Truck Efficiency Improvements Using V2V and I2V Cooperation

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Potential Efficiency Improvements

- **Platooning and cooperative adaptive cruise control (CACC)**
  - **Aerodynamic drag reductions (drafting)**
  - **Smoother traffic flow dynamics**
- **Freight signal priority**
- **Eco-signal control**

Truck Platooning History

- 1996-2004: CHAUFFEUR Project analyses and tests (DaimlerBenz trucking, for EU)
- 1996-7: National Automated Highway System Consortium analyses of capacity
- 2001 - 03: PATH 2-truck platoon tests
- 2005 - 09: KONVOI Project (Germany) – 4-truck platoon tests
- 2008 – 13: Energy ITS Program (Japan) – 4-truck platoon tests
- 2009-12: SARTRE Project mixed truck/car platoon tests (Volvo, for EU)
- 2010-11: PATH 3-truck platoon tests
- 201x: Peloton commercializing 2-truck platoon

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Motivations for Running Truck Platoons

- **Significant reductions in energy consumption by reducing aerodynamic drag**
  - **Minimum 5% saving by lead truck**
  - **Followers saved 15% in preliminary tests, could potentially reach 25%**
- **Relief of driver workload and stress, helping morale and driver retention**
- **Significant increase in capacity per lane (trucks per hour), reducing congestion delays**
  - **Serve heavy demand with fewer lanes**

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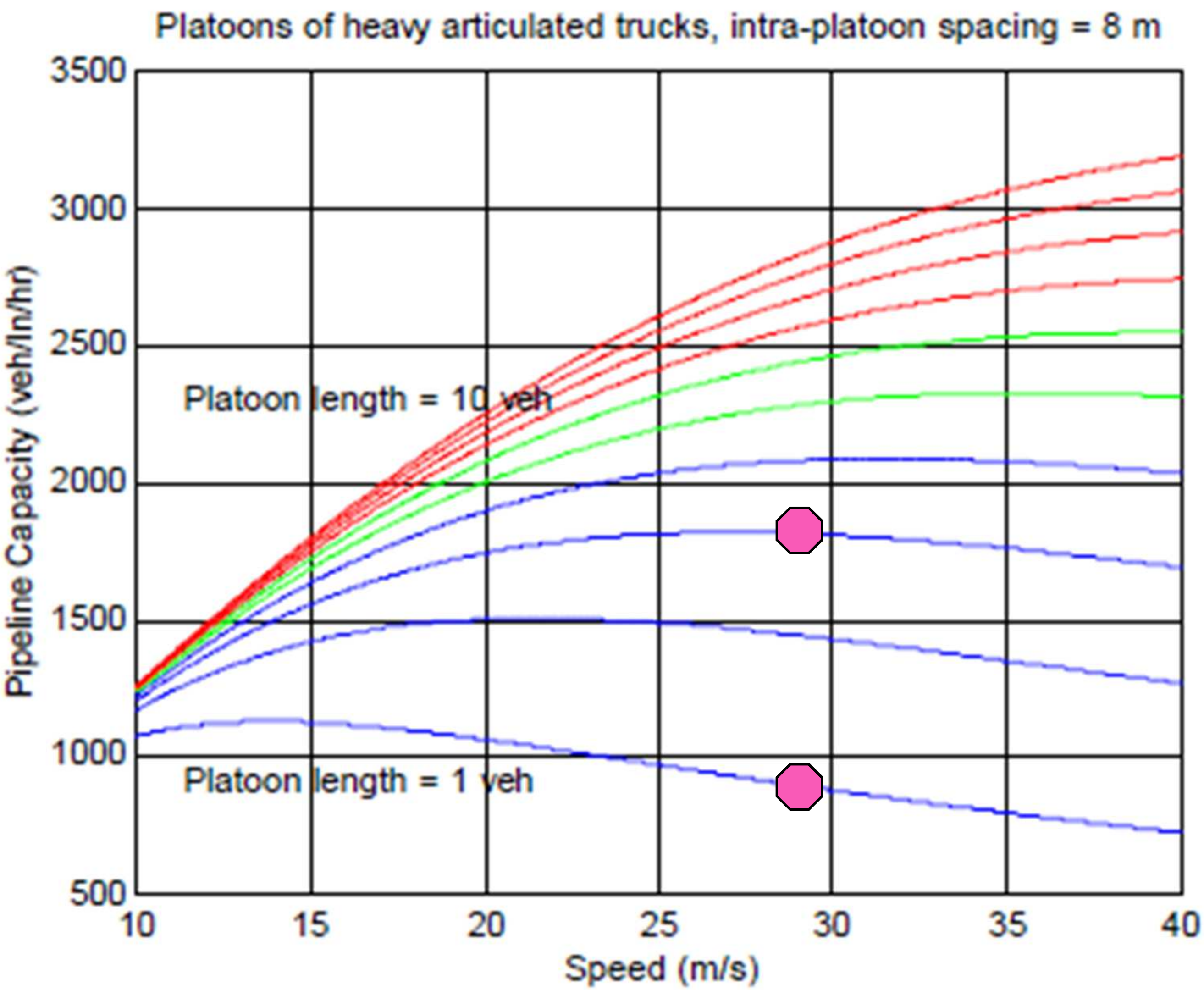
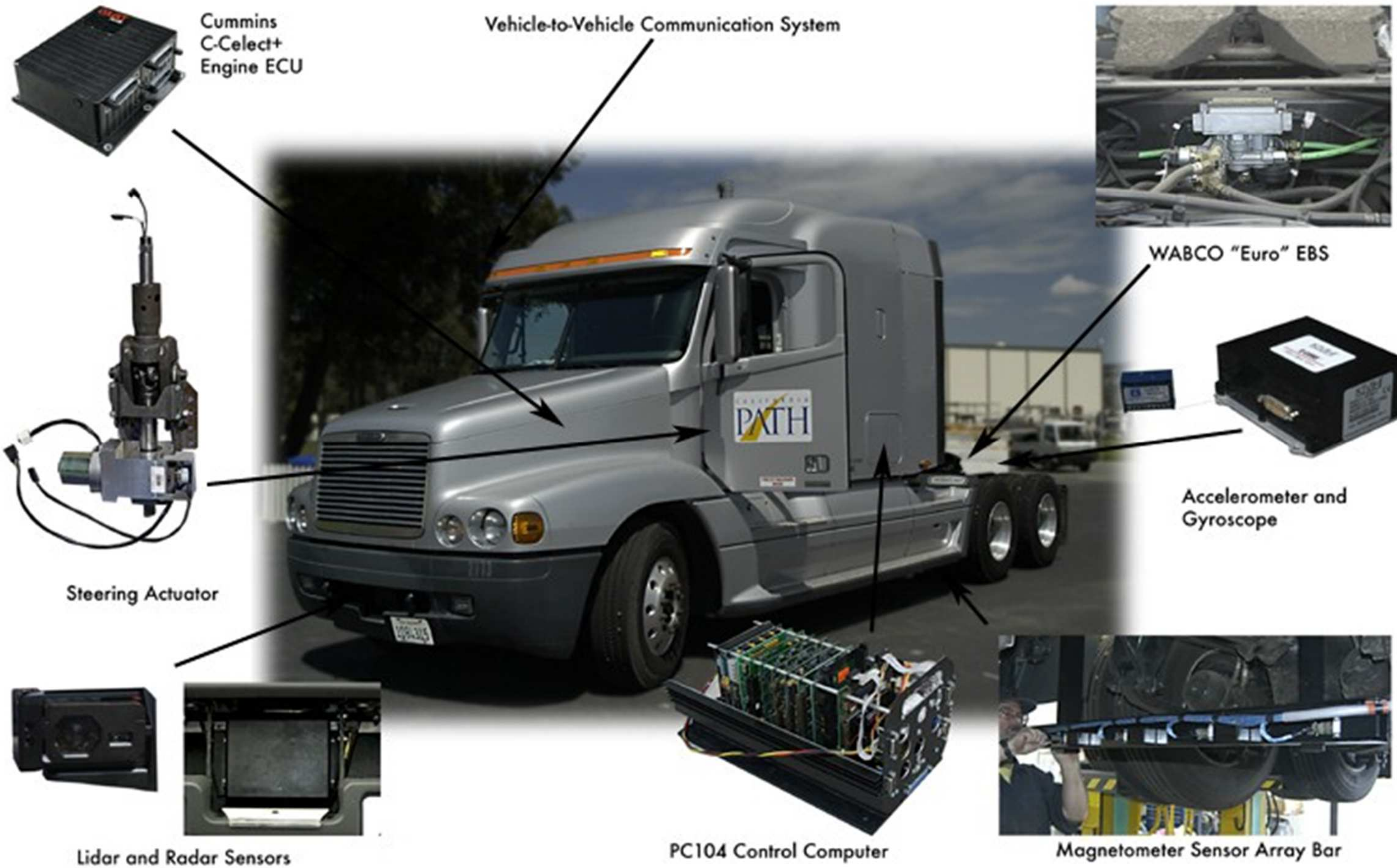
Truck Platoon Capacity Estimates

- **NAHSC studies (1997)**




Cummins
C-Celect+
Engine ECU
Vehicle-to-Vehicle Communication System
WABCO "Euro" EBS
Accelerometer and
Gyroscope
Steering Actuator
PATH
Lidar and Radar Sensors
PC104 Control Computer
Magnetometer Sensor Array Bar

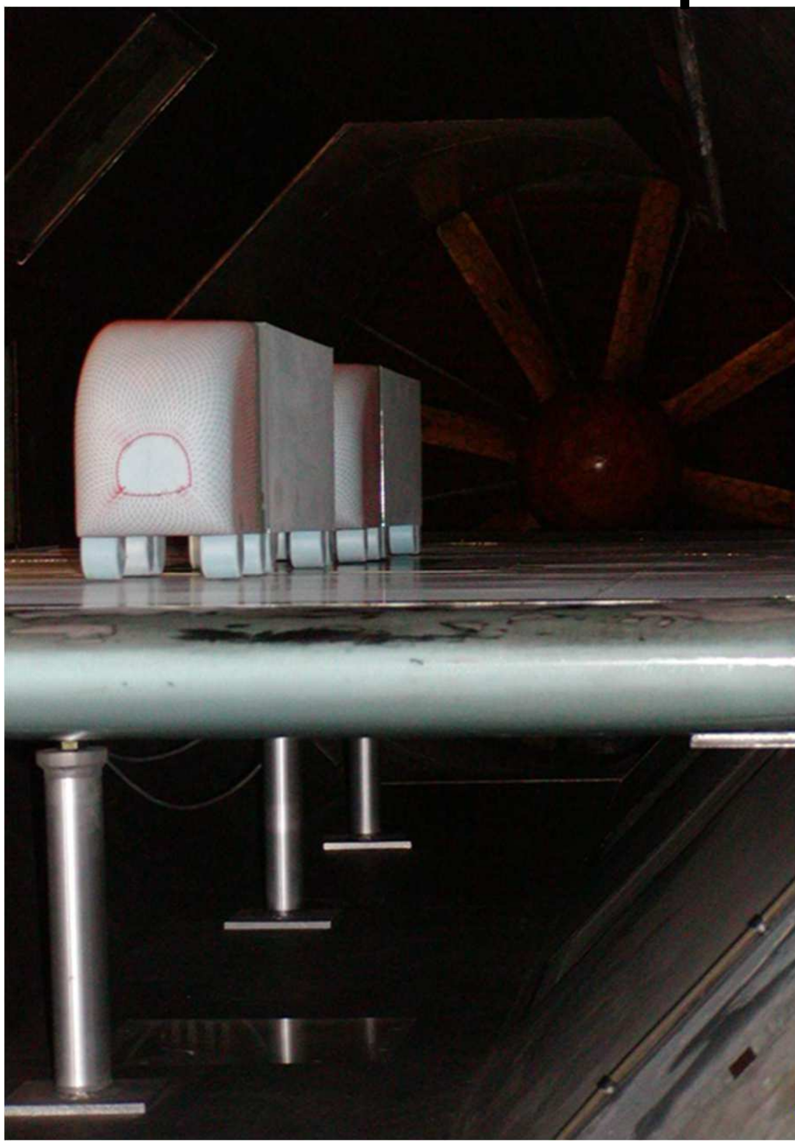
2-Truck Platoon Tests (3, 4 and 6 m gaps)

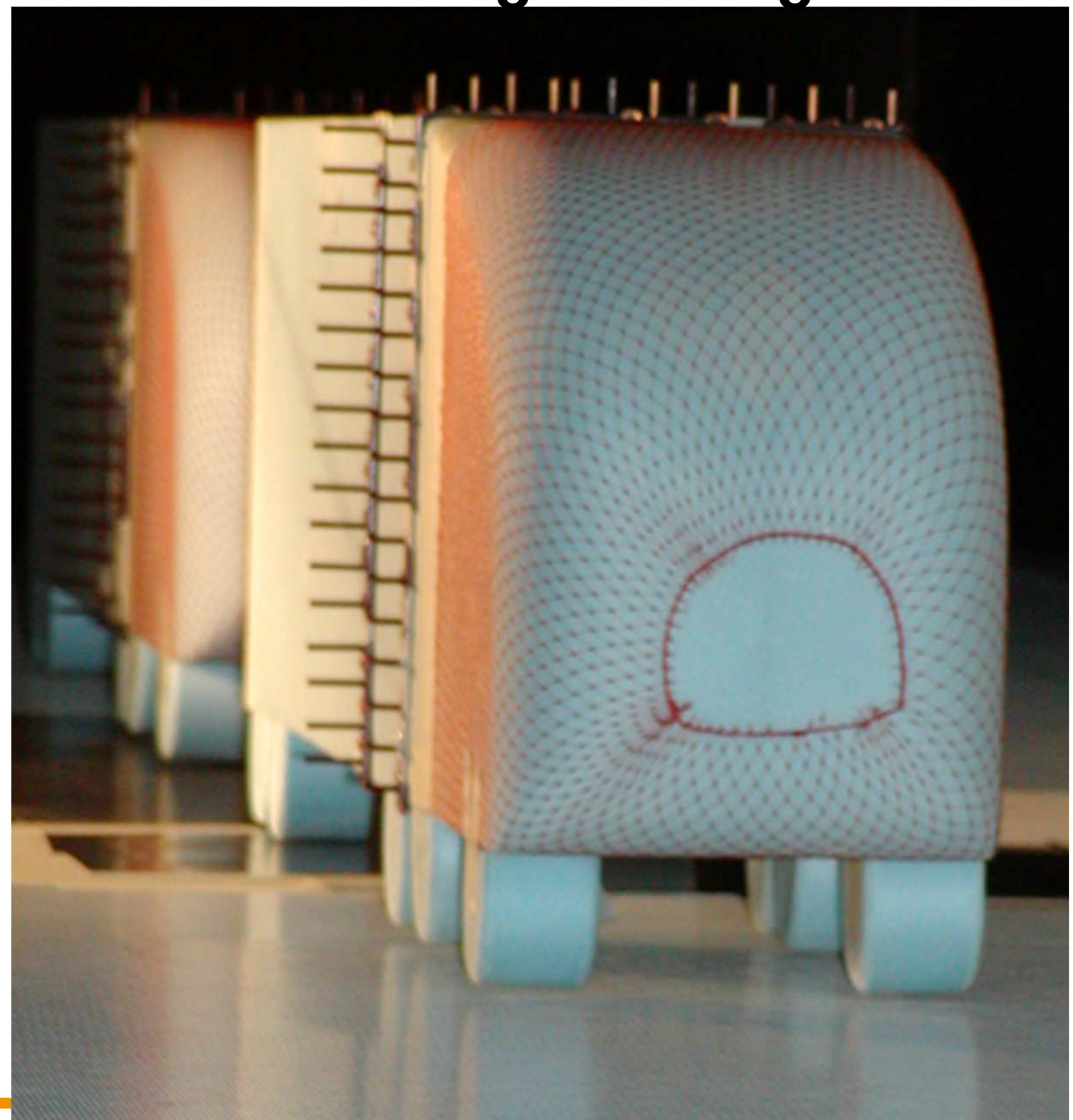
Aerodynamics of Class-8 Tractor-Trailer Trucks

- **PATH research led by Prof. Fred Browand, USC**
- **Scale-model tests in wind tunnel, then full-scale tests on track, directly measuring fuel use**
- **Measuring effects on aerodynamic drag of:**
  - **Separation between trucks (primary purpose)**
  - **Cross-wind components**
  - **Tractor-trailer spacing**
- **Strong effects seen on separation between trucks and on shape of front of truck**

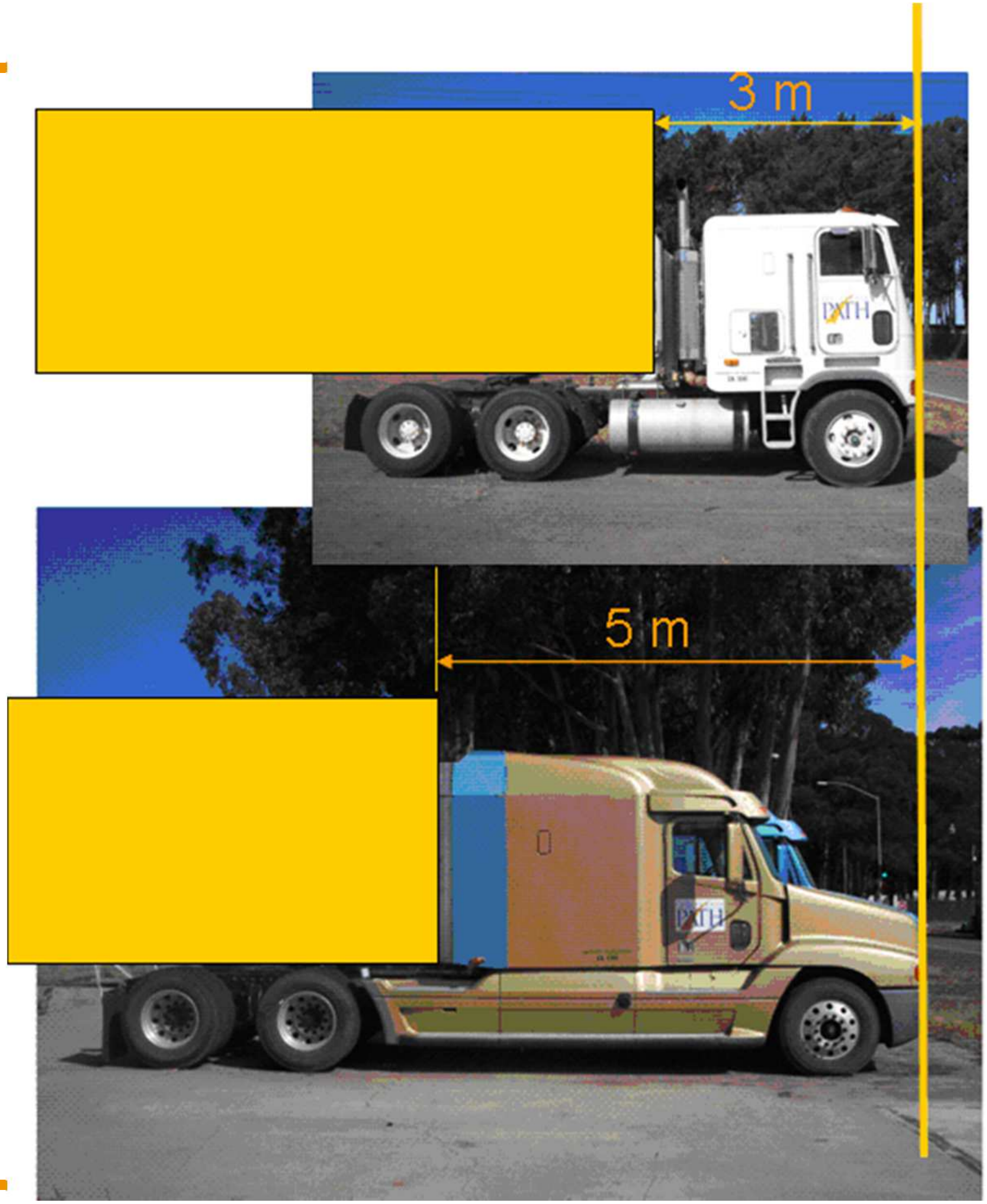
Wind-Tunnel Truck Models

- **Note blunt front comparable to cab-over-engine design tractor**





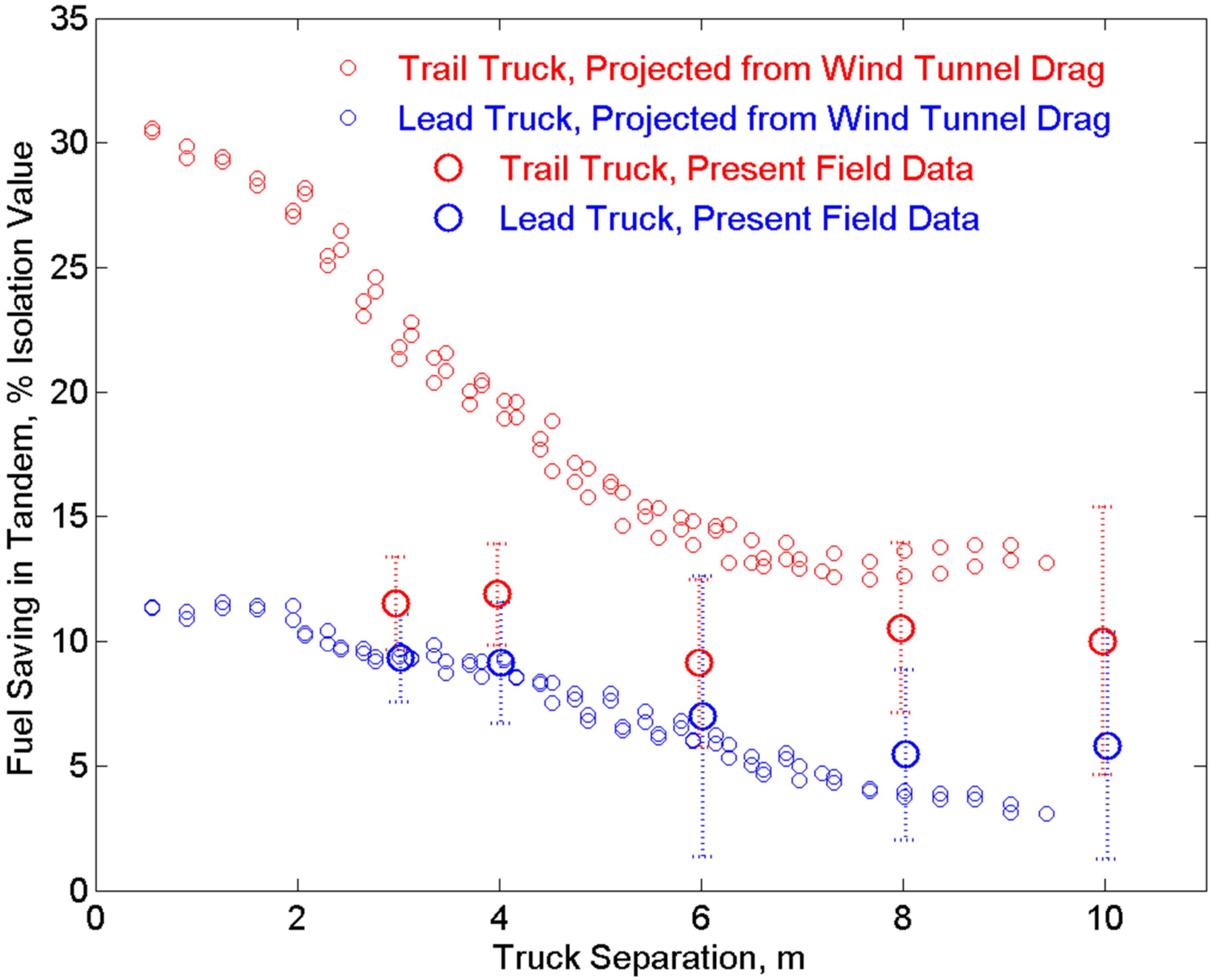
Contrast in Gaps for Truck Tractors



Cab-over-engine (European units could be only 2 m long)

Engine-forward with Sleeper cab – Typical in U.S.

Comparison of Wind Tunnel and Direct Measurements of Fuel Saved



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Three-Truck Automated Platoon

- **Experimental implementation using 5.9 GHz DSRC for V2V communication in 2010-11, under FHWA Exploratory Advanced Research Program (EARP)**
  - **Gaps from 10 m to 4 m**
  - **Platoon join and split maneuvers**
  - **Variations in speed and road grade**
  - **Fuel consumption measurements**
- **Longitudinal control automated, but steering was still manual**
- **8-km section of 2-lane highway, temporarily closed to public traffic for tests**
- **Accurate vehicle following – RMS gap variations of 22 cm for second truck and 25 cm for third truck**

Three-truck Automated Platoon (2010)

Partial Automation for Truck Platooning

- **Cooperative ACC for 3 tractor-trailer trucks, adding DSRC to their production ACC systems**
- **FHWA EARP Project team:**
  - **California Department of Transportation (Caltrans)**
  - **University of California PATH Program**
  - **Volvo Technology Americas**
  - **Cambridge Systematics, Inc.**
  - **Los Angeles Metropolitan Transportation Agency (LA Metro)**
  - **Gateway Cities Council of Governments (COG)**
  - **Peloton Technology (unfunded)**
- **October 2013 – December 2016**

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PATP Project Goals

- Identify market/deployment opportunities for heavy truck CACC based on industry and agency needs
- Show near-term opportunities to gain energy saving benefits from truck CACC, with modest modifications to production ACC
- Combine U.S. and European truck platoon expertise (Volvo/SARTRE and PATH) to synthesize best from both
- Work with local stakeholders on deployment strategies for truck lanes along I-710 (Los Angeles/Long Beach port)
- Test truck driver acceptance of shorter CACC following gaps while they do steering
- Measure energy savings at gaps chosen by drivers and provide results to stakeholders
- Demonstrate truck platooning for stakeholders

At Signalized Intersections

- **Lower speeds than highways, so aerodynamic drafting is not a large benefit**
- **Capacity limited by start-up transient at red-to-green transition, not by vehicle following gap, so emphasize coordinated start to increase effective capacity and reduce delays**
  - **I2V broadcast of signal phase change to all queued trucks simultaneously**
  - **V2V coordination between trucks enables them to "follow the leader" with negligible lag**

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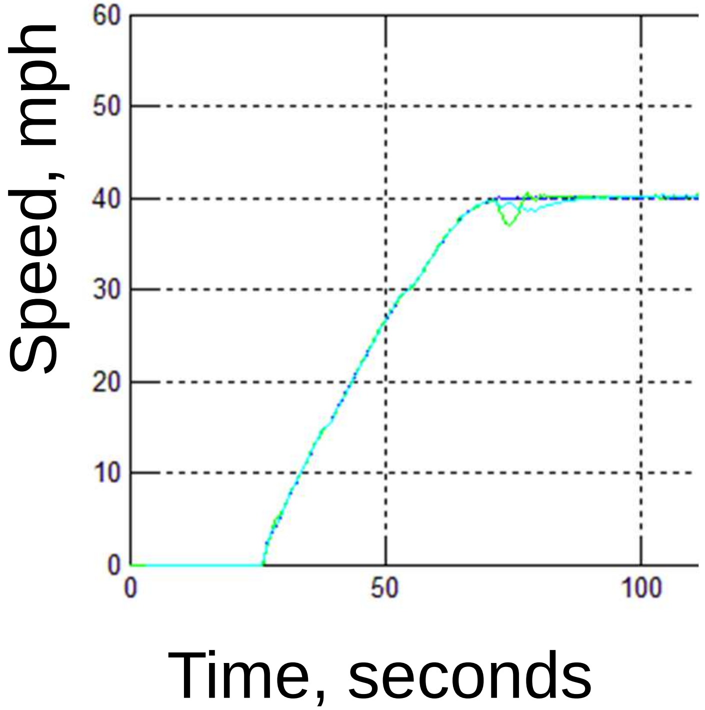
Truck Start-up from Stop



- **Under-powered heavy trucks are slow to start up**
- **Test data shows example of 16 s to reach 20 mph (32 km/h)**
  44 s to reach 40 mph (64 km/h)
- **Response lag for successive trucks under driver control could be 1 – 2 s based on perception/response time plus additional time based on difficulty of perceiving speed difference.**

Other I2V/V2I Opportunities for Trucks at Signalized Intersections

- **Receiving real-time I2V signal phase and timing information:**
  - **Eco-driving profiles to minimize stopping and maximize coasting opportunities at individual intersection or along a corridor**
  - **Minimizing truck stopping reduces start-up delays for all the other traffic behind the trucks and reduces pavement wear**
  - **Eliminating dilemma zones by providing advance information on yellow transition**
- **V2I truck signal priority request avoids splitting truck platoons (even informal ones) and also helps reduce frequency and severity of stopping**

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