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

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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 efficiency. 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 FY13, $900K*
- *Funding for FY14, $600K*

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

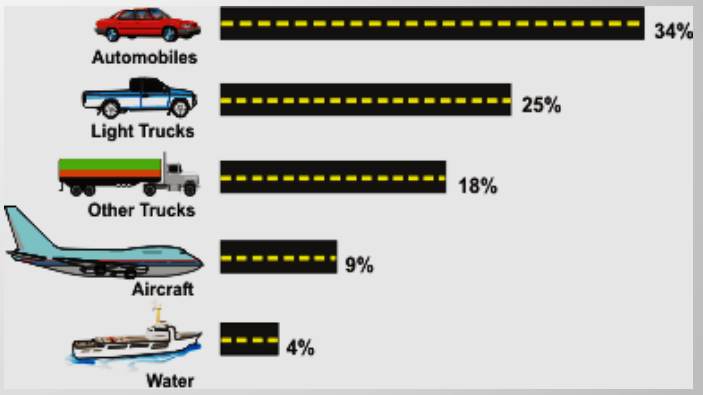
- *Navistar, Inc.*
- *Kentucky Trailer and Wabash National*
- *Freight Wing Inc. and ATDynamics*
- *Frito-Lay, Spirit, and Safeway*
- *Michelin*
- *Praxair*

Class 7-8 tractor-trailers are responsible for 11-12% of the total US consumption of petroleum

Aerodynamic drag reduction contribution

15% reduction in fuel use = 5.1 billion gallons of diesel fuel saved per year and 52 million tons of CO2 emission

$21 billion saved/year ($3.96 per gallon diesel)



Aerodynamics and wide-base single tires contributions

19% reduction in fuel use = 6.5 billion gallons of diesel fuel saved per year and 66 million tons of CO2 emission

$26 billion saved/year ($3.96 per gallon diesel)

Tractor-Trailer integration

Aerodynamics: > 25% reduction in fuel use

With wide-base tires: > 29% reduction in fuel use

U.S. Department of Energy, Transportation Energy Data Book, Edition 32, July 2013

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

FY13

- *Collection of on-the-road performance data for the selected tractor-trailer aero devices in collaboration with Frito-Lay and Spirit fleets*
- *Improve the design/performance of selected aero devices based on the knowledge gained from collected on the road data*
- *Improve the aerodynamics of a common tanker trailer for significant enhancement of fuel economy*
- ***Start the investigation of tractor-trailer integration (geometry, flow, and thermal) in collaboration with our industry partners***

FY14

- ***Design the first generation of a highly aerodynamic and integrated tractor-trailer geometry***
- *Continue to improve the design/performance of selected aero devices*
- *Continue to improve the aerodynamics of tanker trailers*
- *Perform wind tunnel tests to validate the performance of aero devices and integrated design for tractor-trailers and tankers*

Science-based approach is used to improve the aerodynamics of heavy vehicles

Design & validate aerodynamic concepts with industry collaboration and feedback

Design the next Gen of highly aerodynamic and integrated vehicles
- Science based

Virtual testing environment
- Full-scale conditions
- Realistic truck geometry

Full-scale wind tunnel validation
- NFAC/NASA Ames 80′x120′
- NRC, Canada

Track & road demonstration
- Manufacturers and Fleets

Collaborative Efforts

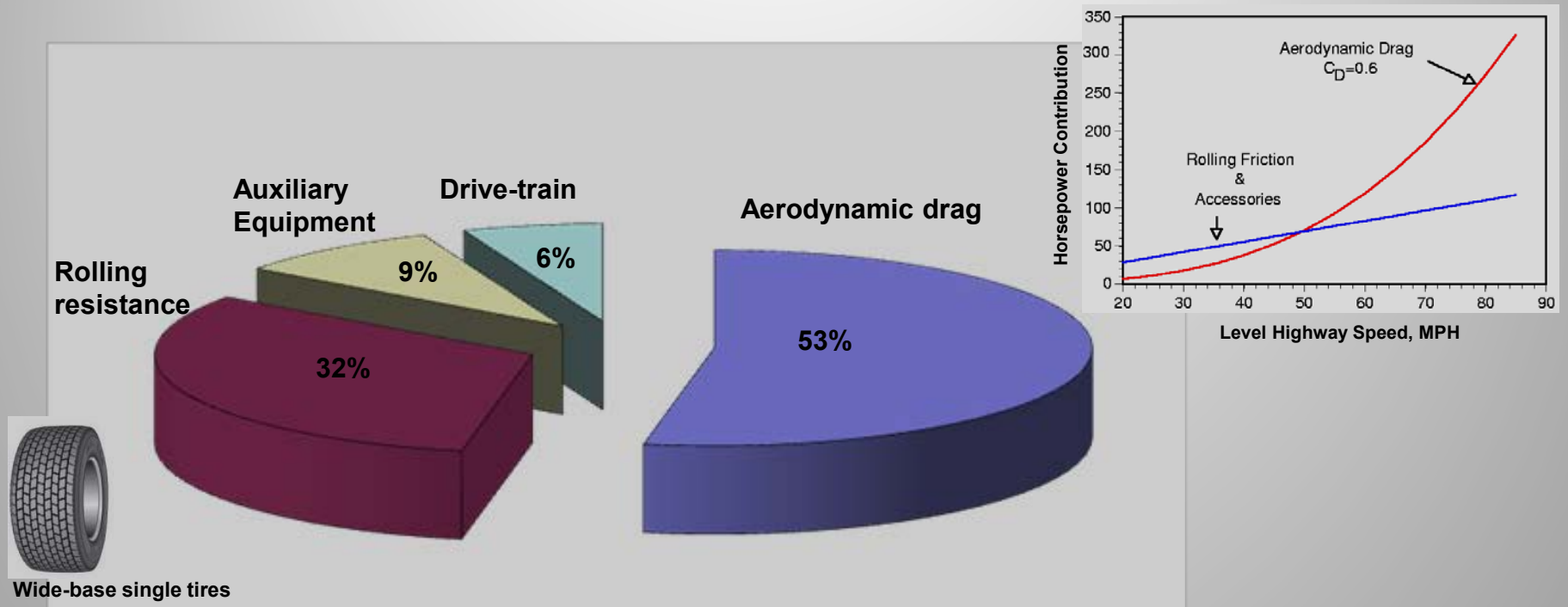
Industry
- Manufacturers
- Fleets

Scientists
- National Labs
- NASA
- Universities

Technical accomplishments

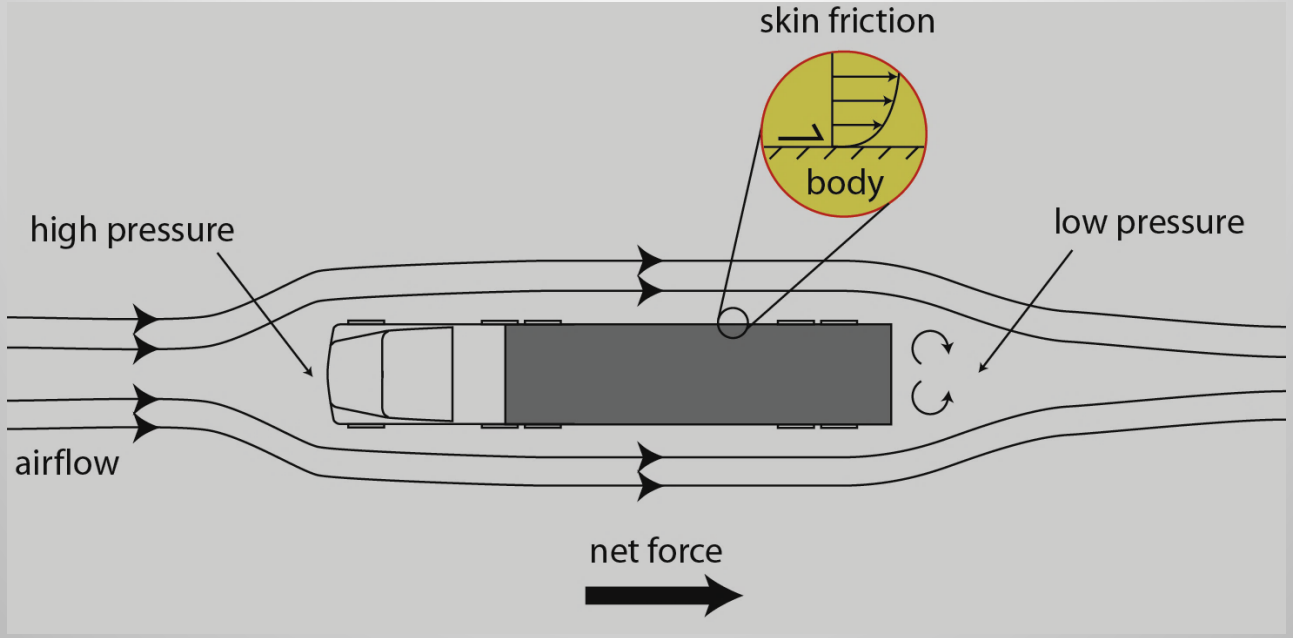
- ***Designed the first generation*** *of an integrated tractor-trailer geometry from ground up that radically decreases aerodynamic drag and improves the fuel efficiency. We have labeled this new design as Generic Speed Form one (GSF1)*
  - *Most of the GSF1 tractor design was completed with the aid of wind tunnel testing*
- ***Conducted 1/8 scale experiments*** *at the Army 7'x10' wind tunnel facility at Ames Research Center*
- ***Evaluated the aerodynamic performance*** *of tail devices*
  - *Optimum angle, curve vs. straight panels, leakage impact, and tail-light requirements*
- ***Improved the aerodynamics of a common tanker-trailer*** *for significant gain in fuel economy*
- ***Published the full-scale wind tunnel test results*** *conducted at NASA Ames 80'x120' NFAC facility*
  - *Two tractors, three trailers, and twenty-three aerodynamic devices/concepts were tested*
- ***Published on the road performance data*** *for selected aero devices in collaboration with our industry team, Navistar, Kentucky Trailer, Freight Wing, Michelin, and Frito-Lay's and Spirit's Fleets*
- ***Achieved international recognition*** *through open documentation and conferences*

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



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

Improved fuel economy is achieved through better aerodynamic design



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

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

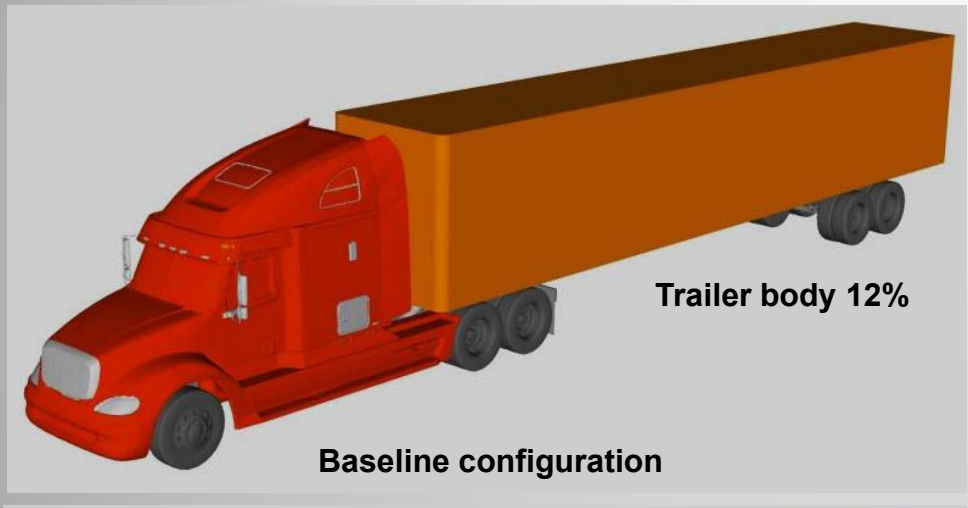
$\eta \approx 0.5\text{-}0.7$ | shape | cross-section | speed

Our recent 1/8 scale wind tunnel tests provided insight into flow physics

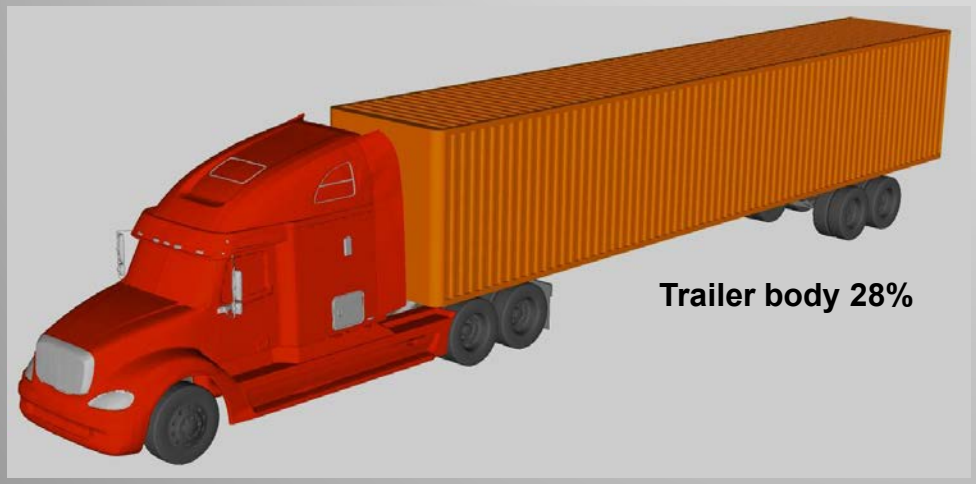
Army 7'x10' wind tunnel facility at NASA Ames Research Center

Baseline model:
ProStar short sleeper
53’ Wabash trailer

Corrugated trailers are responsible for a significant decrease in fuel economy



Baseline configuration



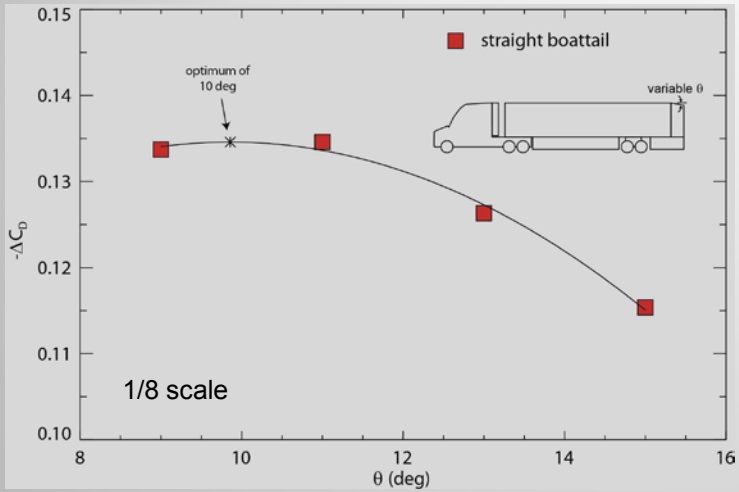
~16% increase in drag at highway speed
~8% decrease in fuel economy

Wind tunnel test
~20% increase in drag at highway speed
~10% decrease in fuel economy

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

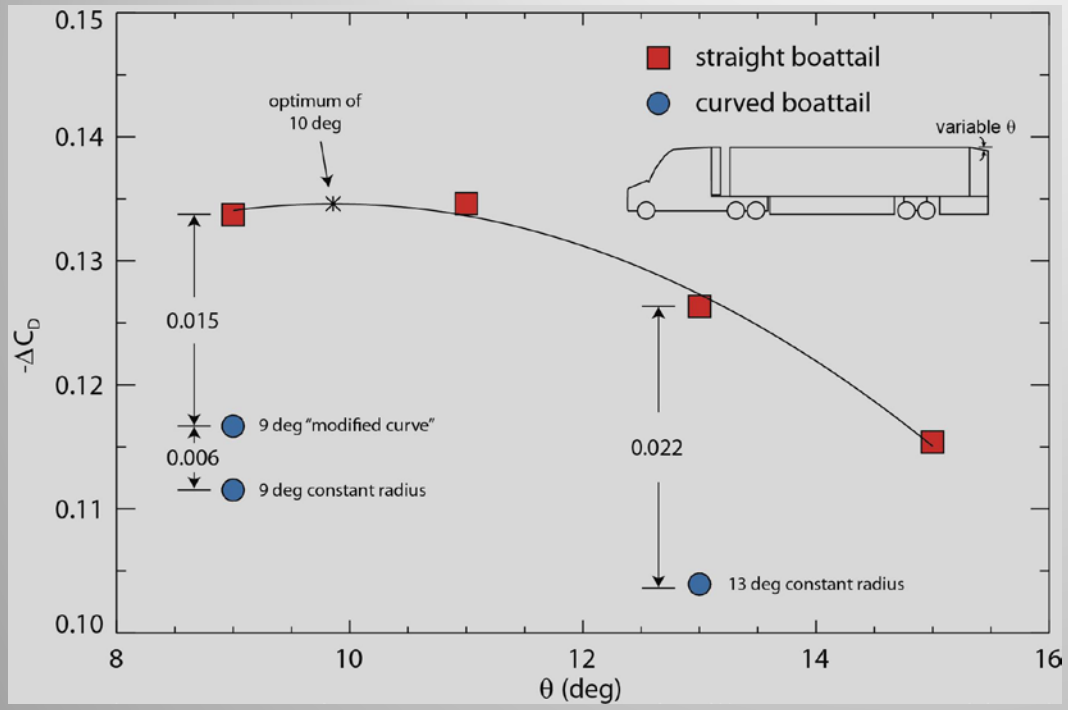
		ΔC_D (%)
Baseline		----
Skirt + 48" tail (3-sided)		(-25%, exp)
Skirt + 32" tail (4-sided)		(-25%, exp)

Similar optimum angles for tail devices were obtained using full and scaled wind tunnel tests



LLNL 48" tail device with full skirt extension

Curved tail devices do not show any additional benefit over straight tail devices



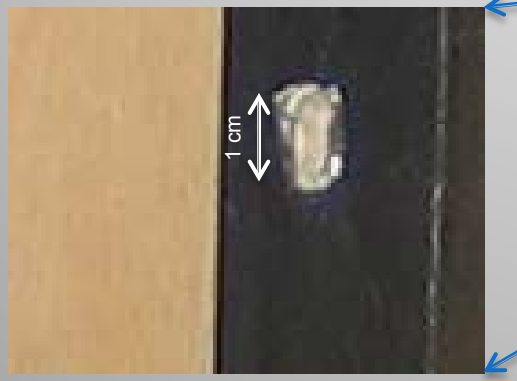
LLNL 48" curve tail device with full skirt extension

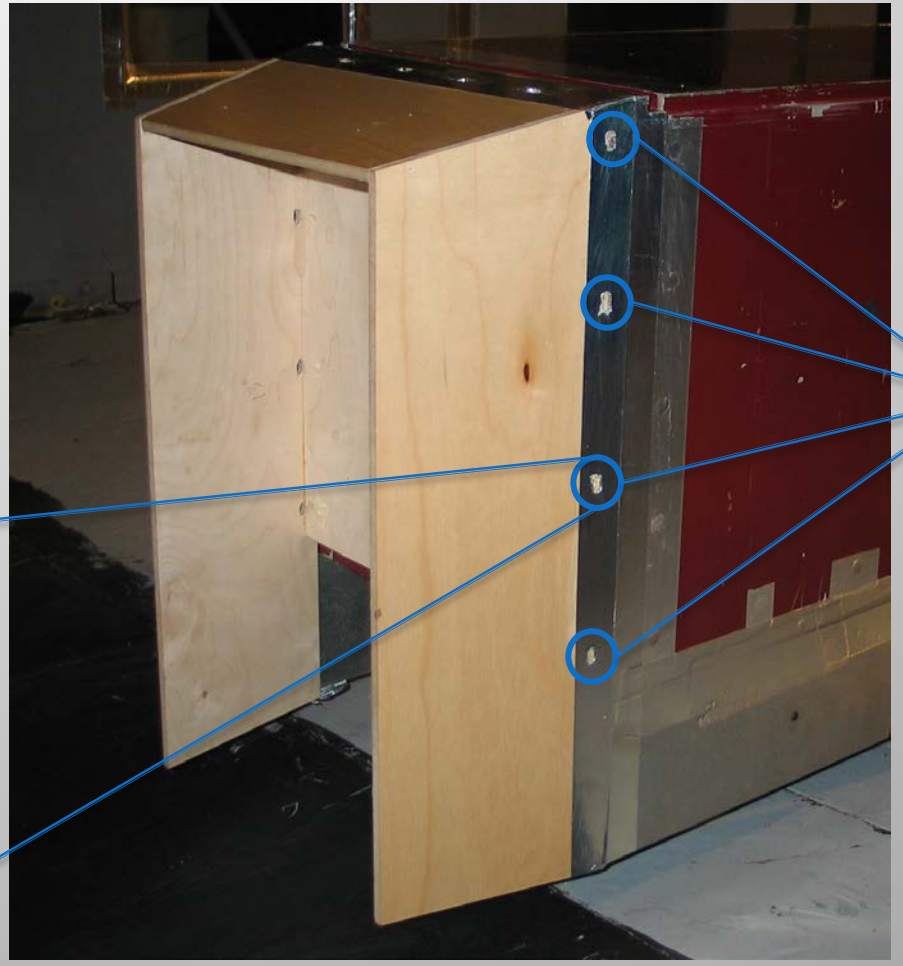
Tail device performance shows sensitivity to the amount of air leakage

48" LLNL tail device with 0.3% area leakage:

$\Delta C_D = +1.6\%$

To maintain tail device performance air leakage should be avoided

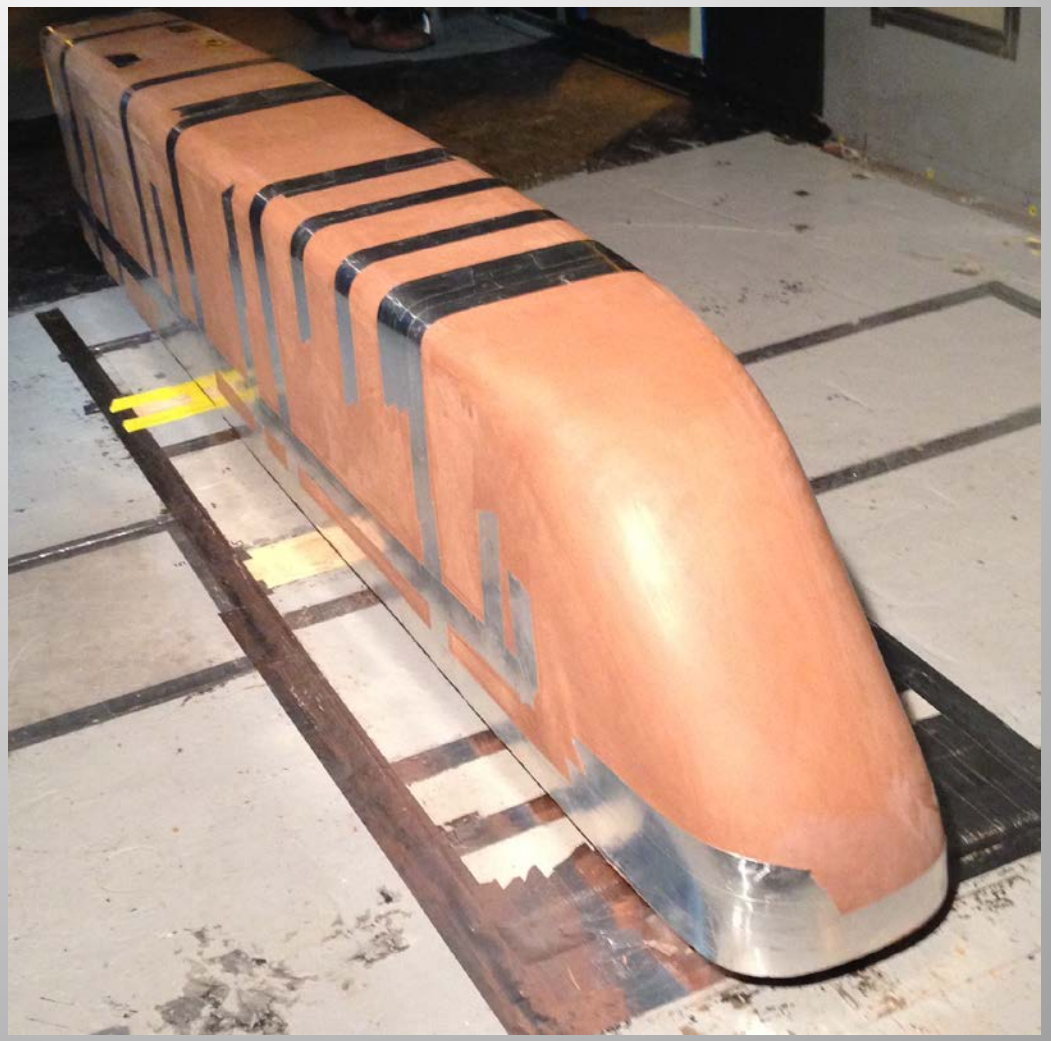




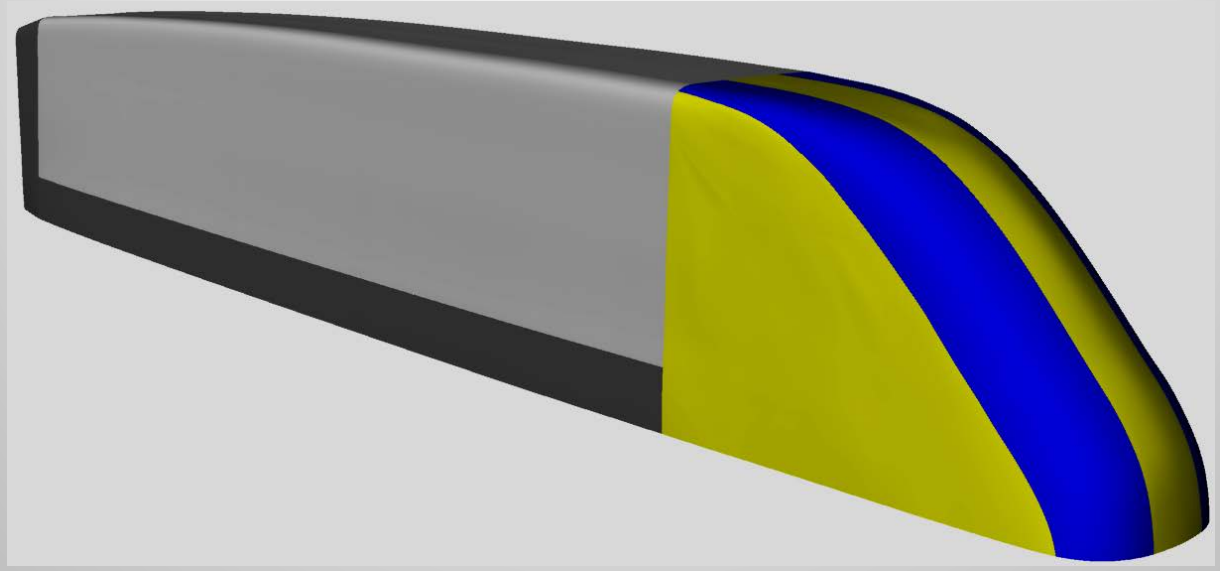
Since 2010 the rate of customers/fleets acceptance of aerodynamic add-on devices has significantly increased

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

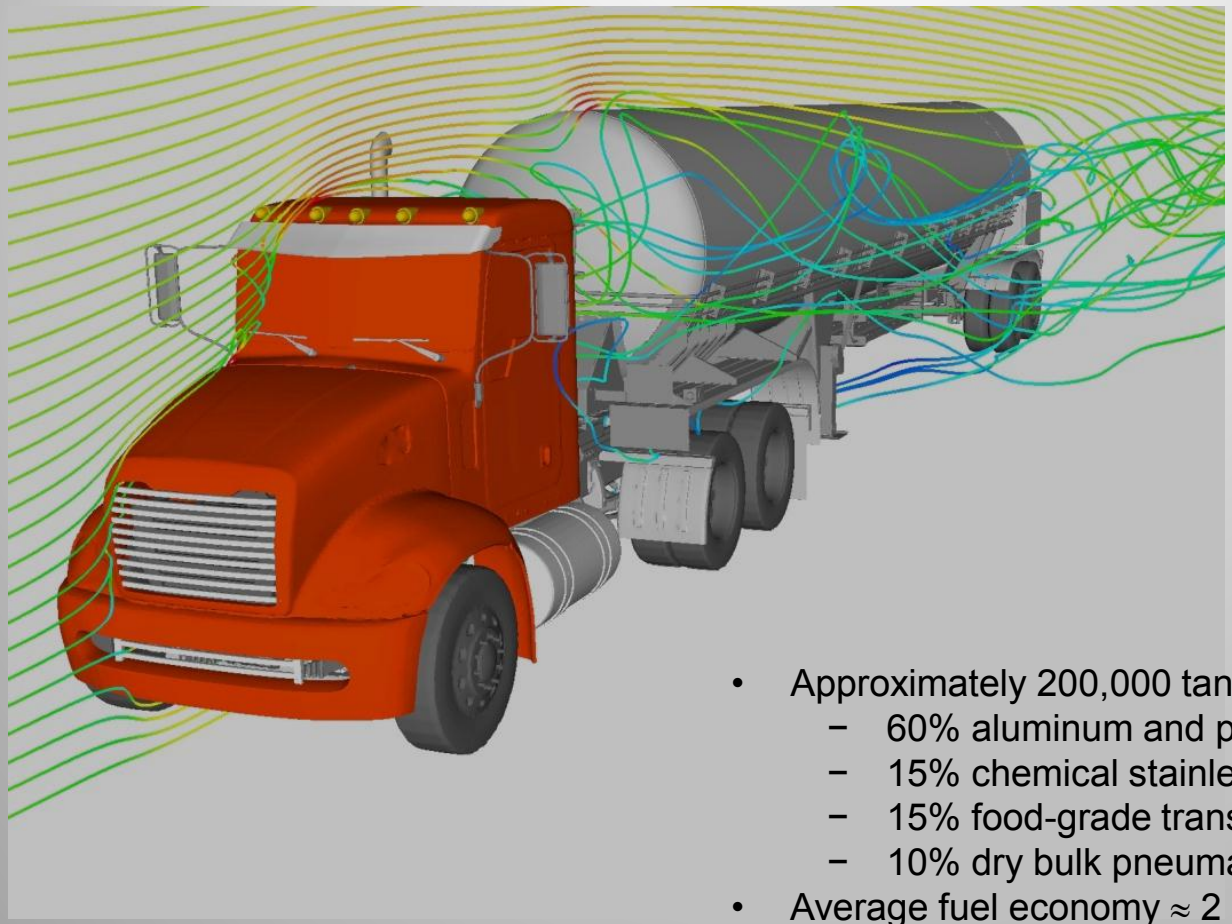
> 50% aerodynamic drag reduction compared to heavy vehicles on the road today



GSF1 is an integrated design that radically improves aerodynamics



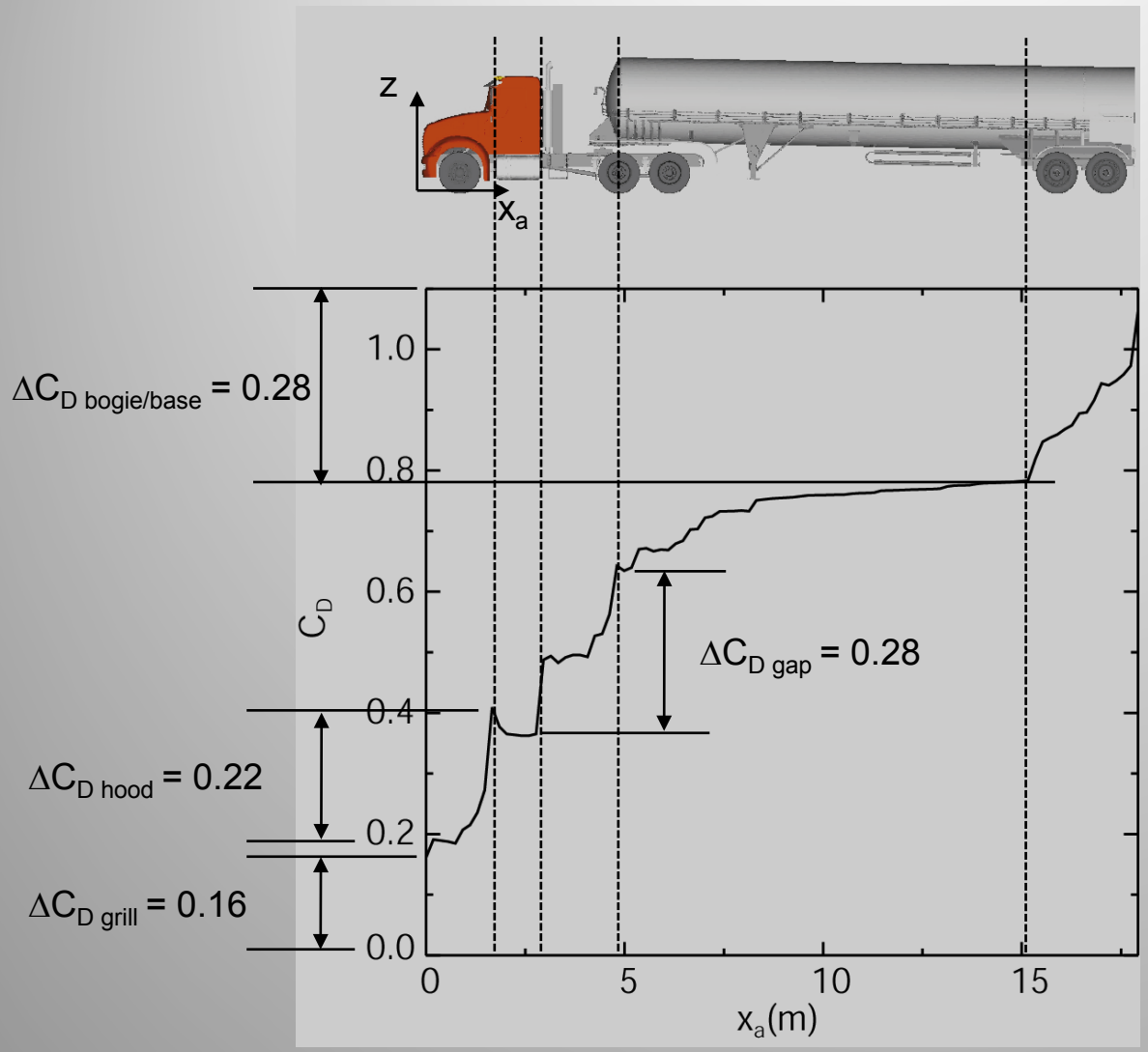
Improving tanker trailer aerodynamics for better fuel economy



- Approximately 200,000 tanker trailers in the United States[1]
  - 60% aluminum and petroleum product service
  - 15% chemical stainless steel trailers
  - 15% food-grade transportation
  - 10% dry bulk pneumatic trailers
- Average fuel economy ≈ 2 km/L (5 mpg)[2]

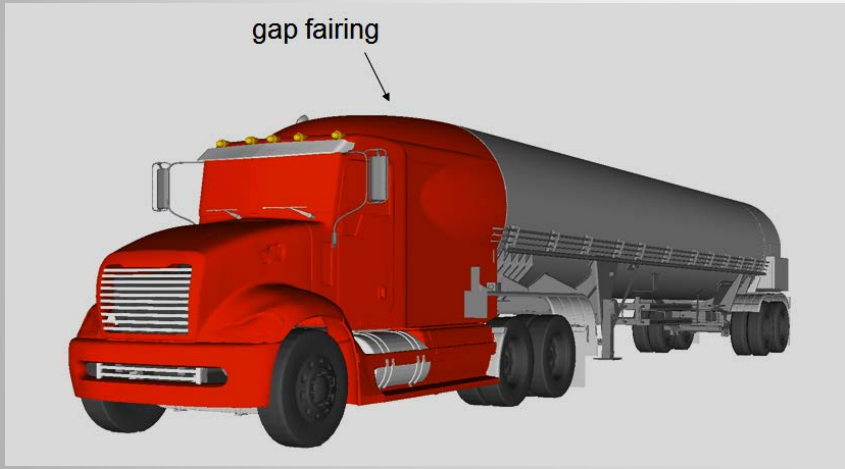
1. National Tank Truck Association, www.tanktruck.org
2. US Department of Transportation, Transportation Energy Data Book, Edition 26, 2007

There are several major drag sources on a tanker trailer



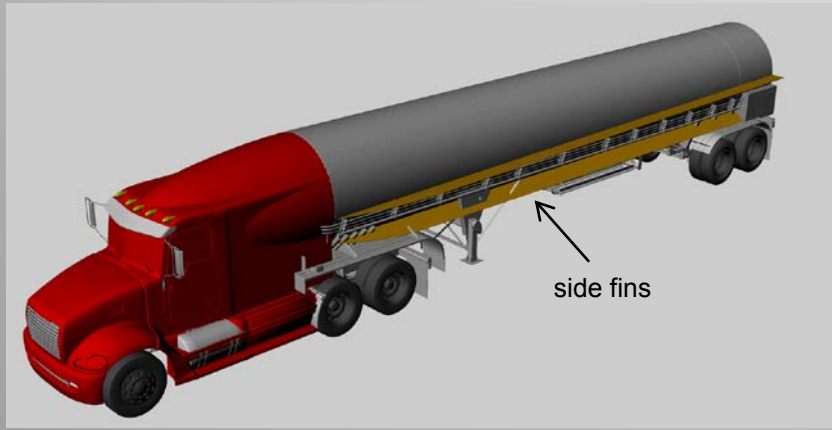
Performed extensive wind tunnel tests at Army 7x10 facility in the NASA Ames Research Center

Tanker aerodynamic enhancements can improve fuel economy by > 17%

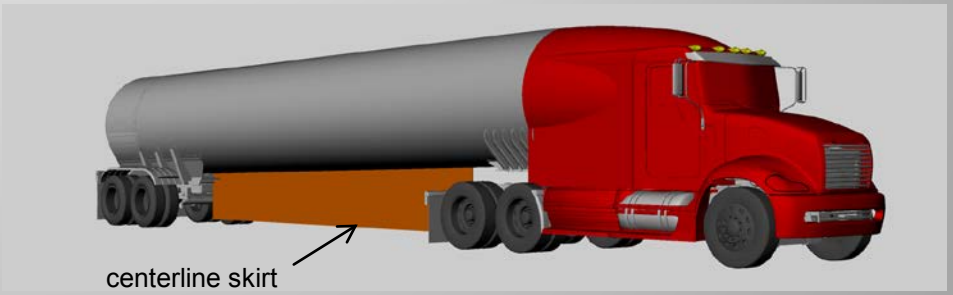


25% drag reduction

10% drag reduction



1.4% drag reduction



1.5% drag reduction

Future plans

- ***Tractor-trailer integration is the next step toward significant fuel economy improvement (> 50% aerodynamic drag reduction compared to heavy vehicles on the road today)***
- *Conduct scaled experiments to design and validate the performance of aerodynamic treatments of an integrated tractor-trailers and tankers*
- ***Start to design the next generation of highly aerodynamic tankers***
- *Continue with the track and on-the-road performance evaluation of aerodynamic treatments*
- *Continue to improve the aerodynamics of tanker trailers*
- *Continue to work with tanker fleets to improve fuel economy*
- *Probe the fuel economy benefits of platooning the line haul trucks in collaboration with ANL systems modeling and control group*
- *On behalf of DOE, continue to coordinate industry participation to design the next generation of highly aerodynamic heavy vehicles*

Summary

- *Published the full-scale wind tunnel test results in collaboration with Navistar, Michelin, and a number of device manufacturers*
  - *Two tractors, three trailers, and twenty-three devices were tested*
- *Published on the road device performance data with our team: Navistar, Kentucky Trailer, Freight Wing, Michelin, Frito-Lay, and Spirit*
- *Conducted 1/8 scale experiments at Army 7'x10' wind tunnel facility at the Ames Research Center*
- *Evaluated the aerodynamic performance of tail devices*
  - *Optimum angle, curve vs. straight plates, leakage impact, and tail-light requirements*
- ***Designed the first generation of an integrated tractor-trailer geometry from ground up that radically decreases aerodynamic drag and improves the fuel efficiency (GSF1)***
- *Achieved major reduction in aerodynamic drag for tanker trailers through geometry modifications*