Summary of NREL’s Recent Class 8
Tractor Trailer Platooning Testing

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Project Objective

- Repeatable track testing to assess fuel savings potential from semi-automated truck platooning
  - Supported by DOE’s Vehicle Technologies Office
  - SAE J1321 Type II Fuel Consumption Test Procedure
- Test American-style line haul sleeper cabs with modern aerodynamics
  - EPA SmartWay tractors; trailers with side skirts
- Test range of following distances, vehicle loadings and speeds common in the U.S. (up to 70 mph)
Platooning System Testing

- Demonstration system provided by Peloton Technology, Inc.
- Enabling technologies for platooning
  - Forward object detection (radar, laser, stereo cameras, etc.)
  - Dedication short-range communication (DSRC)
  - Vehicle-to-vehicle communications (V2V) and driver displays
  - Vehicle braking and torque control interface
- Testing details
  - Ten constant speed tests and one variable speed test
  - 20–75 ft vehicle gaps
    - 65 mph = 95 ft/s; 6-sec rule of thumb would give 570 ft following distance
  - Gravimetric fuel measurements with weigh tanks
  - J1939 data collection, including coolant temperature and fan state

<table>
<thead>
<tr>
<th>Trailing Distance</th>
<th>55 mph, 65,000 lb</th>
<th>65 mph, 65,000 lb</th>
<th>70 mph, 65,000 lb</th>
<th>Variable Speed, 65,000 lb</th>
<th>65 mph, 80,000 lb</th>
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</thead>
<tbody>
<tr>
<td>20 ft</td>
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<tr>
<td>30 ft</td>
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<td>40 ft</td>
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<td>75 ft</td>
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</tbody>
</table>
Summary of SAE J1321 Type II Test Procedure

- Warm-up runs ensure all trucks at stable operating temperatures
- Control truck accounts for changes in atmospheric conditions between baseline and test runs

\[
\frac{T}{C} \text{ ratio} = \frac{\text{Test vehicle fuel use}}{\text{Control vehicle fuel use}}
\]

\[
\% \text{ Improvement} = \frac{[T/C]_{\text{Test}}}{[T/C]_{\text{Baseline}}}
\]
Results: Fuel Savings

- Team fuel savings ranged from 3.7% to 6.4%
- Closer following distances caused the engine fan on the trailing truck to engage, negatively impacting fuel savings

Class 8 - Two Truck Platooning
Fuel Savings at 65 mph 65,000 lb
Fuel Consumption Results: Individual Fuel Savings

- 2.2% to 5.3% savings @ 65,000 lb GVW
- Shorter following distances consistently produced greater fuel savings

*(95% CI bars are calculated with SAE J1321 software)*

Class 8 Truck Platooning Fuel Savings
- Lead Truck -
Fuel Consumption Results: Individual Fuel Savings

- Trailing truck demonstrated savings from 2.8% to 9.7%
  - Tests with no “fan on” time had savings of 8.4% to 9.7%
  - Fan duty cycle as high as 19%
Fuel Consumption Results: Team Fuel Savings

- Team fuel savings ranged from 3.7% to 6.4%
  - Best combined result was for 55 mph, 30-ft gap, 65,000 lb GVW
- Higher GVW negatively impacted fuel-saved percent
- Percent savings at 70 mph were lower than at 55 mph and 65 mph

Class 8 - Two Truck Platooning Team
Combined "Team" Fuel Savings
Fuel Economy Results

- Baseline mpg is the test distance of 59.4 miles divided by an average of all baseline run fuel-consumption results from both test trucks for each speed and load condition.

- Platooning mpg is calculated by applying the SAE procedure calculated-percent fuel savings to the baseline fuel consumption average.

  - Platooning improved fuel economy at all speeds and conditions
    - Best mpg overall was platooning at 55 mph

  - Baseline condition tests show effect of speed on mpg
    - 7.82 mpg @ 55 mph
    - 6.58 mpg @ 65 mph
    - 6.07 mpg @ 70 mph

  - Baseline condition tests show effect of mass on mpg
    - 6.58 mpg @ 65 mph & 65,000 lb
    - 6.33 mpg @ 65 mph & 80,000 lb.
Class 8 Truck Platooning Fuel Economy
- Lead Truck -

Fuel Economy Results: Lead Truck MPG
Fuel Economy Results: Trailing Truck MPG

Class 8 Truck Platooning Fuel Economy
- Trailing Truck -

Following Distance (ft)

Fuel Economy (mpg)

- 55 mph
- 65 mph
- 70 mph
- 65 mph @ 80,000 lb
- 55 mph Baseline Average
- 65 mph Baseline Average
- 70 mph Baseline Average
- 80,000 lb 65 mph Baseline Average
Fuel Economy Results: Team MPG

Class 8 - Two Truck Platooning Team
Combined "Team" Fuel Economy

Following Distance (ft)

Fuel Economy (mpg)

55 mph
65 mph
70 mph

65 mph @ 80,000 lb

55 mph Baseline Average
65 mph Baseline Average
70 mph Baseline Average
80,000 lb 65 mph Baseline Average
Platooning Following Distance Error

- Error biased to greater following distance
- Even aggressive variable speed test had minimal encroachment of following distance
Platooning Driver Position Error

- Driver error bias in consistent direction throughout testing
- Increased maximum error at 30’ could have reduced savings and was a test series run from 8-12PM after a long test day so fatigue / darkness could be contributing
Summary of Key Findings

• Significant line-haul fuel savings possible through platooning
  o Tests showed fuel savings for the lead (up to 5.3%) and trailing (up to 9.7%) trucks
  o The demonstrated “team” savings of 6.4% could be an attractive return on investment for a fleet

• Engine coolant temperature needs to be monitored/addressed for the trailing vehicle
  o Optimum following distance may depend on ambient temperature and vehicle load (absent some aerodynamic aid for radiator air flow)

• Heavy payloads affect the percent improvement from platooning, but still result in substantial fuel savings

Full details from present study will be published:
• At SAE COMVEC in October 2014 (paper number 2014-01-2438)
• In an NREL technical report in late 2014
Potential Future Work

- More data points/test sets to confirm the trends seen here
  - Including greater following distances to clarify the optimum configuration
- Incorporate direct aerodynamic study into track testing (truck-mounted anemometer, smoke trails, etc.)
- Complementary computational fluid dynamics modeling
- Test platoons of more than two tractor trailer combinations
- Further analysis including assessments of current line-haul travel
  - What percent of national line-haul miles would be conducive to platooning?
  - How often trucks typically travel together and at what following distance?
- Design aerodynamic aids specific to platooning to address the loss of cooling airflow over the radiator for the trailing tractor
- Assess any impact of platooning on criteria emissions (e.g., NO\textsubscript{x})
Acknowledgements

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Thanks! Questions?

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