DOE's Effort to Improve Heavy Vehicle Fuel Efficiency through Improved Aerodynamics

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Kambiz Salari

Lawrence Livermore National Laboratory

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Overview

Timeline

A new integrated tractor-trailer design from ground up has been proposed that radically decreases the aerodynamic drag and improves the fuel economy. New aerodynamic treatments have been proposed for tanker-trailers

- *Designed a first generation of an integrated tractor-trailer geometry which we have labeled as Generic Speed Form one (GSF1)*
- *Performed wind tunnel tests of selected aero devices for tractor-trailers and tankers to improve fuel efficiency*

Budget

- *Funding for FY14, $600K*
- *Funding for FY15, $850K*

Barriers

- *Reduce aerodynamic drag of class 8 tractor-trailers by approximately 25% leading to a 10-15% increase in fuel efficiency at 65 mph*

Partners

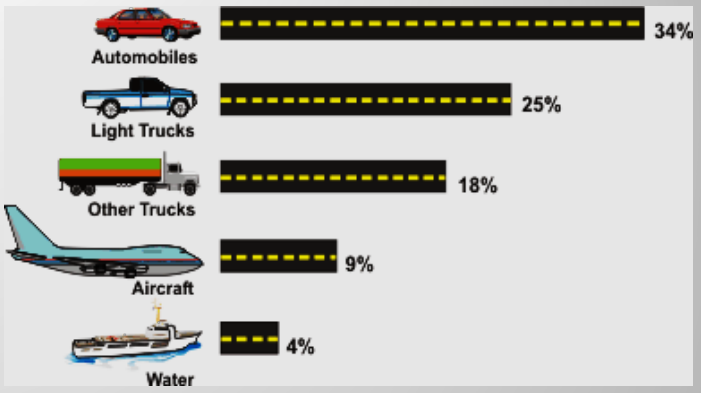
- *Navistar, Inc.*
- *Kentucky Trailer and Wabash National*
- *Freight Wing Inc. and ATDynamics*
- *Frito-Lay, Spirit, and Safeway*
- *Michelin*
- Praxair

Class 7-8 tractor-trailers are responsible for 12% of the total US consumption of petroleum

2.5 million combination trucks[1]
66,161 average miles/year/vehicle
5.8 average miles/gallon

Aerodynamic drag reduction contribution

15% reduction in fuel use = 4.2 billion gallons of diesel fuel saved per year and 42 million tons of CO_2 emission
$12 billion saved/year ($2.78 per gallon diesel)



Tractor-Trailer integration radically decreases aerodynamic drag

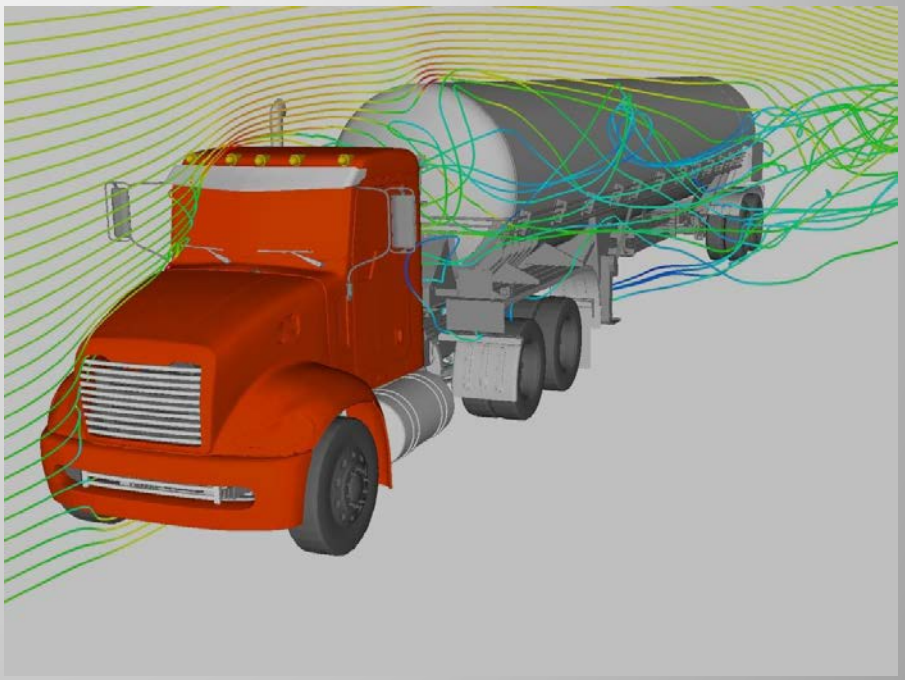
Opportunity to double the savings offered by drag reduction add-on devices

Wide-base single tires add about 4-5% to overall vehicle fuel economy

1. U.S. Department of Energy, Transportation Energy Data Book, Edition 32, July 2014

Tanker trailers are responsible for 1.3% of the total US consumption of petroleum

Approximately 200,000 tanker trailers[1]
60,000 average miles/year/vehicle
4.5 average miles/gallon



Aerodynamic drag reduction contribution

17% reduction in fuel use = 0.6 billion gallons of diesel fuel saved per year and 6 million tons of CO_2 emission
$1.7 billion saved/year ($2.78 per gallon diesel)

Tractor-Trailer integration radically decreases aerodynamic drag

Opportunity to double the savings offered by drag reduction add-on devices

Wide-base single tires add about 4-5% to overall vehicle fuel economy

1. National Tank Truck Association, www.tanktruck.org

Objectives

- ***In support of DOE's mission,*** *provide guidance to industry to improve the fuel efficiency of class 8 tractor-trailers and tankers through enhanced aerodynamics*
- ***Demonstrate*** *new drag-reduction techniques and concepts*
  - *Class 8 tractor-trailers and tankers*
- ***Joined with industry in getting devices on the road***
- ***Develop the next generation of highly aerodynamic and integrated class 8 tractor-trailers and tankers***
- ***On behalf of DOE*** *to expand and coordinate industry participation to achieve significant on-the-road fuel economy improvement*

Milestones

FY14

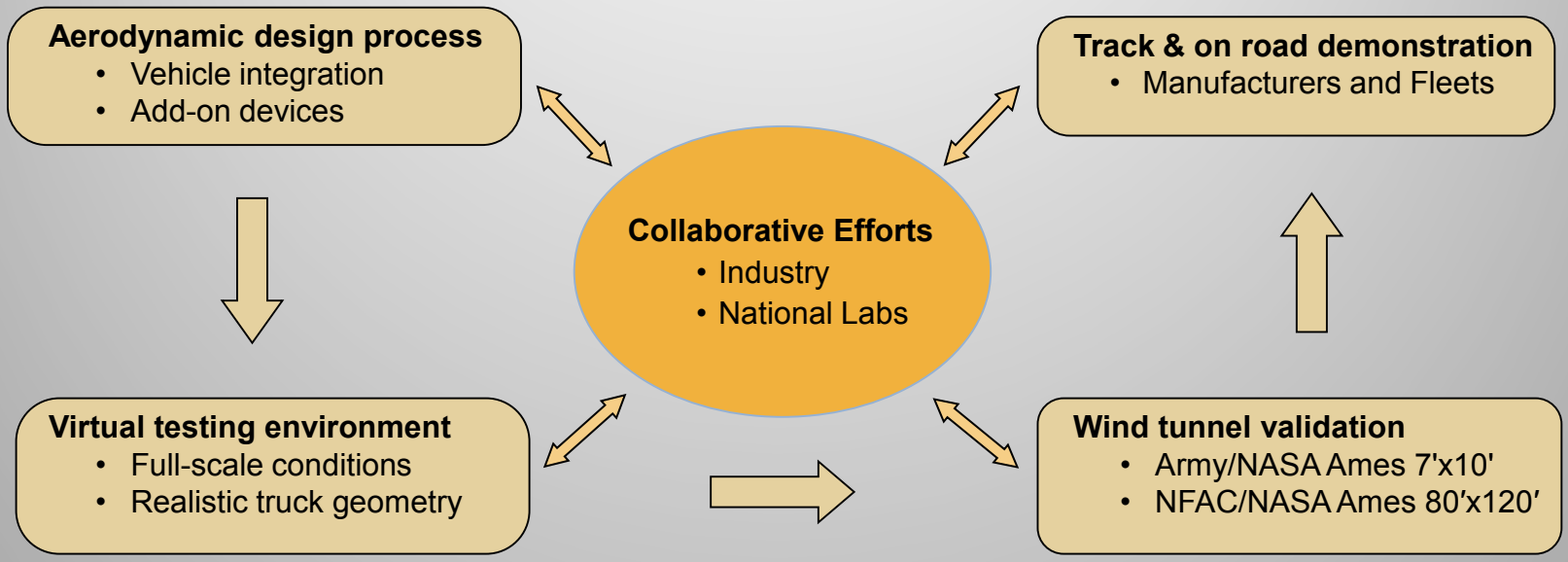
- ***Started the design process of the first generation of a highly aerodynamic and integrated tractor-trailer geometry called Generic Speed Form 1 (GSF1)***
- *Continue to improve the design/performance of selected aero devices*
- *Continue to improve the aerodynamics of tanker trailers*
- *Performed wind tunnel tests to validate the performance of aero devices and integrated design for tractor-trailers and tankers*

FY15

- ***Analyzed wind tunnel test results on our first generation integrated tractor-trailer geometry (GSF1)***
- ***Analyzed wind tunnel test results on aerodynamically treated tanker-trailers***
- *Continue to improve the design/performance of an integrated skirt and tail devices*
- *Investigated tractor-trailer underbody flow for drag reduction*
- *Investigated the performance of aero devices and integrated design for tractor-trailers and tankers*

Science-based approach is used to create an aerodynamic and highly integrated vehicles

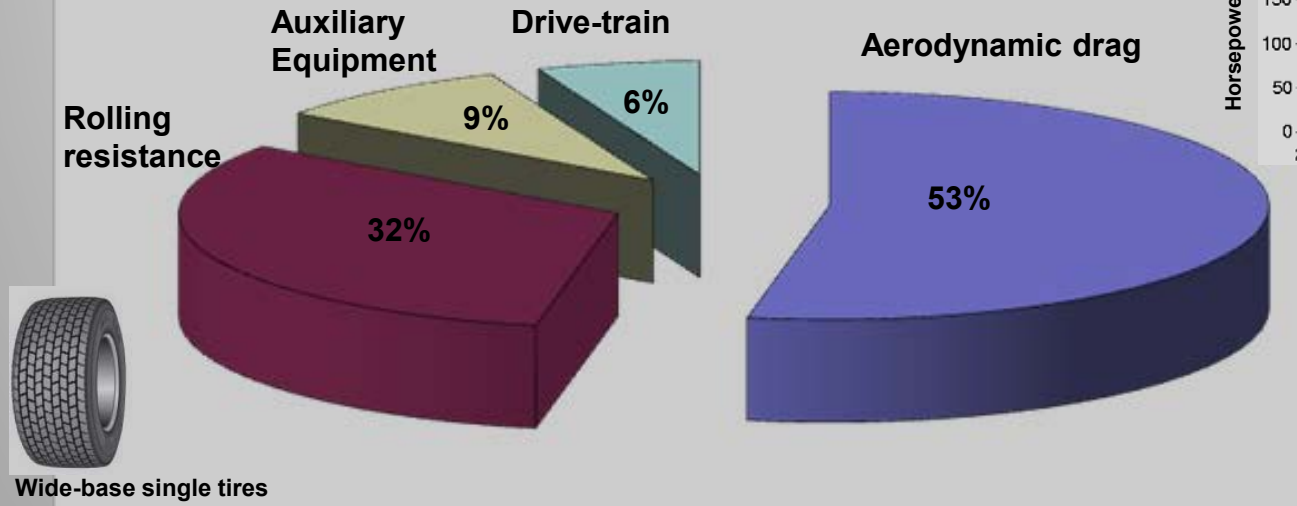
Validate aerodynamic concepts with industry collaboration and feedback

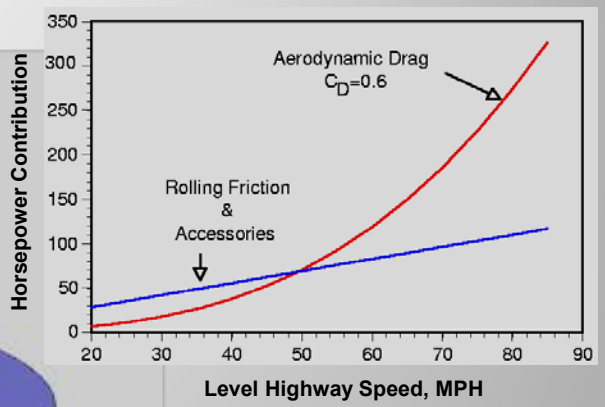


Technical accomplishments

- ***Designed the first generation*** *of an integrated tractor-trailer geometry from ground up that radically decreases aerodynamic drag and improves the fuel efficiency (GSF1).*
  - *Most of the GSF1 tractor design was completed with the aid of wind tunnel testing*
- ***Conducted 1/8 scale experiments*** *at the Army 7'x10' wind tunnel facility at Ames Research Center*
- ***Conducted computational simulations of GSF1*** *to better understand its aerodynamic performance*
- ***Evaluated the aerodynamic performance*** *of skirt and tail devices*
  - *Underbody flow investigation and integration of skirt and tail devices*
- ***Improved the aerodynamics of a common tanker-trailer*** *for significant gain in fuel economy*
- ***Achieved international recognition*** *through open documentation and conferences*

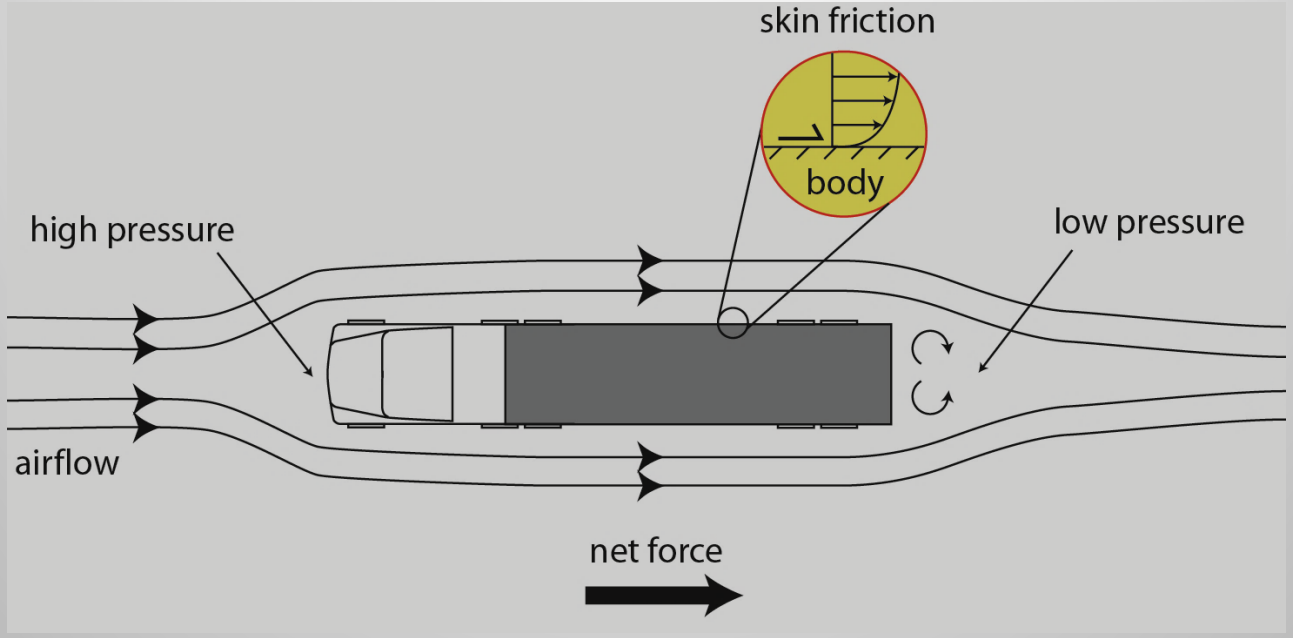
Heavy trucks use most of their usable propulsion energy to overcome drag and rolling resistance at highway speed





Losses in nearly all of these categories can be reduced by employing presently available technology

Improved fuel economy is achieved through better aerodynamics

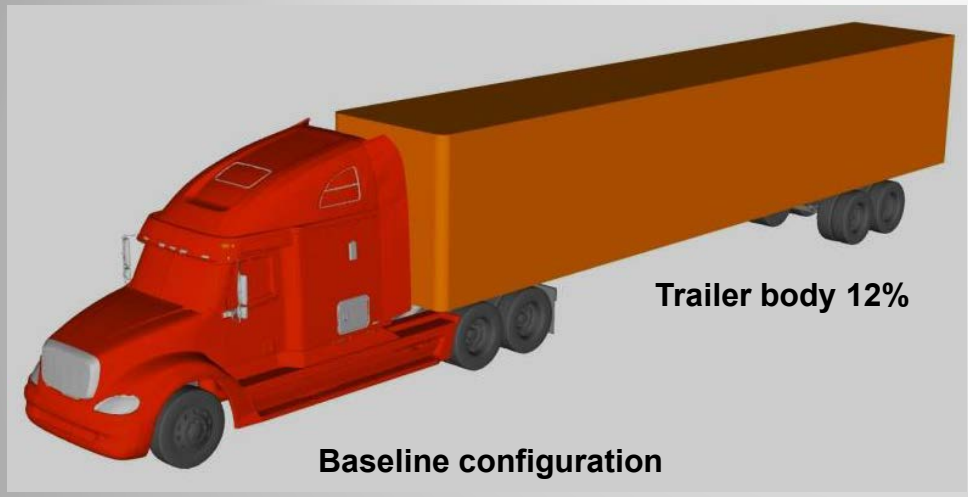


$$Drag = C_D \times S \times (1/2)\rho U^2$$

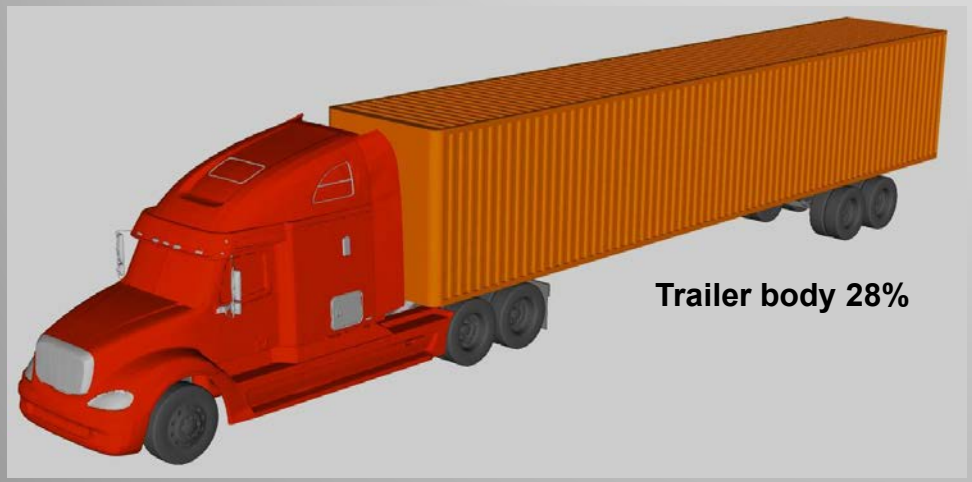
$$\frac{\Delta FuelConsumption}{FuelConsumption} = \eta \times \left(\frac{\Delta C_D}{C_D} + \frac{\Delta S}{S} + \frac{3\Delta U}{U} \right)$$

$\eta \approx 0.5\text{-}0.7$ | shape | cross-section | speed

As a nation we pay a significant price in moving corrugated shipping containers



Baseline configuration

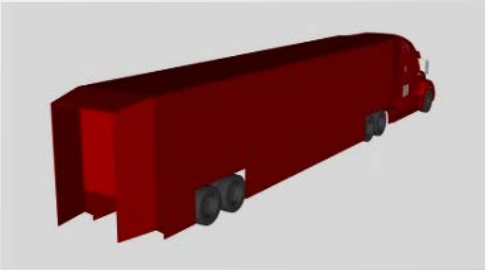


Wind tunnel test:
~10% decrease in fuel economy

Computation: ~8% decrease in fuel economy

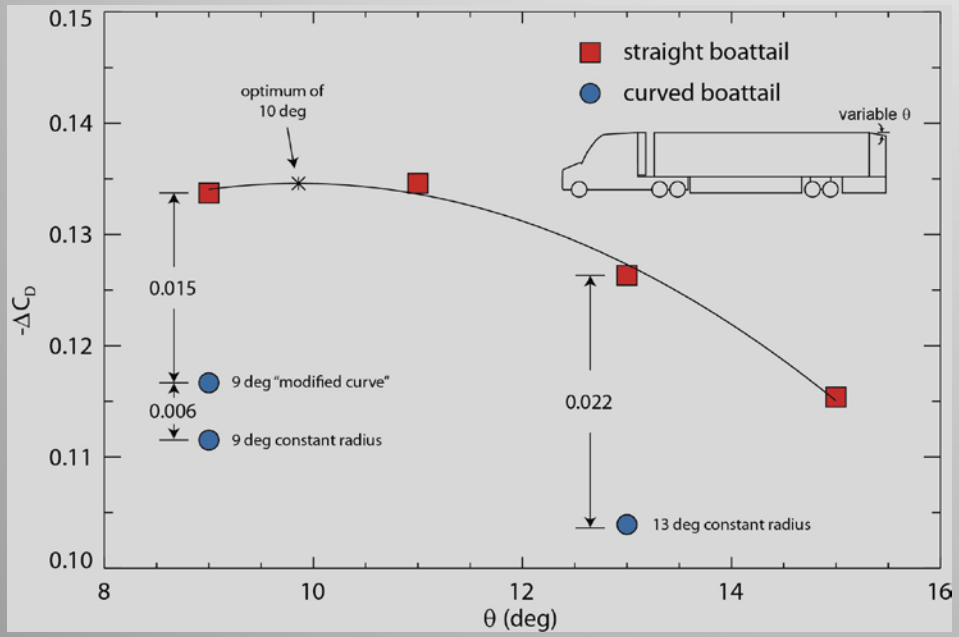
Add-on aerodynamic devices show significant potential to improve fuel economy

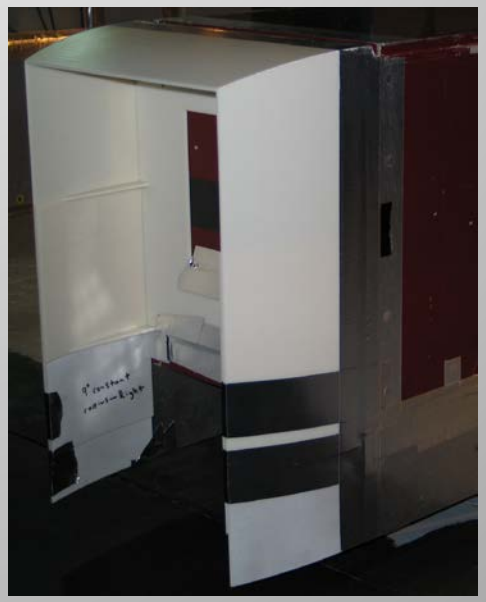
Skirt + 48" tail (3-sided)



ΔC_D (%)

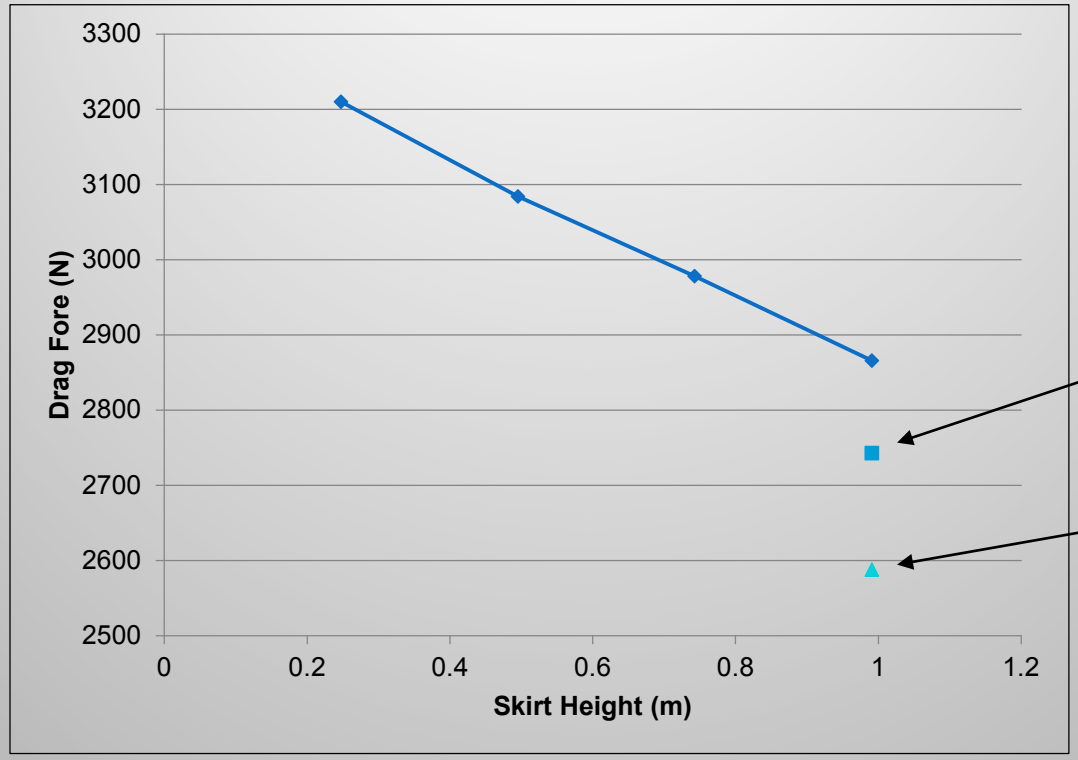
(-25%, wind tunnel)



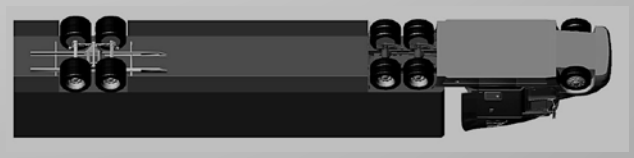


LLNL 48" curve tail with full skirt extension

Aerodynamic performance of skirt increases with adding more surface area

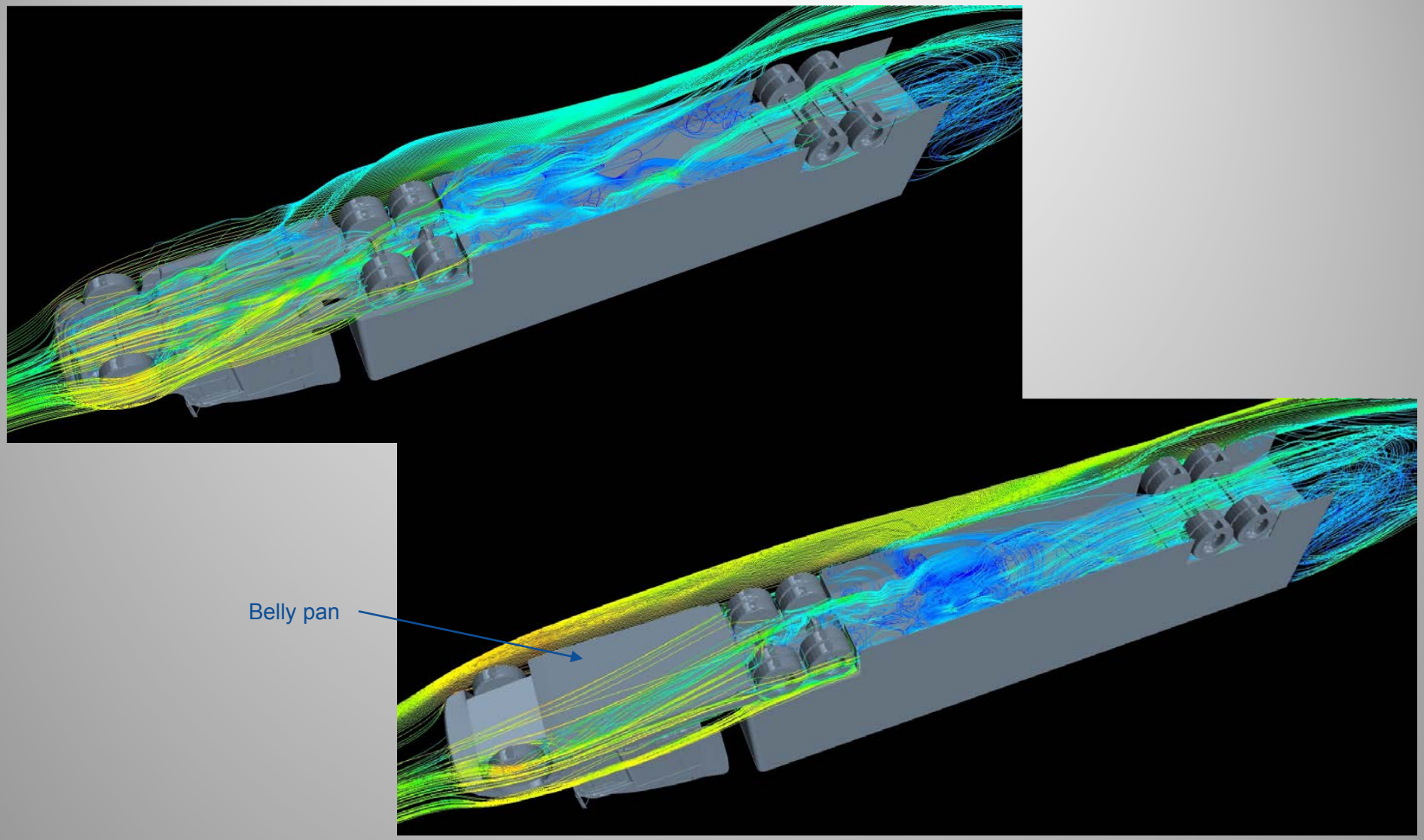


Extended tractor skirt

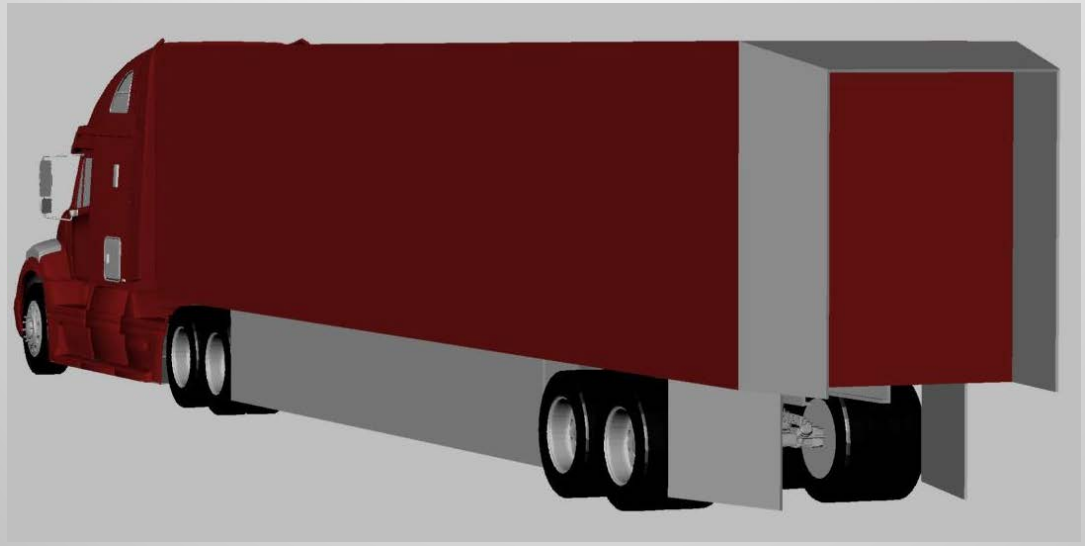


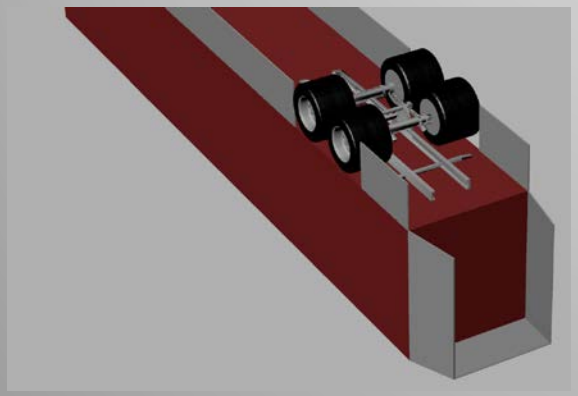
Belly pan

Tractor belly pan helps to improve underbody flow

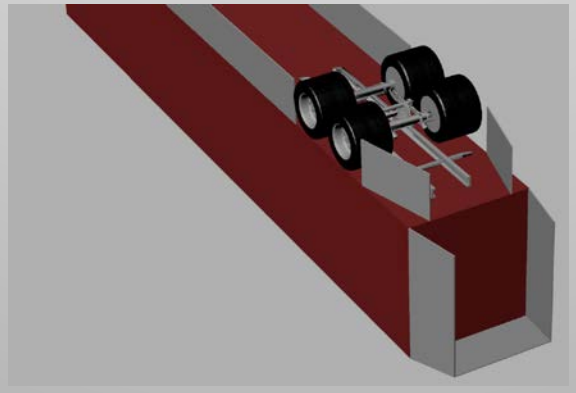


Angled trailer aft short skirt with a combination of a short or a long tail shows no aerodynamic benefits

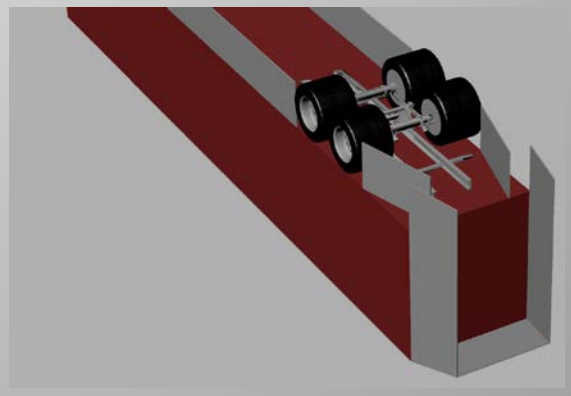




ΔC_D = -0.157

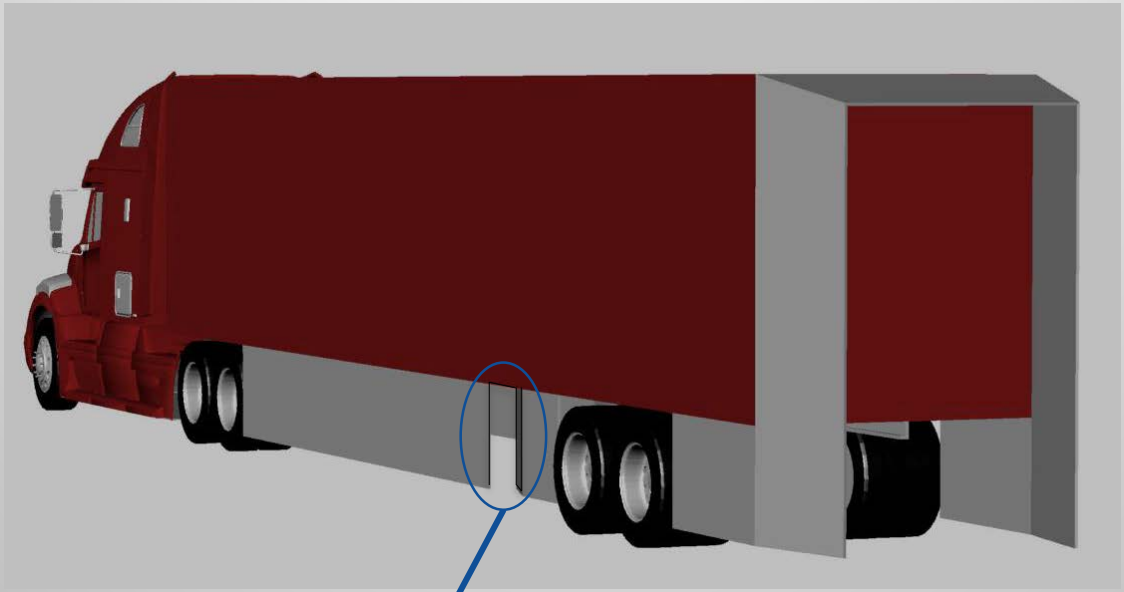


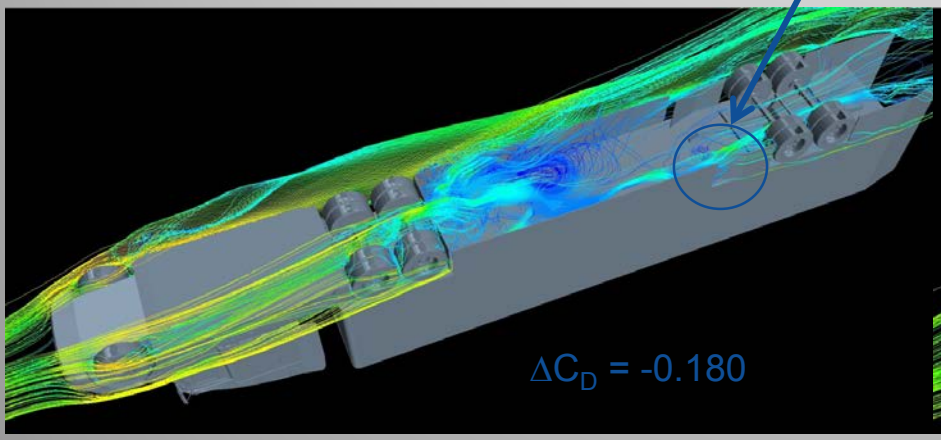
ΔC_D = -0.158

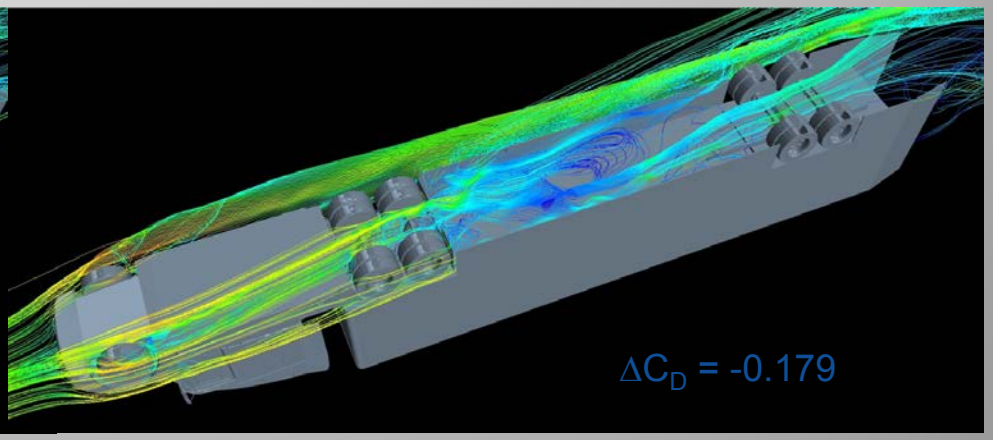


ΔC_D = -0.157

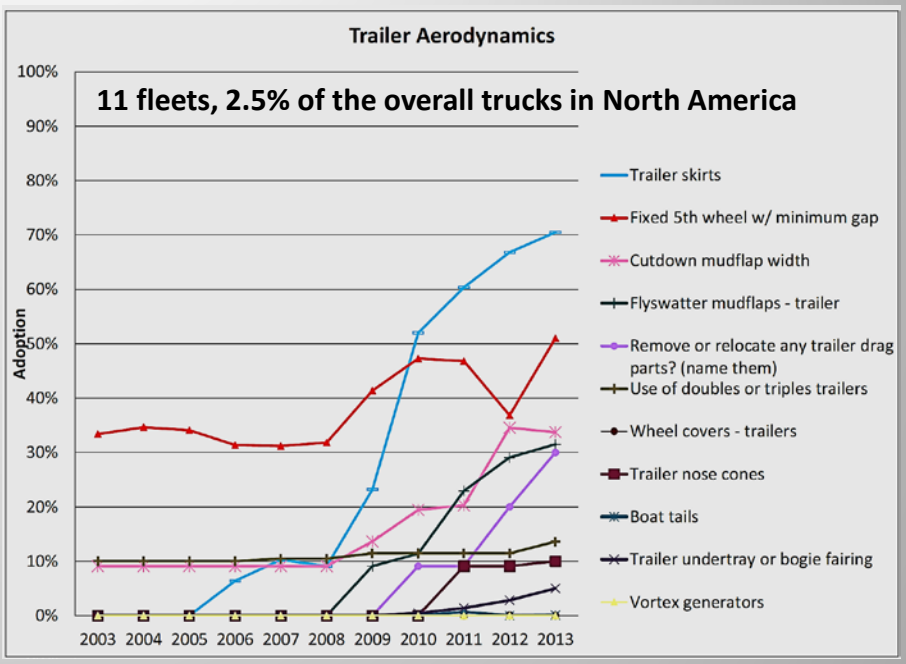
Venting does not improve skirt aerodynamic performance







Since 2010 the rate of customers/fleets acceptance of aerodynamic add-on devices has significantly increased

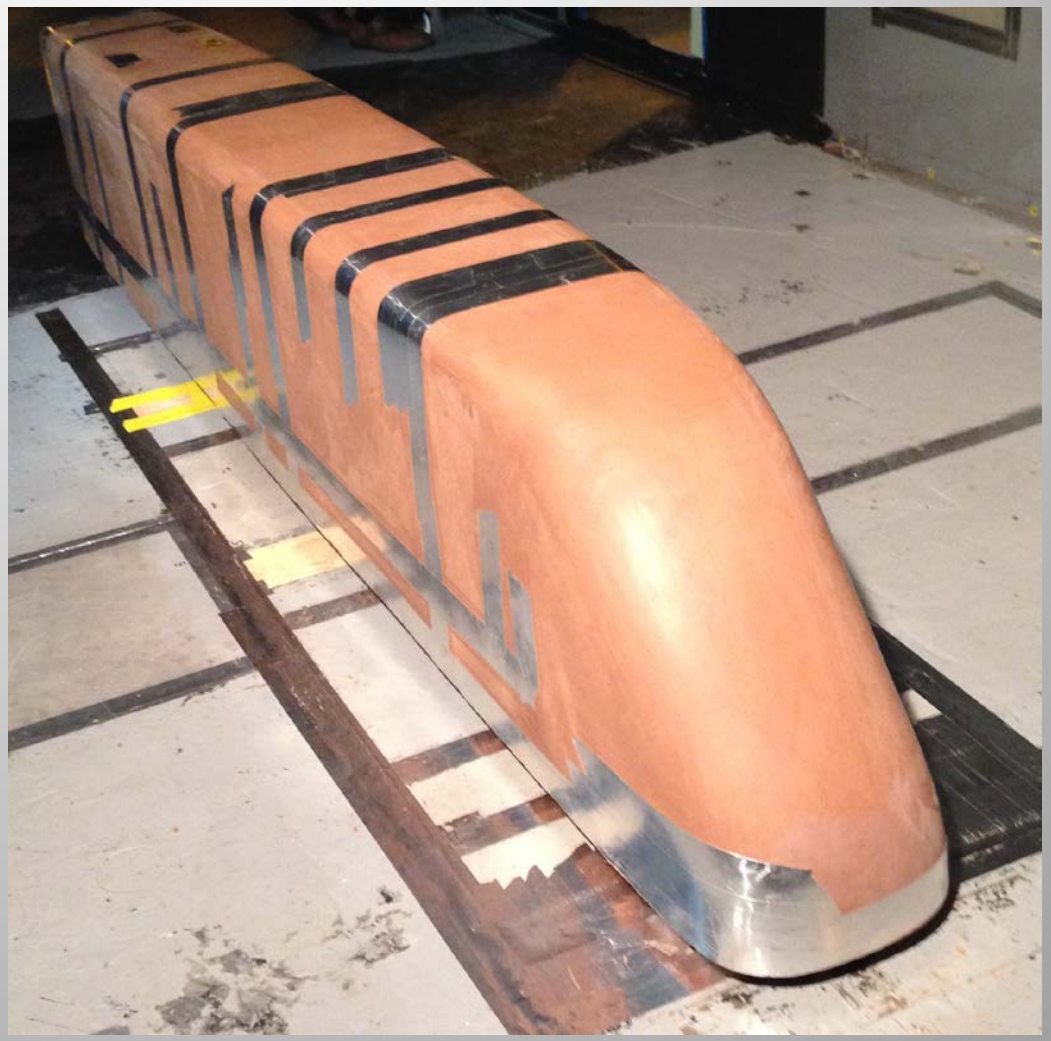


Fleets in the 2014 study included CR England, Challenger Motor Freight, Con-way Truckload, Frito Lay, Paper Transport, Ryder, Schneider, Werner, Bison Transport and United Parcel Service. The primary goal was to study the level of adoption of 66 technologies

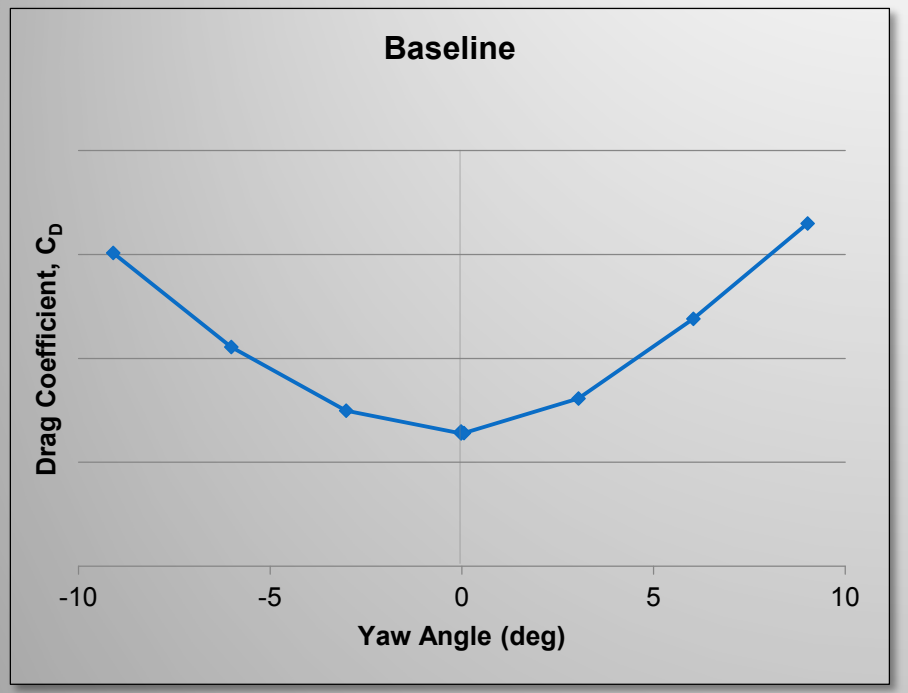
2014 Fleet Fuel Efficiency Benchmark Study: conducted by the North American Council for Freight Efficiency, August 31, 2014

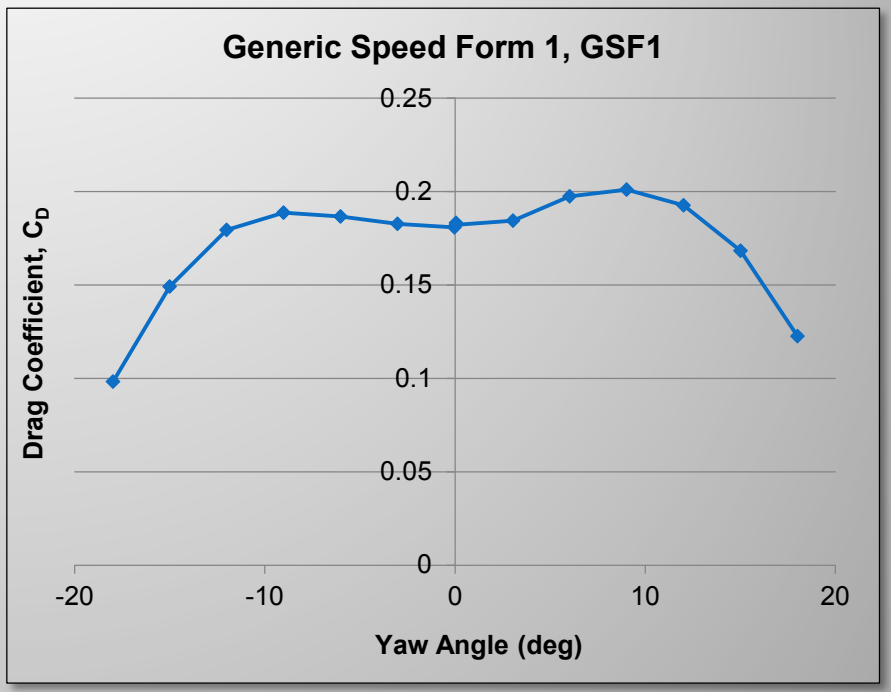
Tractor-trailer integration is the next step in achieving a radical improvement in fuel economy

> 60% aerodynamic drag reduction compared to heavy vehicles on the road today

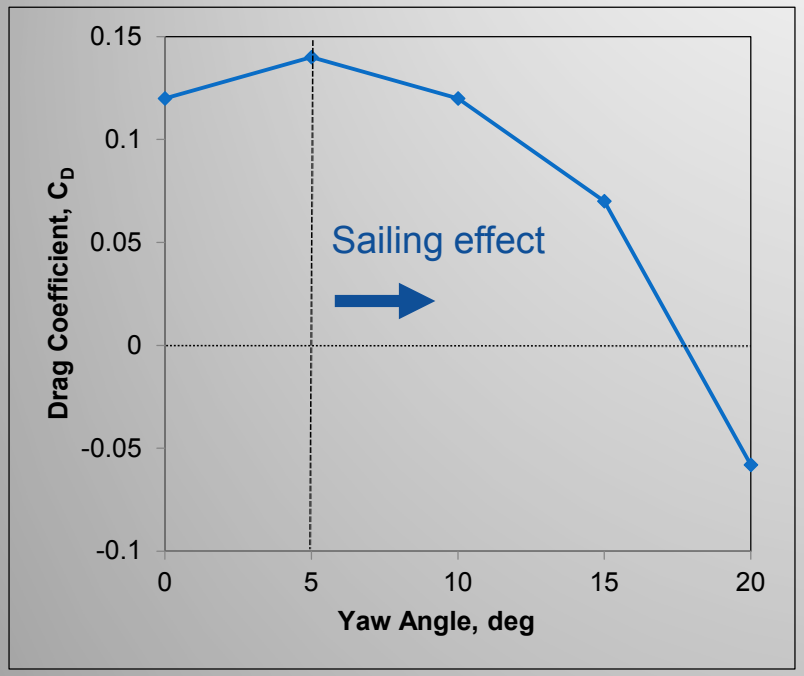


GSF1 radically reduces drag

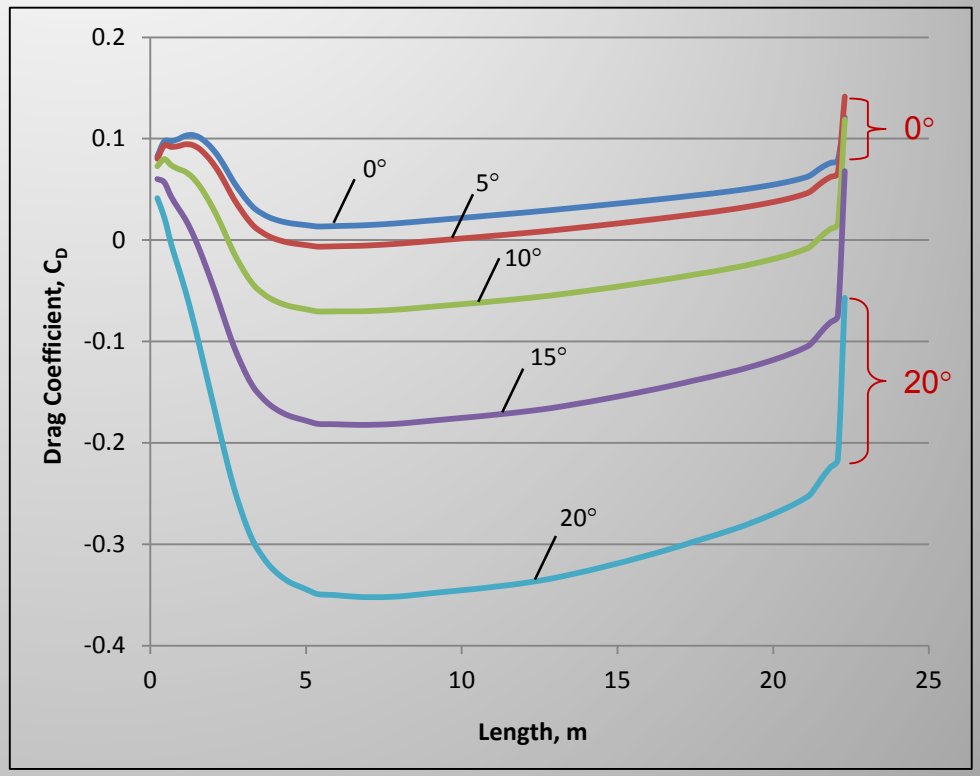




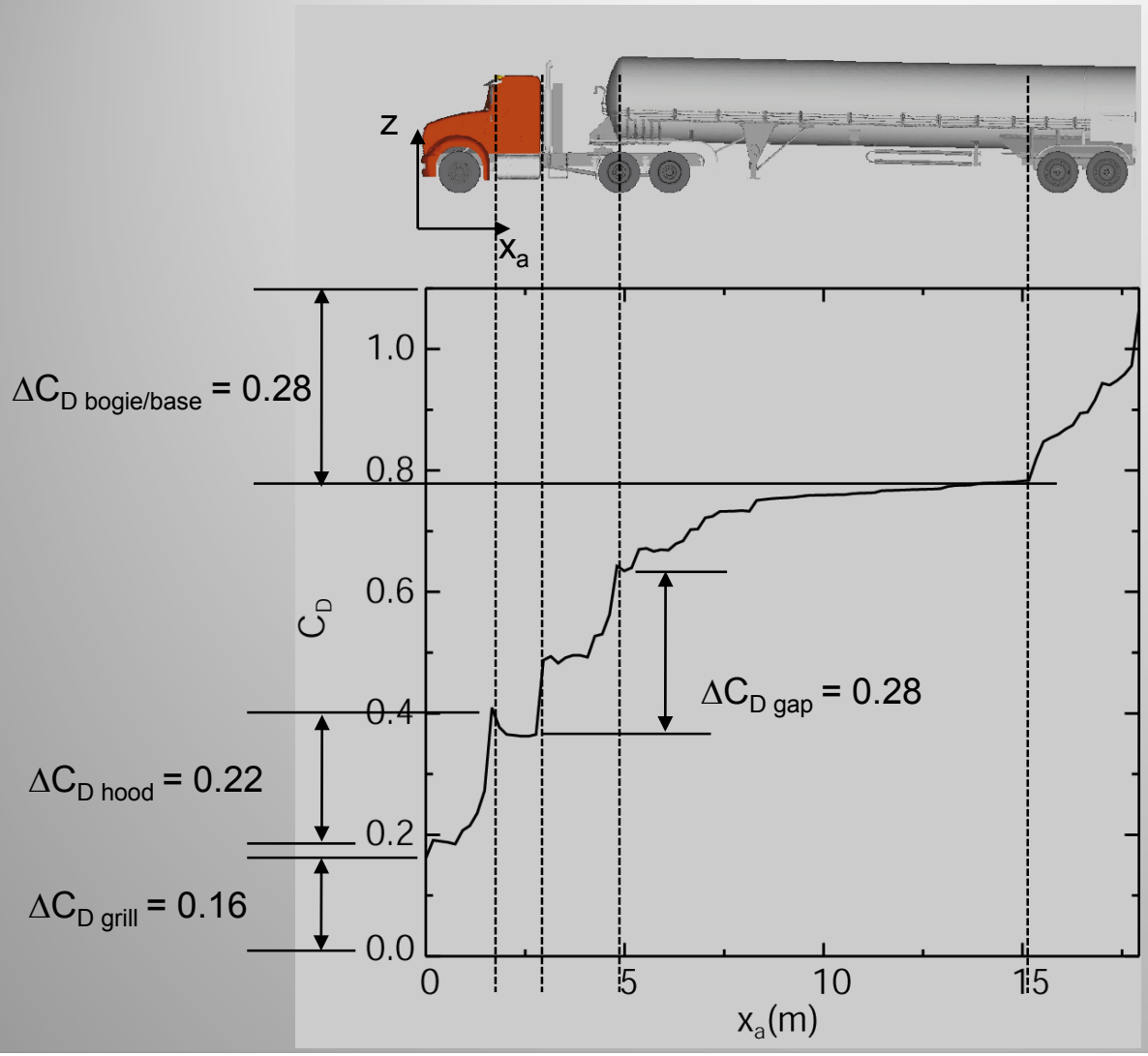
GSF1 exhibits sailing effect in wind tunnel testing



Base drag increases with increasing yaw angle

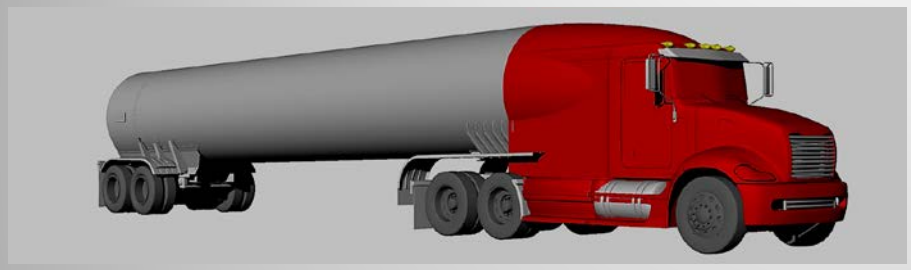


There are several major drag sources on a tanker trailer

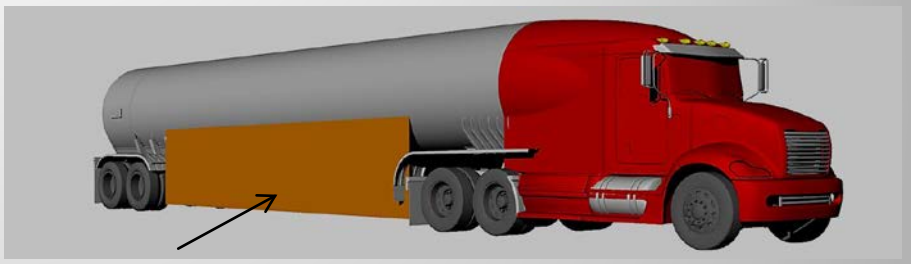


Performed extensive wind tunnel tests at Army 7'x10' facility in the NASA Ames Research Center

Improved tanker aerodynamics can improve fuel economy by > 20%

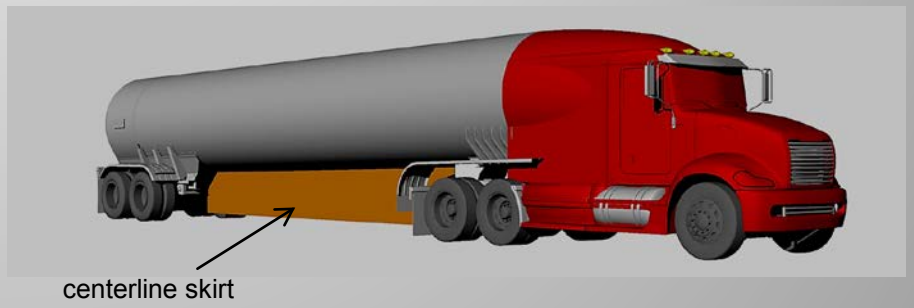


26% drag reduction



39% drag reduction

41% drag reduction



33% drag reduction

We have started to collaborate with NREL to investigate the fuel economy benefits of platooning the line haul trucks

Summary

- ***Designed the first generation of an integrated tractor-trailer geometry from ground up that radically decreases aerodynamic drag and improves the fuel efficiency (GSF1)***
- *Conducted 1/8 scale experiments at Army 7'x10' wind tunnel facility at the Ames Research Center*
- *Analyzed wind tunnel experimental results for GSF1 and different aerodynamic treatments for tanker*
- *Evaluated the aerodynamic performance of full skirts with an integrated tail*
  - *Various distance to the ground*
  - *Angled short skirt aft the trailer axle*
  - *Vented skirt*
- *Started to collaborate with NREL to investigate the fuel economy benefits of platooning the line haul trucks for two to three vehicles*
- *Achieved major reduction in aerodynamic drag for tanker trailers through geometry modifications*

Future plans

- ***Continue with tractor-trailer integration design for radical improvement in aerodynamic drag and fuel economy***
- ***Perform experiments to start the design of GSF2 integrated tractor-trailer***
- *Continue to perform scaled experiments to design and validate the performance of aerodynamic add-on devices an integrated tractor-trailers and tankers*
- ***Start to design the next generation of highly aerodynamic tankers***
- *Continue to work with tanker fleets to improve fuel economy*
- *Probe the fuel economy benefits of platooning the line haul trucks in collaboration with NREL*
- *On behalf of DOE, continue to coordinate industry participation to design the next generation of highly aerodynamic heavy vehicles*