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Class 8 Tractor Trailer Platooning: Effects, Impacts, and Improvements

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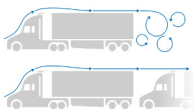
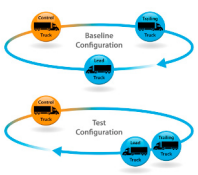
PROJECT OBJECTIVE

The objective of this work is to evaluate the fuel savings potential of semi-automated truck platooning. Platooning involves reducing aerodynamic drag by grouping vehicles together and decreasing the distance between them through the use of electronic coupling, which allows multiple vehicles to accelerate or brake simultaneously.

The U.S. Department of Energy's interest in platooning stems from the opportunity to reduce petroleum consumption. This work addresses the need for data and analysis on what aspects of operation can impact platooning savings and what can be done to maximize the savings realized.



Configurations for SAE Procedures



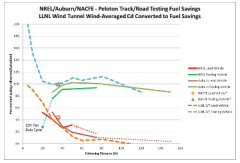
PLATOONING TEST COMPARISONS – FUEL SAVINGS

Independent platooning evaluations:

- SAE J1321 road testing conducted in 2013 in Utah (North American Council for Freight Efficiency (NACFE))
- SAE J1321 track testing conducted in 2014 in Uvalde, Texas (National Renewable Energy Laboratory (NREL))
- SAE J1321 track testing conducted in 2015 in Ohio (Auburn University, Transportation Research Center (TRC))
- 1/50th scale wind tunnel testing conducted in 2015 in California (Lawrence Livermore National Laboratory (LLNL))
- DENSO presented computational fluid dynamics (CFD) modeling results in 2015 to 21st Century Truck Partnership

General evaluation results:

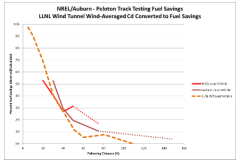
- Data suggests that platooning provides a significant net improvement in fuel savings
- Generally consistent magnitudes and trends of fuel savings for track, road, and wind tunnel testing
- Wind tunnel results at less than 30 ft following distance show likely trend departure, though limited road/track data exists for comparison



NACFE testing used a different method of calculating fuel savings of lead and trailing vehicles

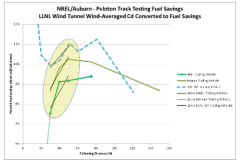
Evaluation results pertaining to lead vehicle:

- Larger fuel savings at distances less than 50 ft, with very modest savings at longer distances
- Lead vehicle trends match well for following distance at knee in the curve (50–60 ft) as well as slope before and after the knee



Evaluation results pertaining to trailing vehicle:

- Significant fuel savings for the trailing vehicle at most distances
- Trailing vehicle trends match well for magnitude and slope:
  - Reduced savings in 30–50 ft range (note: net savings for both vehicles combined was still achieved)
  - Cause of reduced savings at these distances is not fully understood

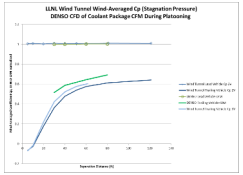


PLATOONING TEST COMPARISONS – COOLING AIR FLOW

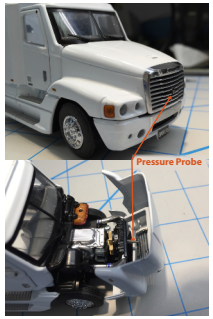
LLNL wind tunnel test results show that wind average stagnation pressure matches well with DENSO's CFD model of airflow to the radiator

In platooning, the trailing vehicle experiences a reduction in airflow and pressure at the radiator, with sharply decreased airflow exhibited at following distances of less than 40 ft (similar to where reduced fuel savings observed on trailing vehicle):

- Current testing shows engine cooling airflow is adequate in platoon formation, except at very close following distances
- Potential cooling system alternatives are under development (see DENSO)
- Aerodynamic options to direct air cooling to the engine at close following distances are under investigation



DENSO CFD results presented with permission from Michael Bima



Photos courtesy of LLNL, NREL 28961 and 28964

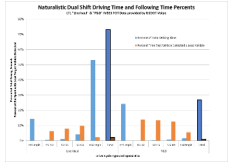
NATURALISTIC "BACKGROUND PLATOONING" – LESS THAN 0.2% FUEL SAVINGS

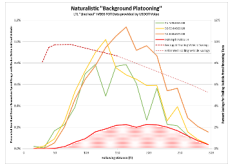
Don't truck drivers draft like this already? Answer = NO

- Volpe, the U.S. Department of Transportation's National Transportation Systems Center, published its *"Naturalistic Study of Truck Following Behavior Final Report"* in February 2016
  - Integrated vehicle-based safety systems field operational test (IVBSS FOT) data
    - Ten 2008 International TransStar tractors
    - 10 months
    - Pickup and delivery (P&D) day shift and line-haul night shift
  - Safety Pilot Model deployment data
    - Eight 2012–13 Freightliner Cascadia tractors
    - One year primarily P&D
  - Report is "event" based (short and long "events" count the same)
  - Data on time spent in various conditions is needed to evaluate fuel economy impacts

NREL/Volpe Cooperation

- IVBSS and Safety Pilot data tables show total time in bins of following speed and distance
  - IVBSS split P&D versus line-haul shifts – focus of NREL investigation is line-haul shifts
  - Safety Pilot is only P&D operation, less value for "background platooning"
- Volpe report is the best evaluation of driver following behavior available
  - Study of larger population would be valuable
- Answer goes against perception that "background platooning" is prevalent
  - **Only 2.2% of driving time >60 mph had a lead vehicle detected within 300 ft**
  - **< 0.2% background "savings" possible**
- Lead vehicle was at a distance greater than 130 ft for bulk of time detected
- Video-validated sample, showed 57% of events were LDV not HDV
  - Likely much less aerodynamic savings





NOx EMISSIONS

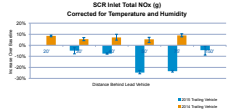
2014 NREL track testing detected an increase in NOx emissions for the trailing vehicle during platooning:

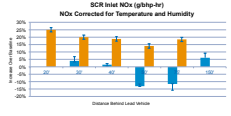
- Engine temperatures (intake air, coolant, and exhaust) and engine map explanations ruled out
- Frequency and amplitude of commanded torque changes correlated with magnitude of NOx increase

Peloton was informed of the issue and chose to address the control issue independently

2015 Auburn track testing included NREL data-logging devices to collect NOx emissions data:

- Observed "dither" in torque command control was significantly reduced
- Raw grams of NOx reduced over baseline test configuration
- Brake specific g/bhp-hr NOx emissions lower than baseline at 50 ft and 75 ft; still slight increases at 30 ft and 40 ft, but greatly reduced from 2014





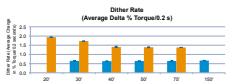


Photo courtesy of Peloton, NREL 25237

FOLLOW-ON STUDIES – PLANNED AND/OR UNDERWAY

Platooning-specific aerodynamic device design and testing to improve aerodynamic performance and engine cooling performance (joint NREL/LLNL activity):

- Current trailer tail designs may augment or inhibit fuel savings from platooning
- Identify optimum platooning aerodynamic package configurations that may differ from an isolated truck
- Aerodynamic device design may be able to counteract loss of ram air cooling

"Big data" fleet platooning opportunity analysis from high-resolution fleet telematics data (planned NREL activity):

- Large multi-fleet aggregate geospatial analysis
- Currently looking for fleet/telematics provider partners
- Define fuel savings for large fleets that adopt platooning technology
  - Geospatial analysis of current platooning opportunity
  - Fuel savings based on fuel rates when platooning available
  - % of miles platooning capable for a large fleet acting independently
- Estimate fuel savings potential if all applicable long-distance trucking fleets adopted platooning (operating independently)
- Define maximum possible fuel savings from the case in which all commercial highway vehicles are equipped with compatible platooning technology (i.e., any truck has ability to communicate and operate under controlled platooning, regardless of ownership)
- Define gallons saved versus adoption curve with cooperative platooning systems
  - Unique relationship means greater savings with greater adoption—non-linear savings rate
- Define curve between individual independent fleet adoption and maximum possible case
  - Quantify the value (fuel savings) of developing competing systems with the ability to function together
  - Identify how much assistance is needed to become self-sustaining technology
  - Provide scale of fuel savings possible from cooperative fleets and national perspectives

Three-vehicle platoon investigation (joint NREL/LLNL activity):

- Fuel savings difference – center position opportunity
- Logistic opportunities/challenges – extension of "big data" study

Photos courtesy of LLNL, NREL 28961, 28964, and 28963

KEY TAKEAWAYS

- Independent test data show significant fuel and emissions savings for all platooning scenarios being considered for near-term deployments
- In the longer term, platooning fuel savings can be enhanced by addressing barriers to closer platoon formation—such as reduced engine cooling—and more vehicles in platoon
- Significant correlation was observed between multiple track studies, wind tunnel testing, and CFD, but there is more to learn regarding behavior under close formation and longer following distances
- Naturalistic study shows that existing "background platooning" is minimal and does not significantly impact fuel savings
- Early measurements of increased NOx emissions appear to have been addressed through control strategy adjustments—latest data show decreased NOx emissions for platooned vehicles

ACKNOWLEDGMENTS

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