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 9-13, 2011

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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-473472

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Navistar International Corporation

Rod Bailey and Jeff Pyle
Michelin Americas Research Company

Mark Betzina and Christopher Hartley
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Work sponsored by
U.S. Department of Energy
Energy Efficiency and Renewable Energy
Vehicle Technologies Program

Overview

Timeline

On going

- Completed full-scale wind tunnel test
- Improving design and retesting of selected aerodynamic devices
- Tanker trailers aerodynamic evaluation for drag reduction

Barriers

Target

- By 2013 - Reduce aerodynamic drag of class 8 tractor-trailers by approximately 25% leading to a 10-15% increase in fuel efficiency at 65 mph

Budget

- Total project funding prior to FY10, \$3.5M
- Funding received in FY10, \$500K
- Funding for FY11, \$750K

Partners

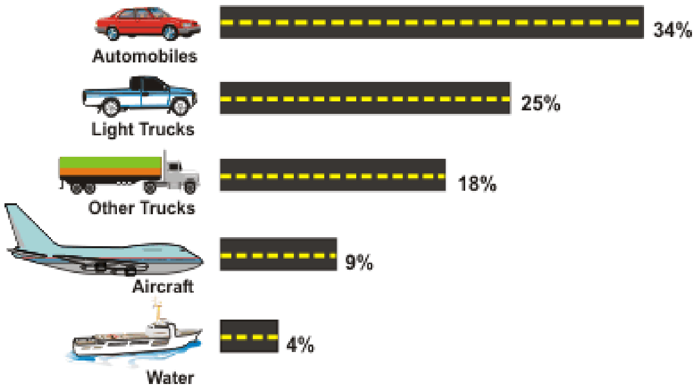
- Navistar, Inc.
- Michelin
- Freight Wing Inc. and ATDynamics
- Kentucky Trailer and Wabash National
- Frito-Lay and Safeway
- Praxair

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 = 4.4 billion gallons of diesel fuel saved per year and 44 million tons of CO2 emission

$17.2 billion saved/year ($3.91 per gallon diesel)



Aerodynamics and Wide-base single tires contributions

17% reduction in fuel use = 6.2 billion gallons of diesel fuel saved per year and 63 million tons of CO2 emission

$24.2 billion saved/year ($3.91 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 through the use of aerodynamic drag reduction
- ***On behalf of DOE*** to expand and coordinate industry participation to achieve significant on-the-road fuel economy improvement
- ***Demonstrate*** new drag-reduction techniques and concepts through use of virtual modeling and testing
  - *Class 8 tractor-trailers and tankers*
- ***Joined with industry in getting devices on the road***

Milestones

- **FY10**
  - Full-scale wind tunnel test of class 8 tractor-trailer combinations at NASA Ames Research Center, NFAC facility
- **FY11**
  - Improve design/performance of existing drag reduction devices based on the knowledge gained in the full-scale wind tunnel test
  - Perform scaled experiments to validate the improved performance of redesigned aero devices
  - Design new aerodynamic drag reduction fairings for tanker trailers

Science based approach to aerodynamic drag reduction for heavy vehicles

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

New/existing devices and integration concepts
- Science based

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

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

Collaborative Efforts

Industry - Manufacturers
- Fleets

Scientists - National Labs
- NASA
- Universities

Track & road demonstration
- Manufacturers and Fleets
- Scientists

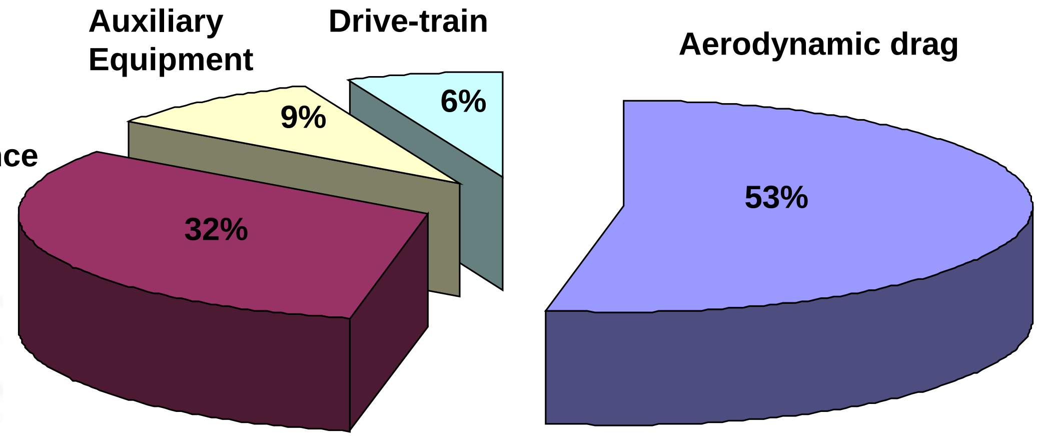
Full-scale wind tunnel test at NFAC facility

- 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

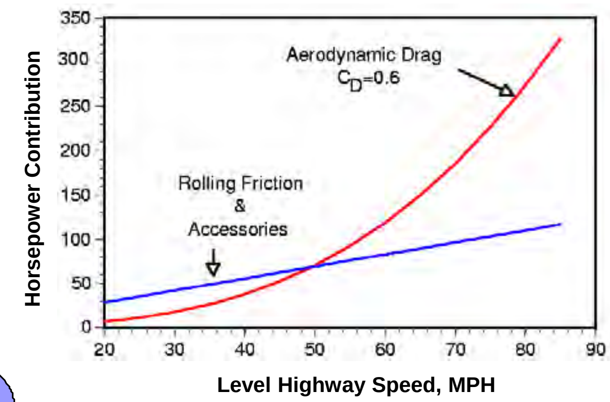
Technical accomplishments

- ***In collaboration with Navistar*** conducted a full-scale wind tunnel validation tests of candidate devices at NASA Ames research center, NFAC facility
  - Twenty-three aerodynamic drag reduction devices/concepts were tested
- ***In support of the DOE's objective to bring candidate devices to the market within 2.5 years,*** we are teaming with Navistar, Kentucky Trailer, Freight Wing device manufacturer, Michelin, and Frito-Lay's Fleet to perform track and on the road tests
  - Down selected aerodynamic devices for the track and on the road tests
- ***Aerodynamic investigation of a common tanker trailer*** has been performed in collaboration with Praxair to significantly improve the fuel economy
  - Designed and evaluated a gap fairing to be tested on the road by Praxair
- ***Published a design guidance document*** for trailer aft devices, entitled "Aerodynamic Design Criteria for Class 8 Heavy Vehicles Trailer Base Devices to Attain Optimum Performance"
- ***International recognition* achieved** through open documentation and conferences
  - Presented in an international heavy vehicle conference, Potsdam, Germany, 2010

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



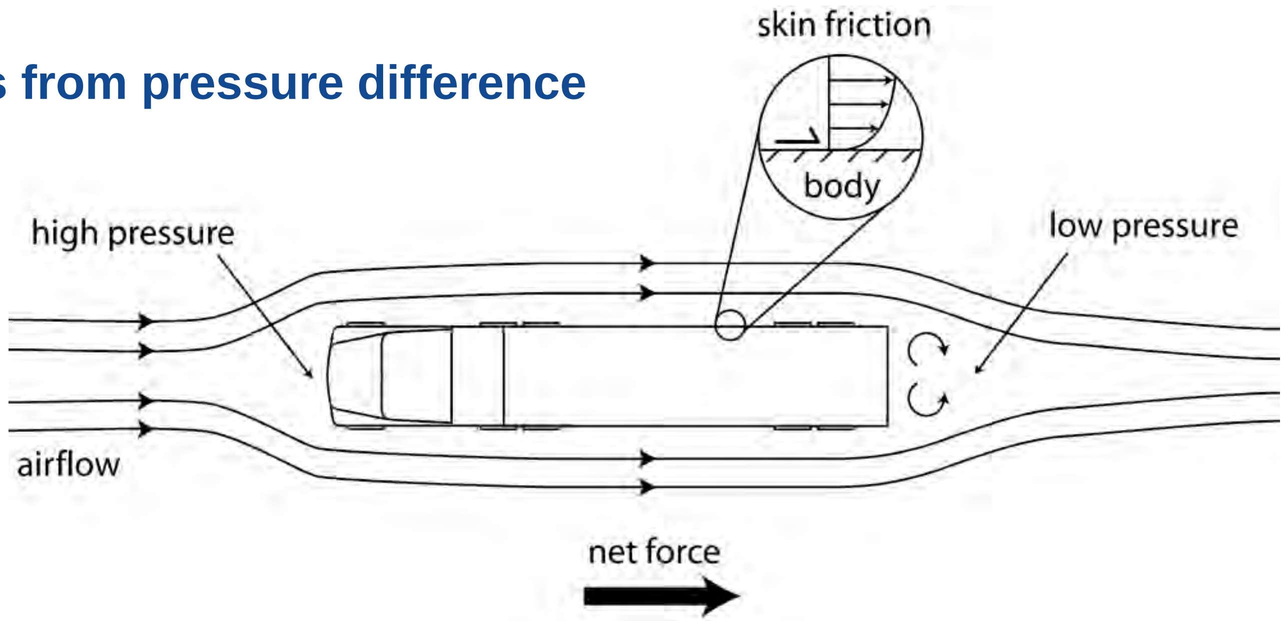
Wide-base single tires



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

Fuel consumption and aerodynamic drag

Most drag is from pressure difference



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

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

$\eta \approx$ **0.5-0.7** **shape** **cross-section** **speed**

A corrugated trailer results in a larger drag force

Trailer body 12%

Baseline configuration

Trailer body 28%

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

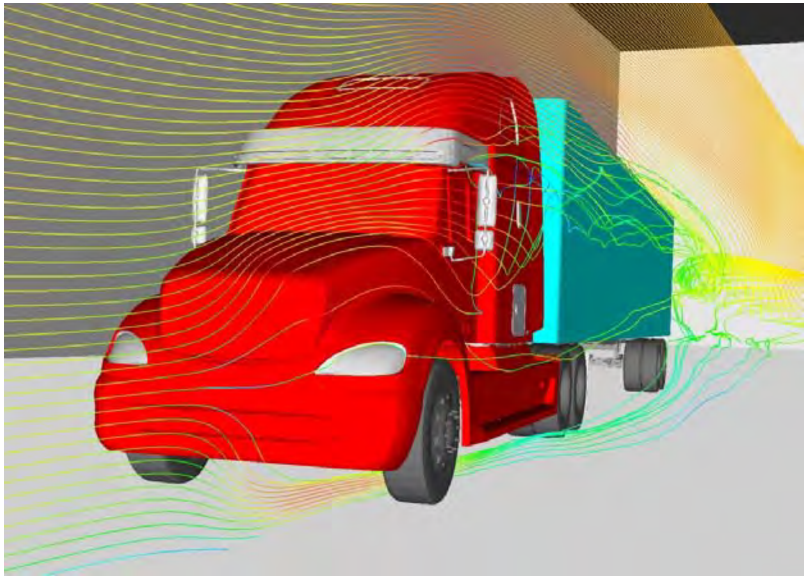
Design improvements of current aero devices

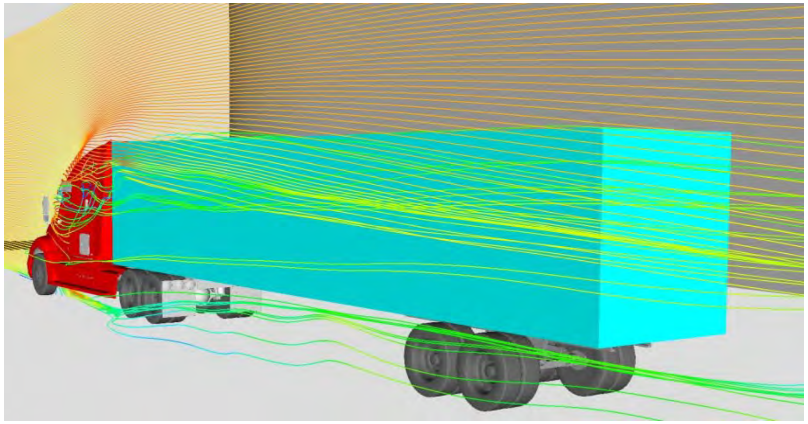
Published design guidance document, entitled “*Aerodynamic Design Criteria for Class 8 Heavy Vehicles Trailer Base Devices to Attain Optimum Performance*”, LLNL-TR-464265, December 20, 2010

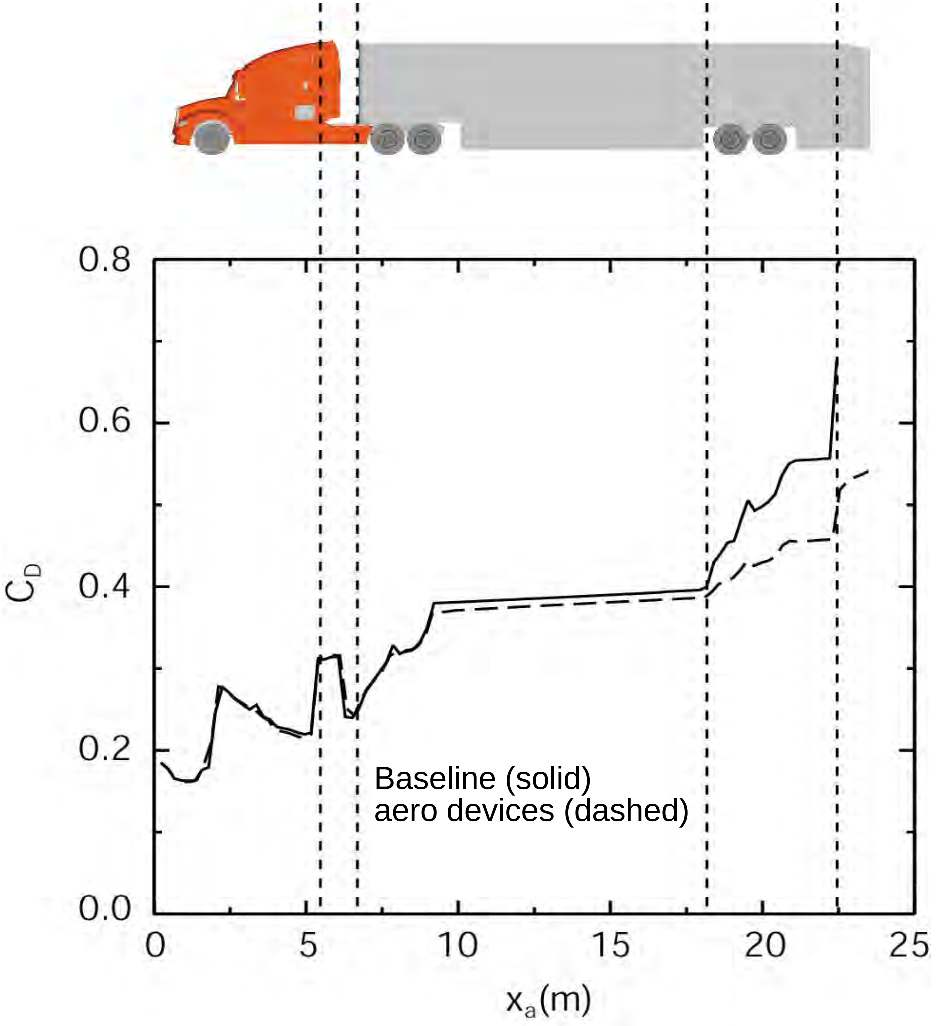
Suggested design improvements for

- Trailer tail devices
- Trailer skirts

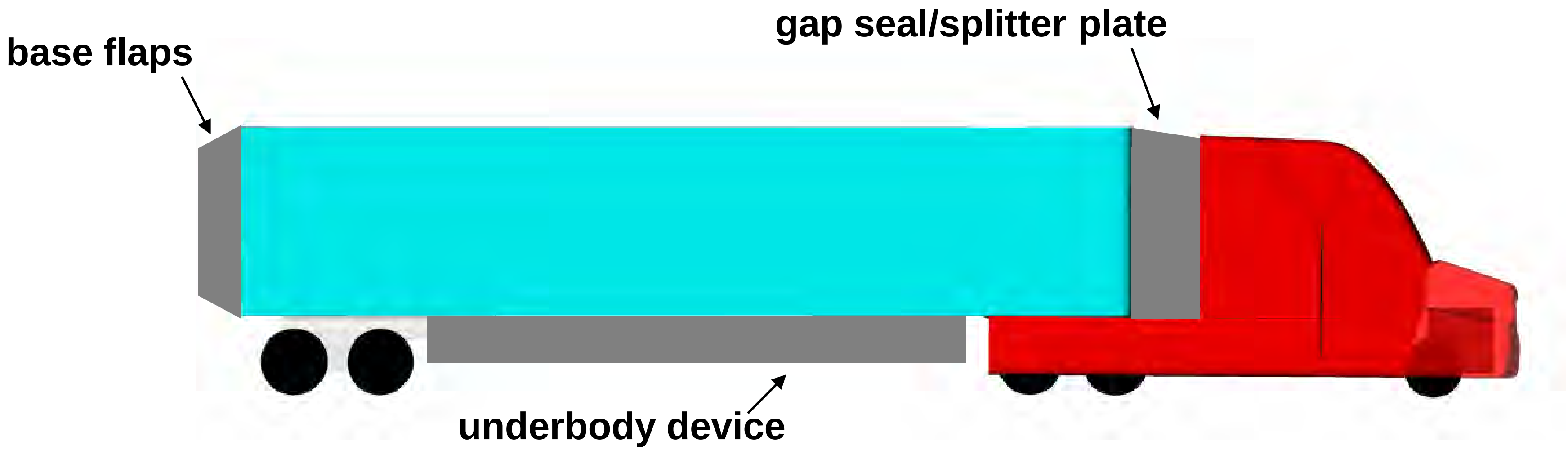
Impact of trailer skirts and trailer boattail on aerodynamic drag





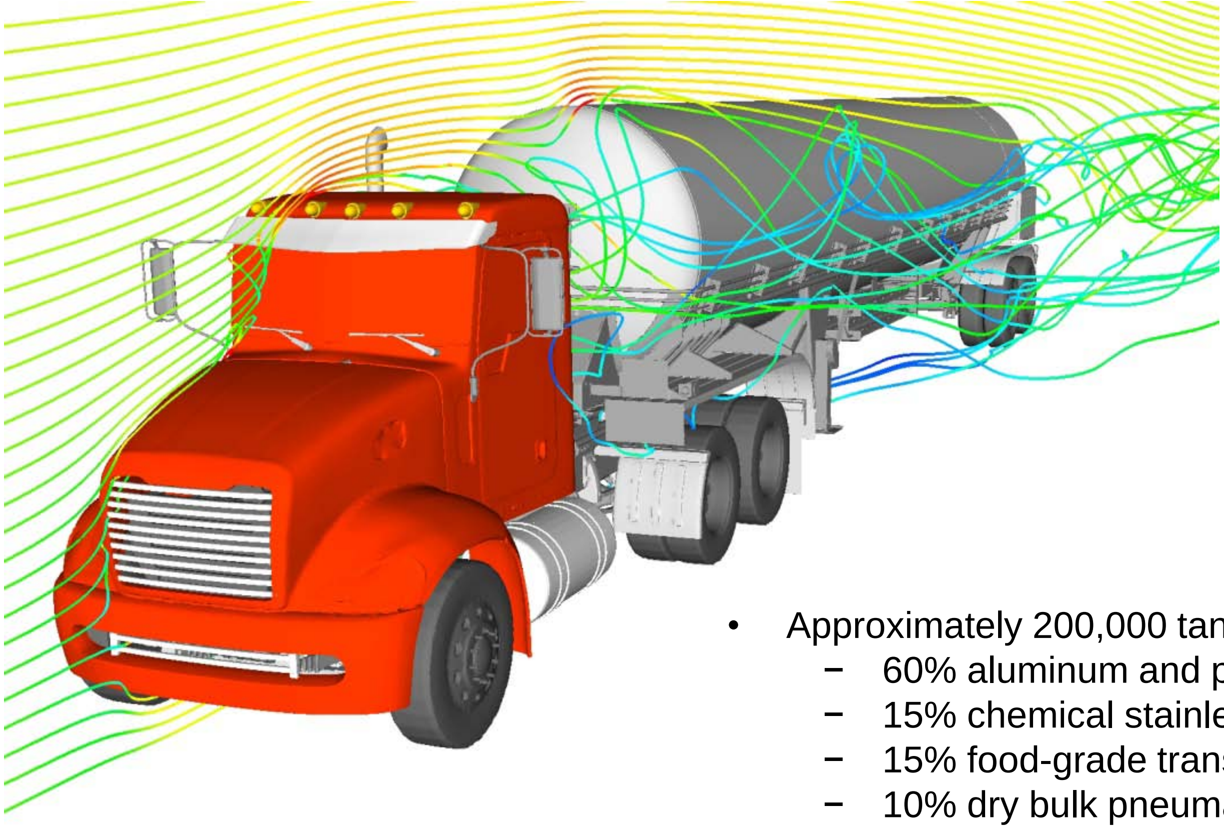


Performance of aerodynamic devices



- Base flaps: 4-7% FEI (Fuel Economy Improvement)
- Underbody devices: 5-7% FEI
- Gap devices: 1-2% FEI
- Wide-base single tires: 4-5% FEI

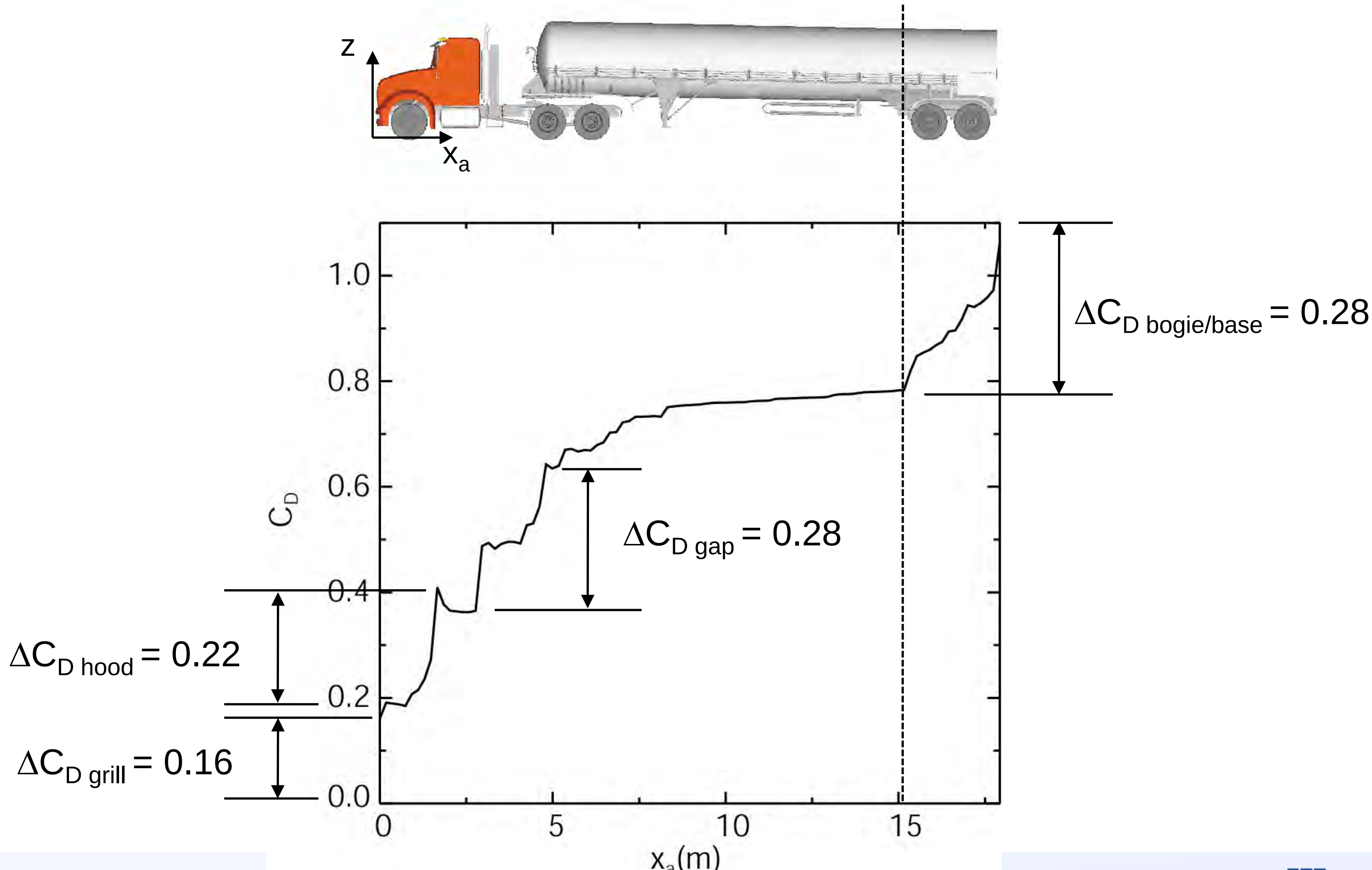
Tractor-tanker aerodynamics



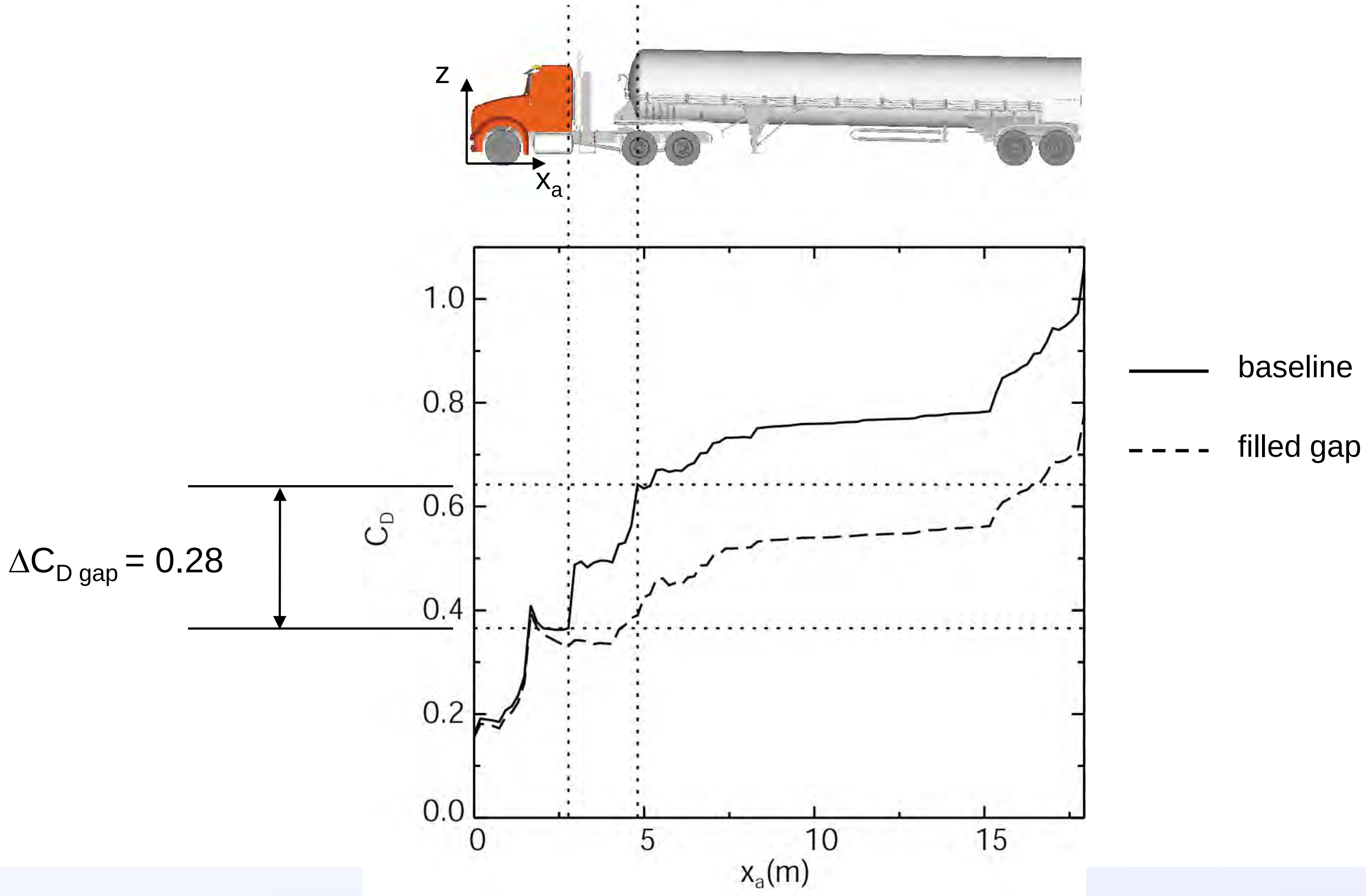
- Approximately 200,000 tanker trailers in the United States[1]
  - 60% aluminum and petroleum product service
  - 15% chemical stainless steel trailers
  - 15% food-grade transportation
  - 10% dry bulk pneumatic trailers
- Average fuel economy ≈ 2 km/L (5 mpg)[2]

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 the tanker trailer



Aerodynamically treating the tractor-tanker gap significantly reduces the drag



Future plans

- Continue with the track and on the road tests of the down selected devices
  - Improve design/performance of selected drag reduction devices
  - Validate the performance of the redesigned aero devices
- Continue to work with Praxair to design aerodynamic drag reduction devices for tanker trailers to improve the fuel economy
- Apply aerodynamic-based surface optimization to add-on devices
- Continue to evaluate and design new and existing drag reduction devices/concepts using LLNL's virtual testing environment
- Explore the benefits of tractor-trailer integration for drag reduction (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 tests in collaboration with Navistar and Michelin to obtain performance data for aero devices
  - Two tractors and three trailers were used
  - Twenty-three aerodynamic drag reduction devices/concepts were tested
  - High quality data was obtained due to negligible wind tunnel blockage effects (~1%)
- Full-scale wind tunnel data has been reduced and it will be published in the next few months
- Improved the performance of selected aerodynamic devices
- Started the aerodynamic evaluation of tanker trailers for the purpose of drag reduction
- Developed and evaluated a gap fairing for tanker trailers