Lawrence Livermore National Laboratory

DOE's Effort to Reduce Truck Aerodynamic Drag through Joint Experiments and Computations

DOE Annual Merit Review, Project ID # VSS006
May 14-18, 2012

Kambiz Salari

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Lawrence Livermore National Laboratory, P. O. Box 808, Livermore, CA 94551

This work performed under the auspices of the U.S. Department of Energy by
Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

LLNL-PRES-543431

Overview

Timeline

On going

- On the road testing of aero devices
- Improving design and retesting of selected aerodynamic devices
- Tanker trailers aerodynamic evaluation for drag reduction

Barriers

Target

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

Budget

- Funding received in FY11, $750K
- Funding for FY12, $560K

Partners

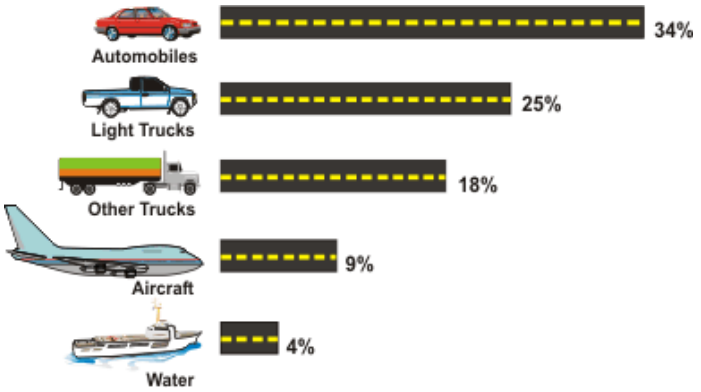
- Navistar, Inc.
- Michelin
- Freight Wing Inc. and ATDynamics
- Kentucky Trailer and Wabash National
- Frito-Lay, Spirit, and Safeway
- Praxair

Class 8 tractor-trailers are responsible for 12-13% of the total US consumption of petroleum

Aerodynamic drag reduction contribution

12% reduction in fuel use = 3.2 billion gallons of diesel fuel saved per year and 28 million tons of CO2 emission

$13.2 billion saved/year ($4.14 per gallon diesel)



Aerodynamics and Wide-base single tires contributions

17% reduction in fuel use = 4.6 billion gallons of diesel fuel saved per year and 40 million tons of CO2 emission

$19.0 billion saved/year ($4.14 per gallon diesel)

U.S. Department of Energy, Transportation Energy Data Book, Edition 29, July 2010

Objectives

- ***In support of DOE's mission,*** provide guidance to industry to improve the fuel economy of class 8 tractor-trailers and tankers through use of aerodynamic drag reduction
- ***Demonstrate*** new drag-reduction techniques and concepts through use of virtual modeling and testing
  - *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
- ***Joined with industry in getting devices on the road***

Milestones

FY11

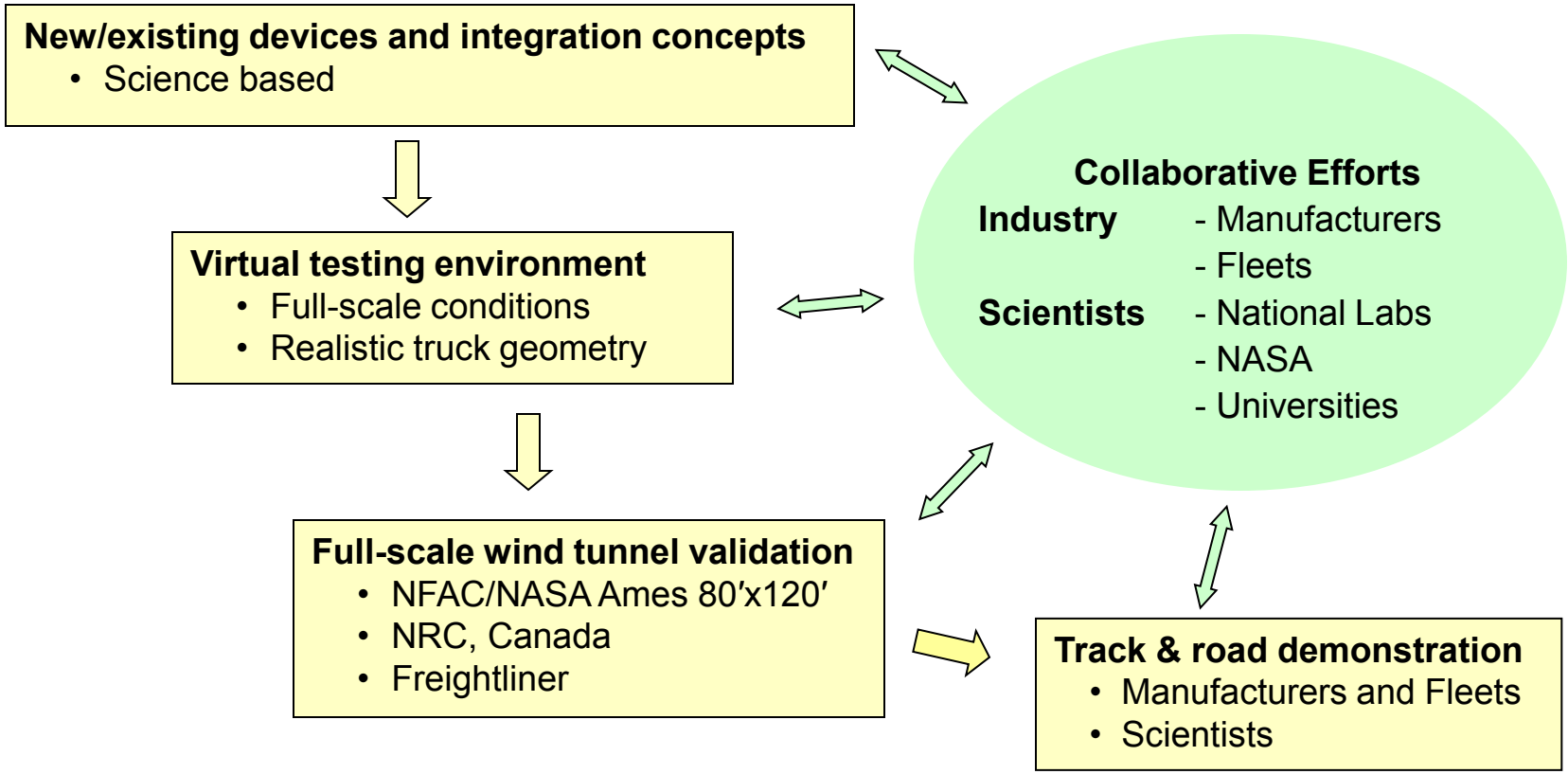
- Completed the fuel economy track testing of selected aerodynamic devices at Transportation Research Center (TRC) facility
- Started to collect on the road performance data for the selected aero devices in collaboration with Frito-Lay and Spirit fleets
- Designed/Improved aerodynamic devices for tractor-trailers and tankers

FY12

- Improved design/performance of selected aero devices based on the knowledge gained from collected on the road performance data
- Explore tractor-trailer integration for drag reduction (geometry, flow, and thermal)
- Conduct scaled experiments to validate the improved performance of aero devices for both tractor-trailers and tankers
- Continue to improve the aerodynamics of tanker trailers

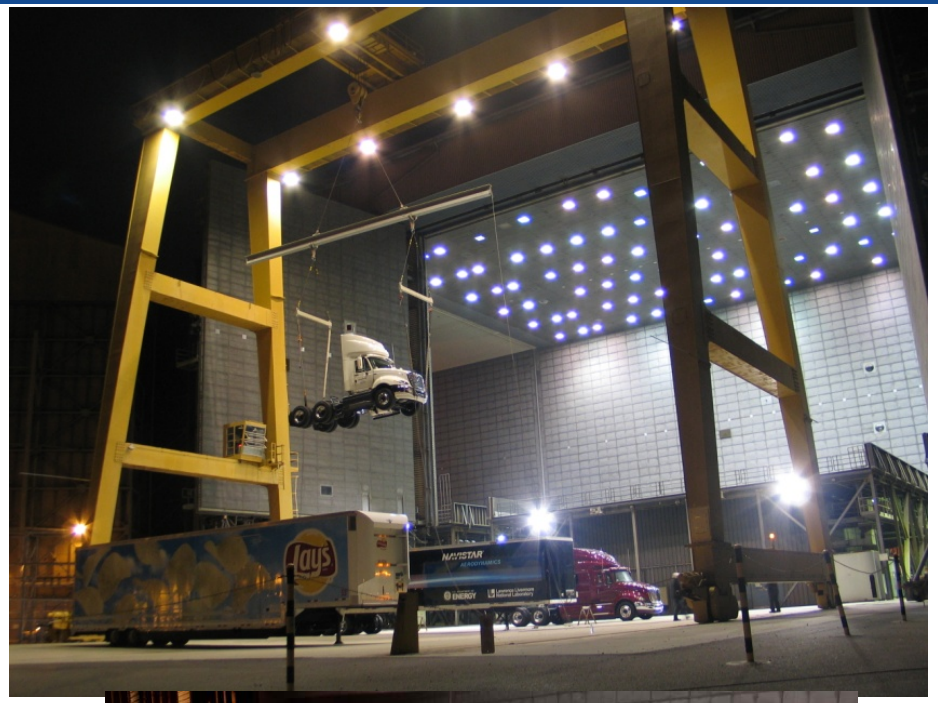
Science based approach to aerodynamic improvements for heavy vehicles

Design & test devices/concepts for aerodynamic drag reduction with industry collaboration and feedback



Full-scale wind tunnel test conducted at NFAC facility

- Different combinations of tractors and trailers were tested
  - Two tractors – Prostar sleeper and day cab
  - Three trailers – 28' & 53' straight frame and 53' drop frame
- Performed 140 wind tunnel runs
- Twenty-three aerodynamic drag reduction devices/concepts were tested from LLNL, Navistar, Freight Wing, ATDynamics, Aerofficient, Laydon, Windyne, and AeroIndustries



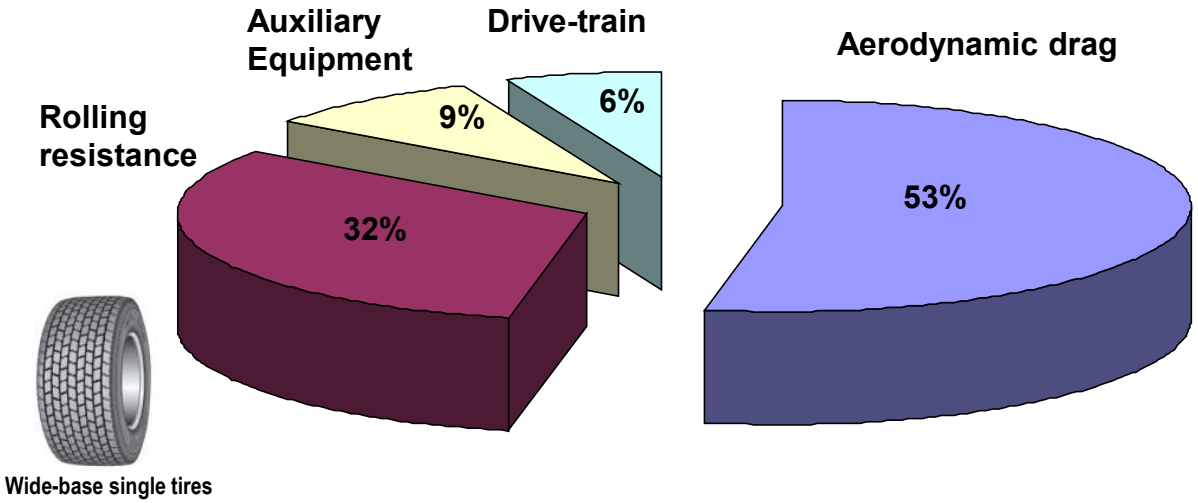
Technical accomplishments

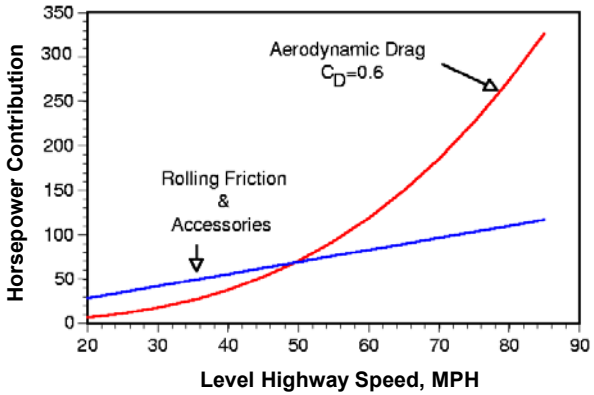
- ***Completed analysis and documentation of the full-scale wind tunnel test*** conducted at NASA Ames 80'x120' NFAC facility
- ***In collaboration with Navistar*** conducted fuel economy track test at Transportation Research Center (TRC) facility
  - Twenty-four vehicle configurations were tested
- ***In support of the DOE's objective to bring candidate devices to the market,*** we are teaming with Navistar, Kentucky Trailer, Freight Wing device manufacturer, Michelin, and Frito-Lay's and Spirit's Fleets to perform track and on the road tests
  - Collecting on the road performance data for selected aerodynamic devices
- ***Performed aerodynamic investigation of a common tanker trailer*** in collaboration with Praxair to significantly improve fuel economy
  - Designed and evaluated tanker fairings
- ***International recognition*** **achieved** through open documentation and conferences

Aerodynamic device proliferation in the market

- There are roughly 2 million tractor-trailers in the US that can be retrofitted with aerodynamic devices:
  - Trailer tail
  - Trailer skirt
  - Tractor-trailer gap fairing
  - Tractor fairings
- Since 2010 the rate of customers/fleets acceptance has significantly increased
- Based on an input from our collaborators Freight-Wing and ATDynamics by the end of 2012 we could see ~3% of the market deploying these devices

Most of the usable energy goes into overcoming drag and rolling resistance at highway speeds

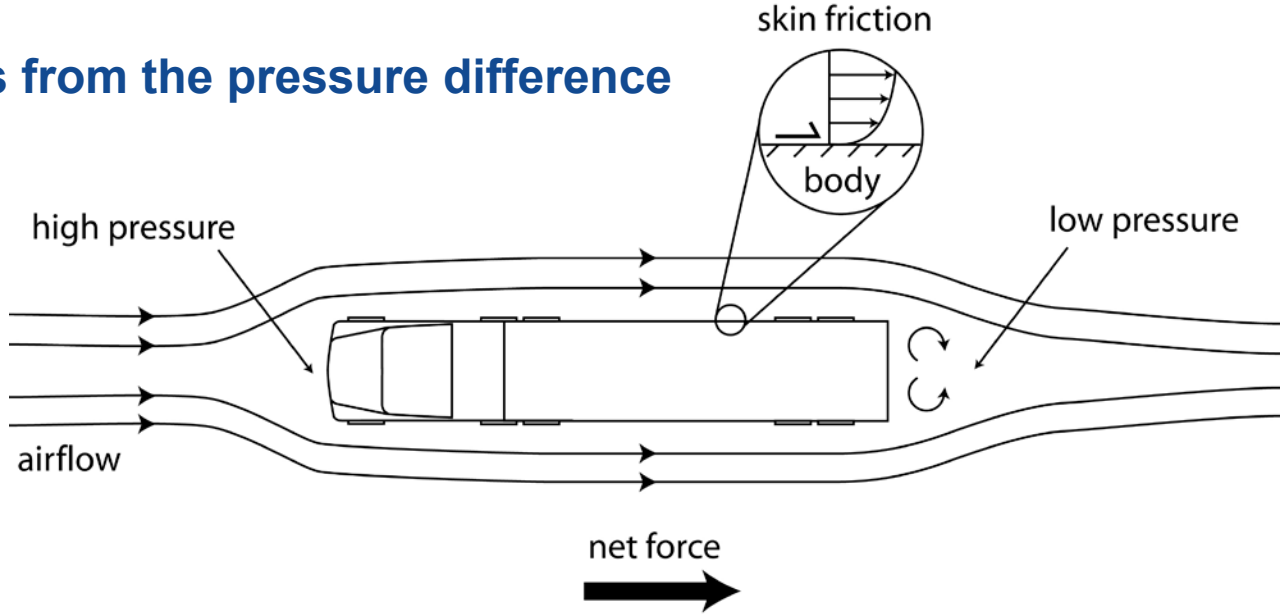




Losses in nearly all of these categories can be reduced by employing presently available technology

Fuel consumption and aerodynamic drag

Most drag is from the pressure difference

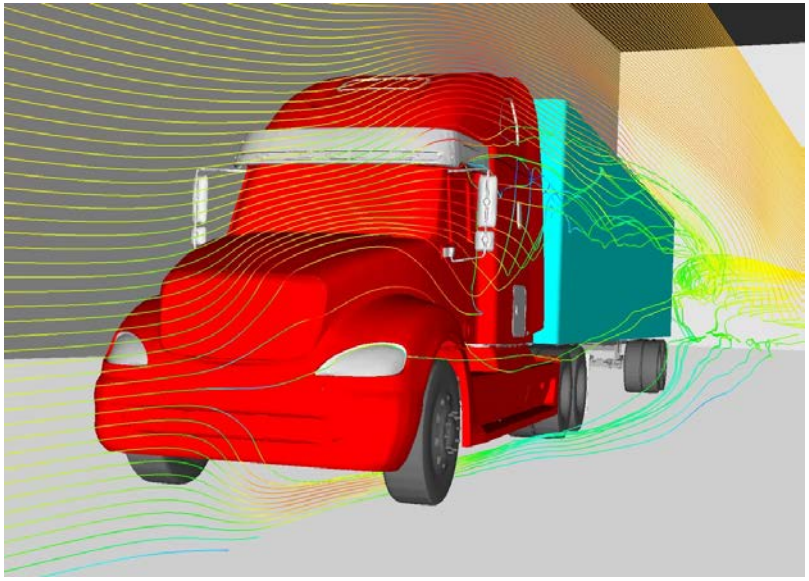


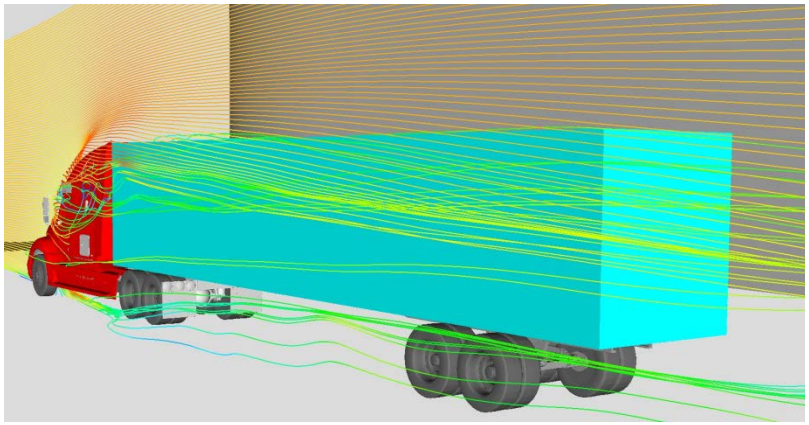
$$Drag = C_D \times S \times (1/2)\rho U^2$$

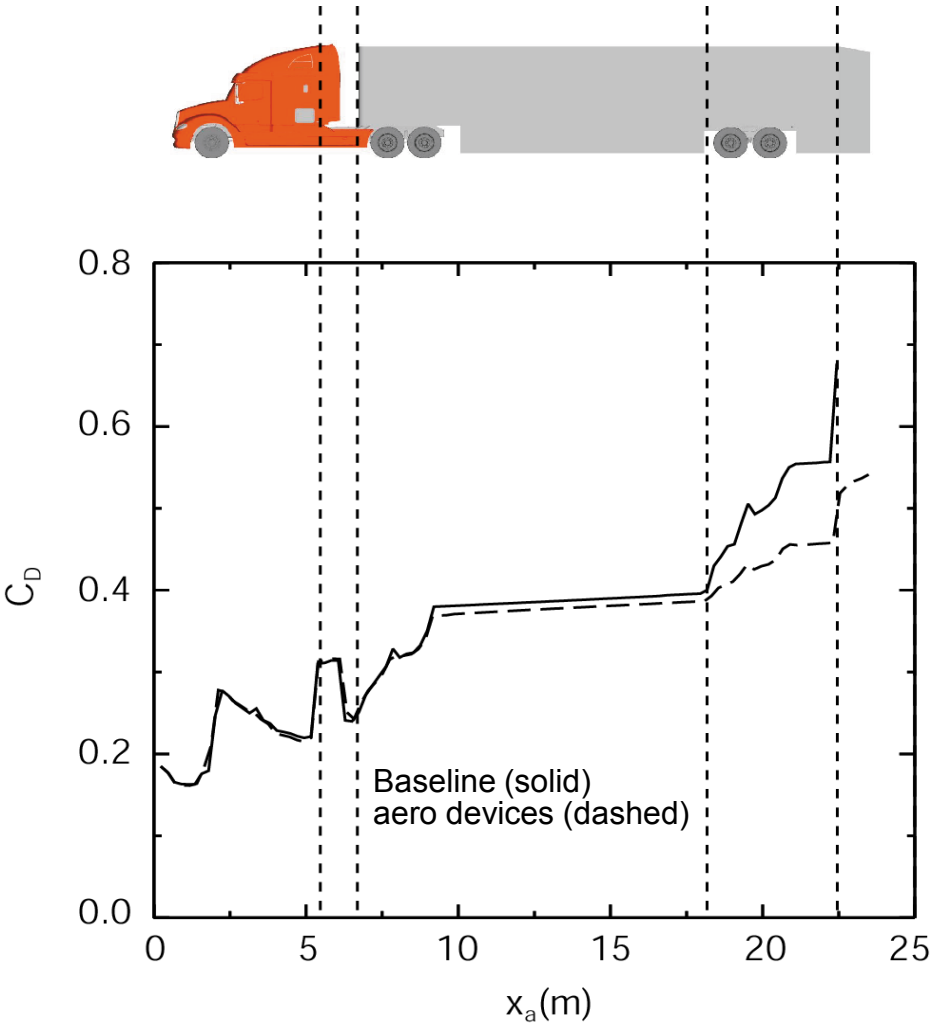
$$\frac{\Delta FuelConsumption}{FuelConsumption} = \eta \times \left(\frac{\Delta C_D}{C_D} + \frac{\Delta S}{S} + \frac{3\Delta U}{U} \right)$$

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

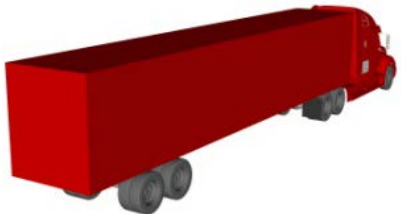
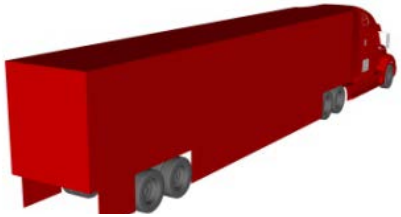
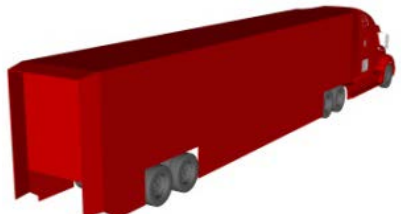
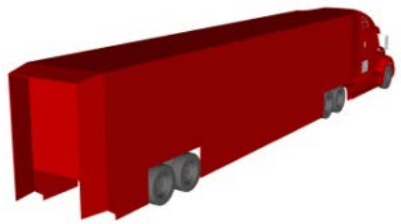
Impact of aero devices on aerodynamic drag





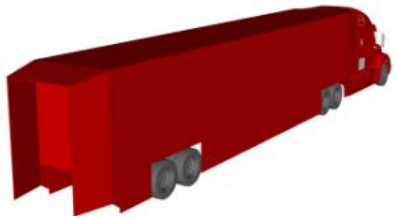


Aerodynamic devices show significant potential to improve fuel economy, …

		ΔC_D (%)
Baseline		 ----
Gap Seal + Skirt		 -0.130 (-19.4 %)
Gap Seal + Skirt + 24” Boattail (3-sided)		 -0.169 (-25.2 %)
Gap Seal + Skirt + 32” Boattail (3-sided)		 -0.168 (-25.1 %)

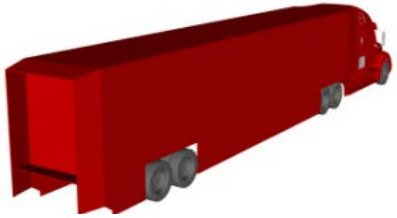
Aerodynamic devices show significant potential to improve fuel economy

Gap Seal + Skirt + 48” Boattail (3-sided)



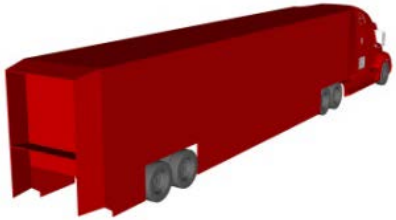
-0.175 (-26.0 %)

Gap Seal + Skirt + 32” Boattail (4-sided, lo)



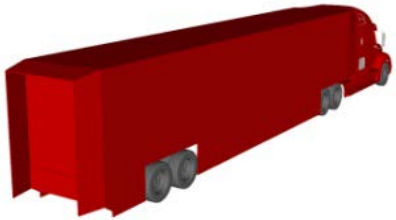
-0.175 (-26.1 %)

Gap Seal + Skirt + 32” Boattail (4-sided, hi)



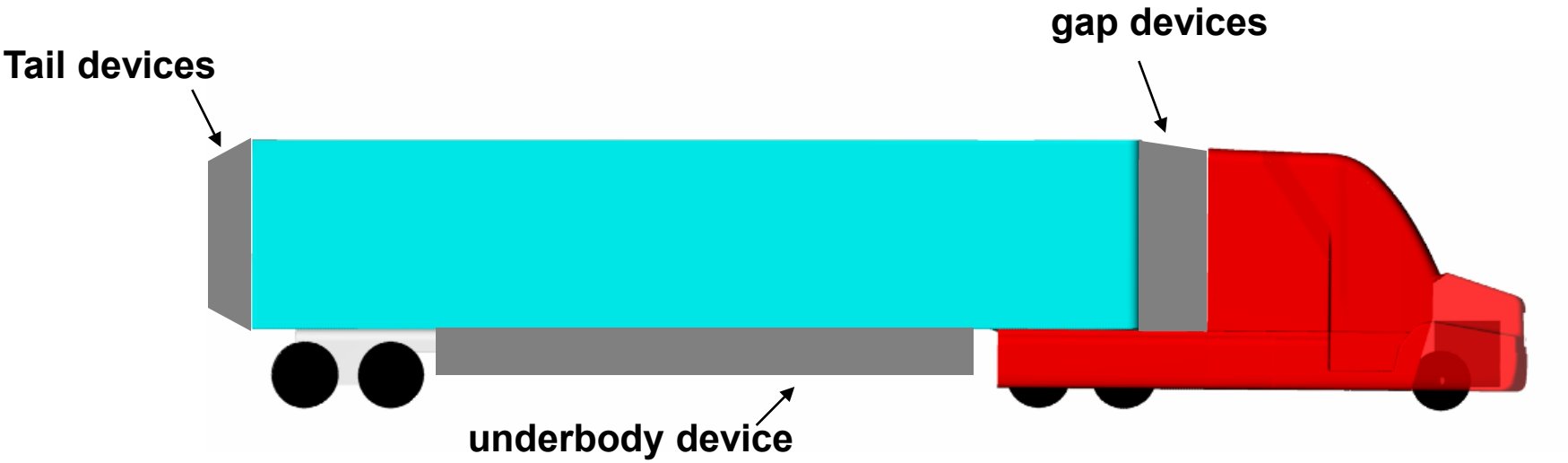
-0.171 (-25.5 %)

Gap Seal + Skirt + 32” Boattail
(3-sided w/ base plate)



-0.165 (-24.6 %)

Performance of aerodynamic devices



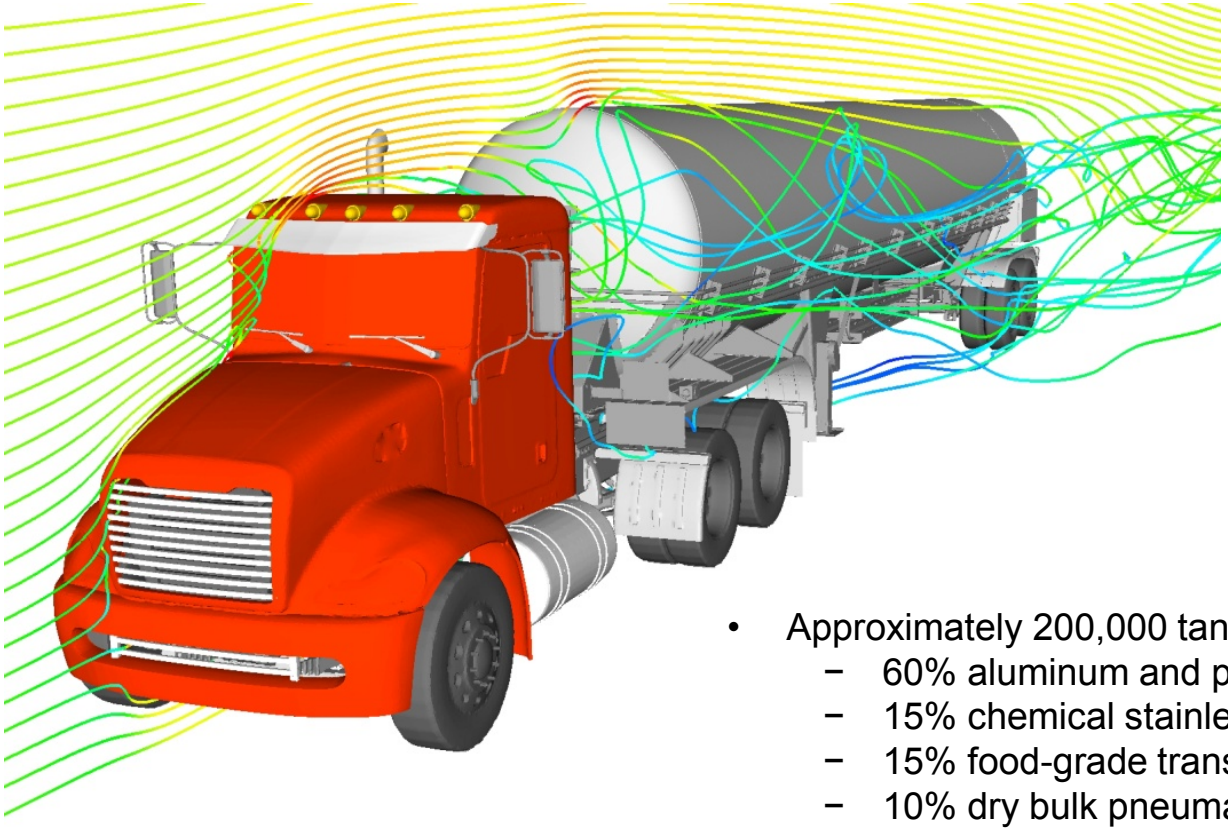
- Tail devices: 4-7% FEI (Fuel Economy Improvement)
- Underbody devices: 5-7% FEI
- Gap devices: 1-2% FEI
- Super wide single tires: 4-5% FEI

On the road fuel economy data are being collected by the Spirit and Frito-Lay fleets for selected aero devices

Total of 57 vehicles are involved in this test

Date_start	Time_start	Date_end	Time_end	Fuel (gal)	Miles	MPG	MPH	Gal/Miles	Device
9/1/2011	0:00	9/1/2011	6:00	17.375	106.5	6.13	62.9	0.163	none
9/1/2011	6:00	9/1/2011	12:00	48.125	344	7.15	62.8	0.14	none
9/24/2011	6:00	9/24/2011	12:00	0.5	0.8	1.6	6.8	0.625	ATD
9/24/2011	18:00	9/25/2011	0:00	33.75	254.8	7.55	58	0.132	ATD
9/25/2011	0:00	9/25/2011	6:00	4.125	30.3	7.35	63.9	0.136	ATD
10/24/2011	6:00	10/24/2011	12:00	29.375	232.3	7.91	61.7	0.126	FW
10/24/2011	12:00	10/24/2011	18:00	35.625	307.5	8.63	60.1	0.116	FW
10/25/2011	0:00	10/25/2011	6:00	1.625	7.6	4.68	19.2	0.214	FW
10/25/2011	6:00	10/25/2011	12:00	24	211.1	8.8	53.8	0.114	FW

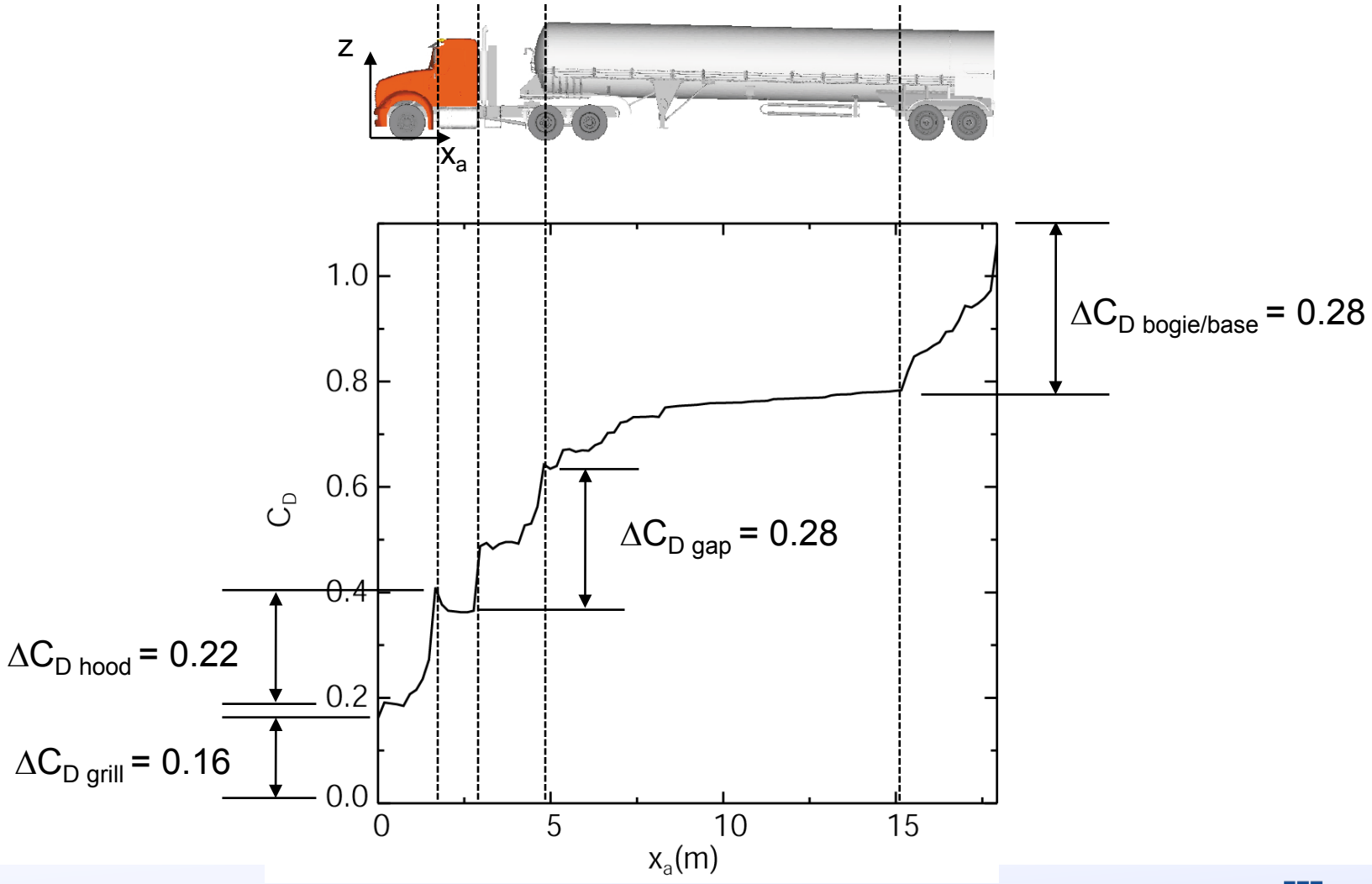
Tanker trailer aerodynamics



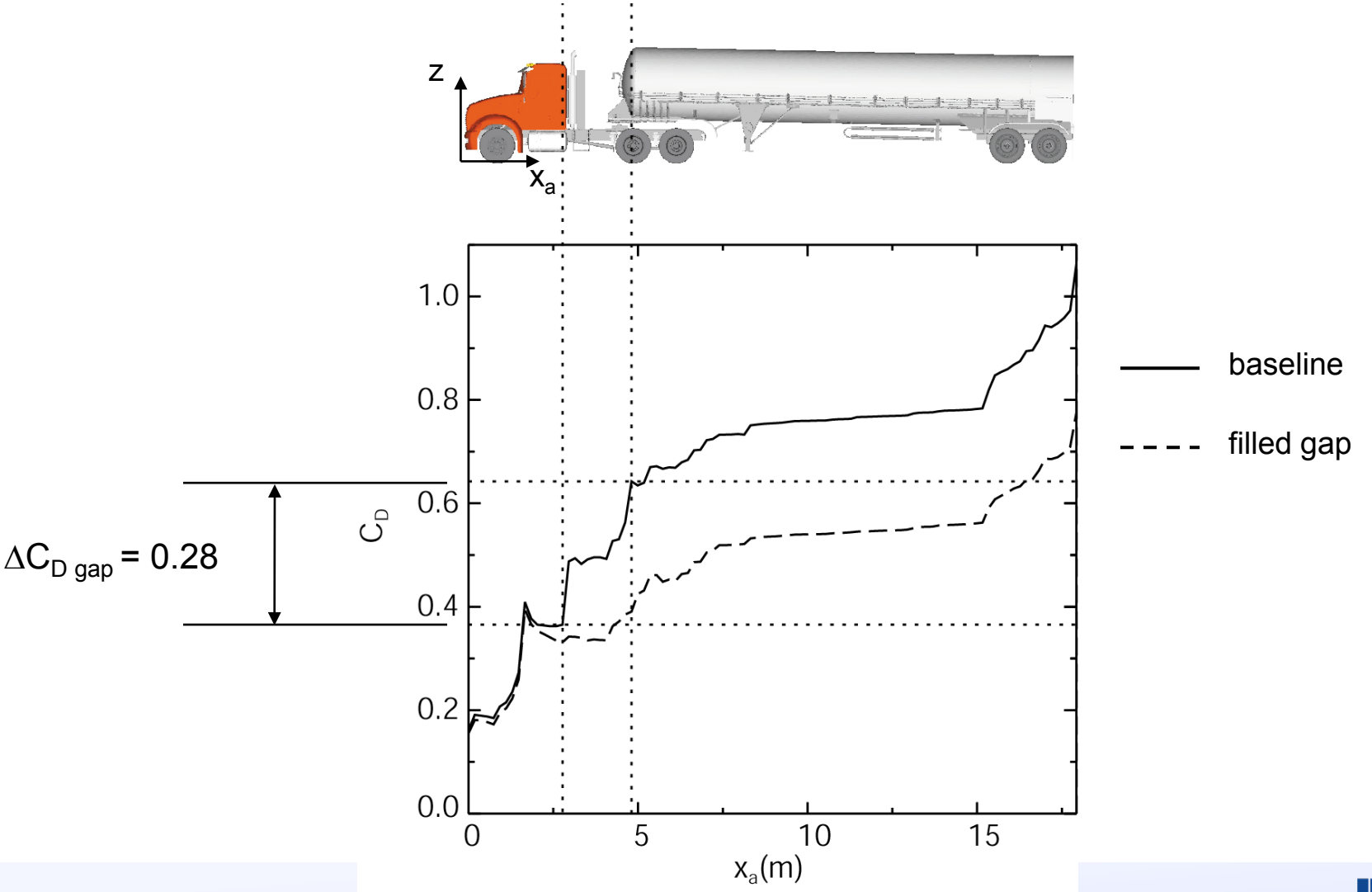
- Approximately 200,000 tanker trailers in the United States[1]
  - 60% aluminum and petroleum product service
  - 15% chemical stainless steel trailers
  - 15% food-grade transportation
  - 10% dry bulk pneumatic trailers
- Average fuel economy ≈ 2 km/L (5 mpg)[2]

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

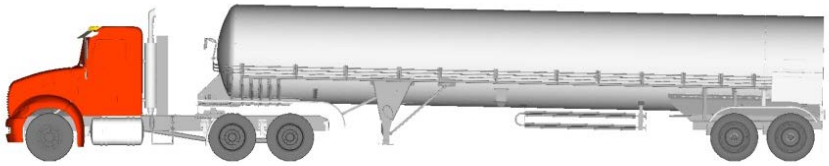
There are several major drag sources on a tanker trailer

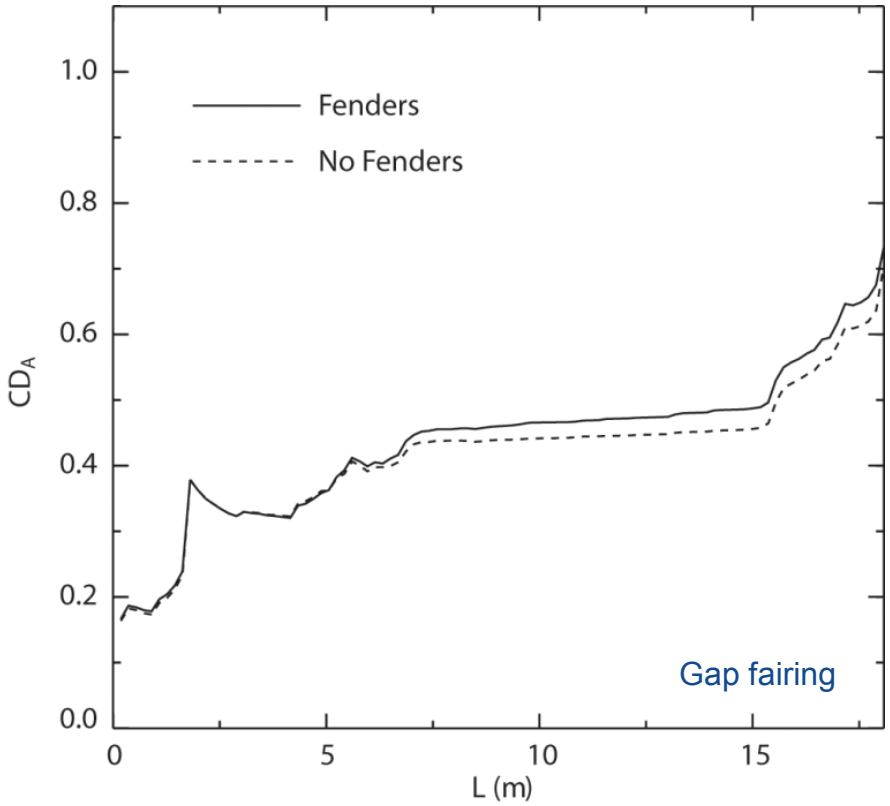


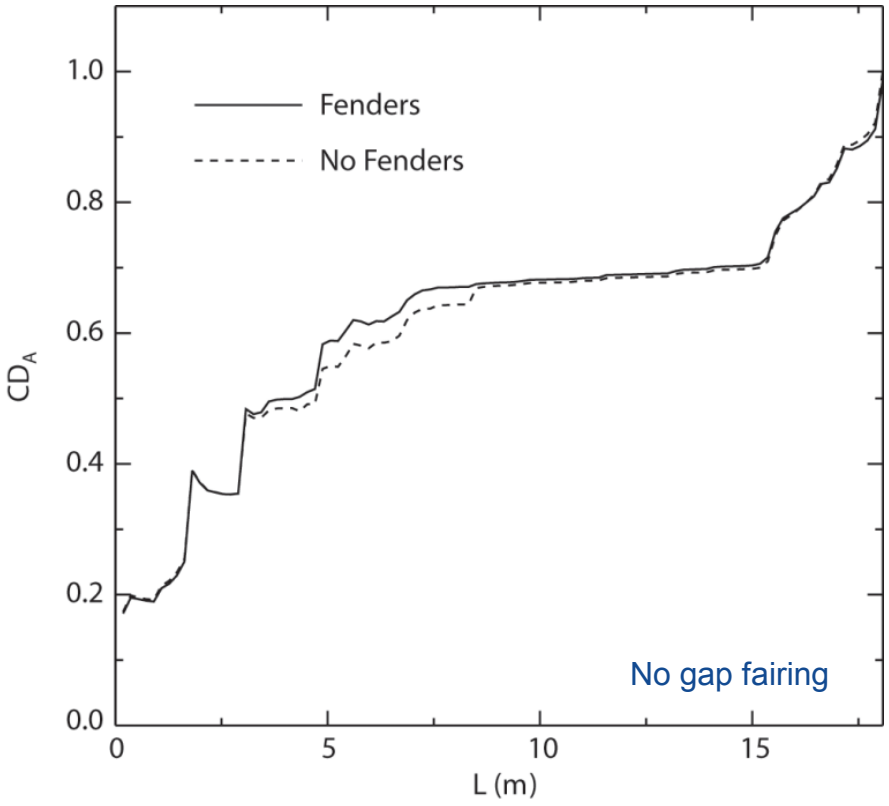
Aerodynamically treating the tractor-tanker gap significantly reduces drag



Impact of drive axle fender on aerodynamics







Future plans

- Continue with the track and on the road performance evaluation of selected aero devices
  - Improve the design based on collected data
  - Validate aerodynamic performance
- Continue to work with Praxair and other tanker fleets to improve the aerodynamics of tanker trailers for better fuel economy
  - Validate aerodynamic performance with small scale wind tunnel, track, and on the road tests
- Explore the benefits of tractor-trailer integration for improved fuel economy (geometry, flow, and thermal)
- On behalf of DOE, continue to coordinate industry participation and achieve industry-accepted drag reduction devices

Summary

- Completed the full-scale wind tunnel test analysis and documentation in collaboration with Navistar and Michelin
  - Two tractors, three trailers, and twenty-three devices were tested
- Performed track tests of selected aerodynamics devices in collaboration with Navistar, Freight Wing, and Michelin
- Continue collecting and analyzing on the road device performance data with our team: Navistar, Kentucky Trailer, Freight Wing, Michelin, Frito-Lay, and Spirit
- Improved the aerodynamic performance of selected devices which are currently being tested on the road
- Improved the fuel economy of tanker trailers through better aerodynamics