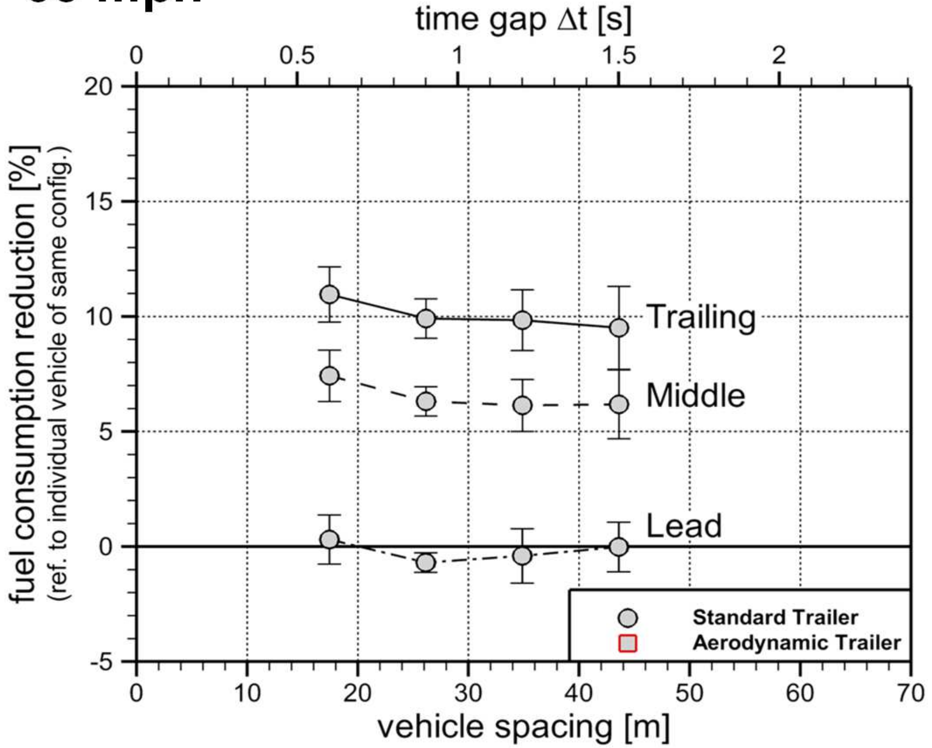
Testing Procedures

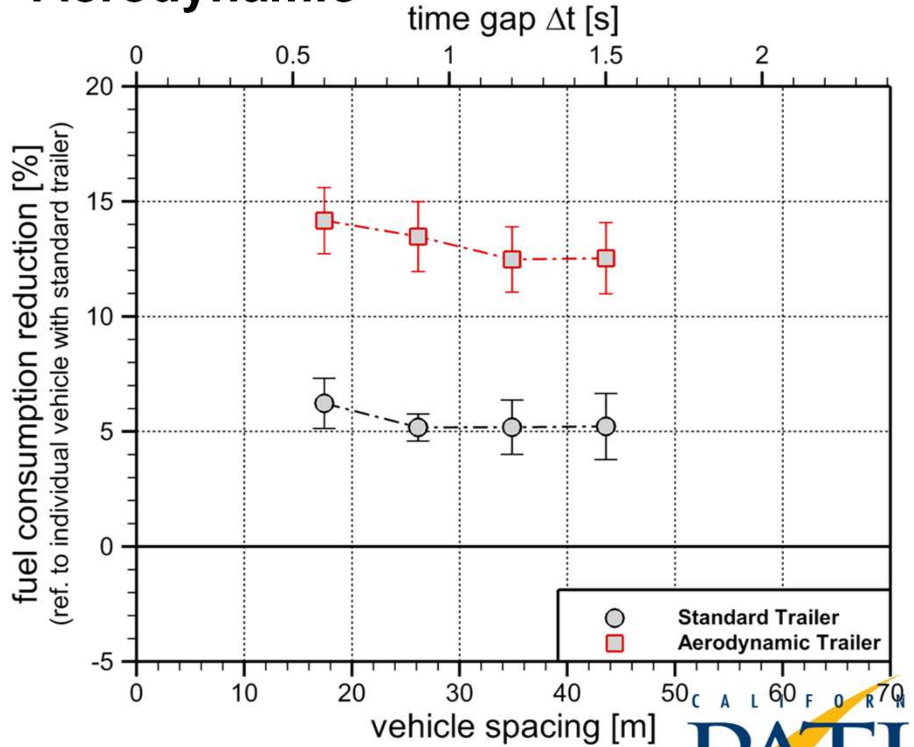
Testing at 0.6 s Time Gap in Blainville

Energy Savings Compared to Single Truck with Standard Trailer

Energy Saving with Standard Trailers, 65 mph



Average Savings, Standard vs. Aerodynamic



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Main Findings

- With standard trailers, trucks can save 5% energy on average in a three-truck CACC string
- With aerodynamic trailers, these savings grow to 12-14% compared to standard-trailer solo driving
- Drag savings not very sensitive to time gap values from 0.6 s to 1.5 s (57 to 143 ft. at 65 mph)
- Lead truck saves limited energy in this range of gaps.
- Third truck saves the most energy
- Effects of short gaps and aerodynamic trailers reinforce each other
- Further studies are needed for shorter and longer gaps

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