

## Drag Reduction of a Modern Straight Truck

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### ABSTRACT

A wind tunnel test program was conducted at the Langley Full Scale Tunnel (LFST) to evaluate the performance of five passive drag reduction configurations on a modern straight truck at full scale. Configurations were tested in a build-up fashion with results representing a cumulative effect. Tested configurations include a front valance, a front box fairing, a boat-tail, an ideal side-skirt, and a practical side-skirt. Configurations were evaluated over a nominal 9 degree yaw sweep to establish wind averaged drag coefficients using SAE J1252. Genuine replicate yaw sweeps were used in an uncertainty analysis. Results show up to 28% improvement in wind-averaged drag coefficient and that significant gains can be made in straight truck fuel economy, even at non-highway speeds.

### INTRODUCTION

Aerodynamic performance in commercial trucks is becoming increasingly more important due to fuel costs as well as pressures due to environmental concerns. Currently the literature primarily contains information on the aerodynamic performance of larger tractor-trailer (class 8) vehicles, however, light and medium straight trucks (class 2-5) have relatively little available data by comparison-particularly using modern designs. This data is important not only because it provides an incentive to update vehicle fleets to improve performance, but also serves as a check of performance claims by makers of after-market components and devices for these vehicles. The latter is becoming more important as more products are entering the market-many of which make claims not substantiated by adequate testing.

Research was conducted at the Langley Full Scale Tunnel (shown in [Figure 1](#)) to evaluate the performance of several add-on devices using a full-scale modern straight truck. This work is aimed at contributing to the art by providing a data set with the following attributes:

- Ideal limits to popular device performance
- Modern vehicle design
- Full-scale vehicle
- Drag reduction devices representative of many current market offerings
- Minimal boundary effects over yaw sweep
- Sufficient Reynolds number
- Minimum interference from support structure
- Overall uncertainty analysis, (not back to back point repeatability)

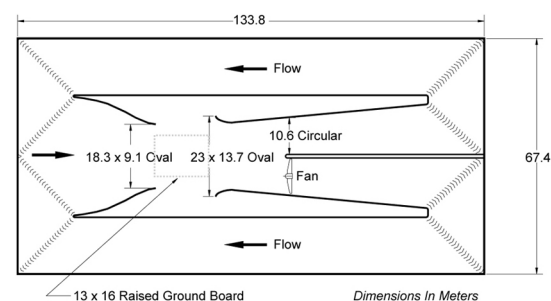


Figure 1. The Langley Full Scale Tunnel Plan View

# EVOLUTION OF HEAVY TRUCK DRAG REDUCTION TECHNOLOGIES

Drag reduction of commercial trucks has been explored since the 1930's with most of the focus, especially in recent years, on the tractor portion of class 8 vehicles.<sup>1,2,3,4</sup> Much of this work has application to light and medium straight trucks. The most recent work specific to straight trucks includes work done in the 1970's and 1980's--much of it by Cooper. Preliminary work included adding treatments above the cab to deflect air over the top of the box<sup>5</sup>. The later studies involved boat-tail designs at the rear of the vehicle<sup>6</sup>. These studies agree well with more general guidelines for vehicle development found in [reference 7](#). Additional details on advances in heavy truck aerodynamics can be found in [reference 8](#).

## EXPERIMENT DETAILS

### FACILITY

While operational, the LFST (formerly the NASA LaRC Full-Scale or NASA 30 by 60) featured a large  $\frac{3}{4}$  open-jet test section and large ground board.<sup>9</sup> Full-scale vehicles ranging from conventional cars to Class-8 tractors with shortened trailers could be accommodated. The test section was semi-elliptical in cross section with a width of 18.3 m (60 ft) and a height of 9.1 m (30 ft). The ground board measured 13 m wide by 16.0 m long and featured a turntable with a diameter of 8.7 m. The overall aerodynamic layout of the facility, used a double return design and is shown in [Figure 1](#). Power was supplied by two 3 MW (4000 HP) electric motors driving two 10.6 m diameter four-bladed fans. For this test the 6-DOF external balance with heavy truck supports was used to measure body-axis vehicle drag, side force, and yawing moment. Ground board boundary layer control was provided through a raised ground board.<sup>9</sup> The large  $\frac{3}{4}$  open jet test section of the LFST was well-suited to testing the full-size straight truck.

### VEHICLE

The vehicle used for testing was a full-size GMC T-series straight truck as shown in [Figure 2](#). The truck features a modern cab-forward design and a standard 16-foot box with radiused corners and edges.

Additionally, it should be noted that the vehicle includes a lift-gate at the rear of the vehicle.



*Figure 2. GMC T-series truck*

## DRAG REDUCTION DEVICES

Several devices were chosen for this test including a front valance, a fairing for the front of the box, a boat-tail at the rear of the box, an ideal side skirt, and a practical side skirt. All of these devices have been shown to be valid methods for reducing drag on ground vehicles, and a few are currently commercially available. The devices were tested in a “build-up” methodology where treatments were progressively added to the vehicle. [Figure 3](#) shows the vehicle treatments. [Figure 4](#) shows the progressive build-up of devices.

### Valance

A valance was added at the front of the vehicle at the front bumper. The valance extended from the bumper down to 3" from the ground and wrapped around the sides to the front wheel well openings. Adding a valance to restrict flow to high drag underbody components is a well known practice among other ground vehicles.

### Box Treatment

A commercially available product design to fair the front of the cargo box was added. Streamlining the box has been used as a means of drag reduction for the past 35 years. This helps to reduce the stagnation zone on the front of the box and reduce separation on the sides and top surfaces.

### Frame Extension Boat-tail

A patented boat-tail concept ([ref A](#)) was added at the rear of the vehicle to aid in base pressure recovery. The boat tail was added on three sides with the freight box floor aft platform acting as the fourth side. The boat-tail consisted of a 18 in. frame extension tapered at 15 degrees from the roof and sides of the box.

### Practical Skirt

The patent pending practical skirt is designed to restrict under body flow impingement onto high-drag undercarriage components--particularly at yaw conditions. The practical side-skirts extended from the lower surface of the freight box to 8 in. above the ground. The skirt extends longitudinally the

full length of the freight box. The forward most section of the skirt is curved inward to form an air dam. Because of the inset rear wheels of this truck's design, the skirt covered the wheels as well with no interference.

#### Ideal Skirt

The patent-pending ideal skirt is similar to the practical skirt except ground clearance is reduced to 3 in. Although it is impractical for regular use as a rigid panel, it serves to bound the ideal limits of performance

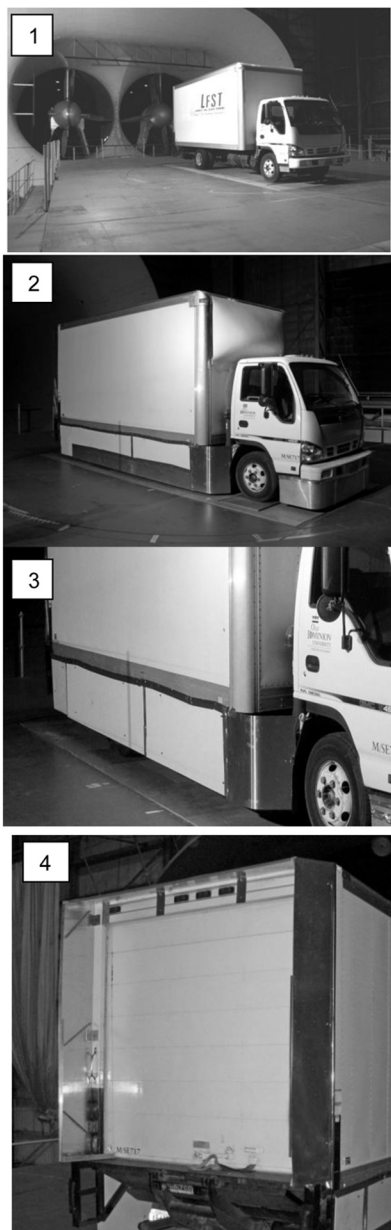


**Figure 3. Treatments for Box Truck: 1--Untreated truck on ground board. 2--Truck shown with valance, box front treatment, and 'ideal' skirt. 3--Truck shown with 'practical' skirt. 4--Truck shown with boat-tail.**

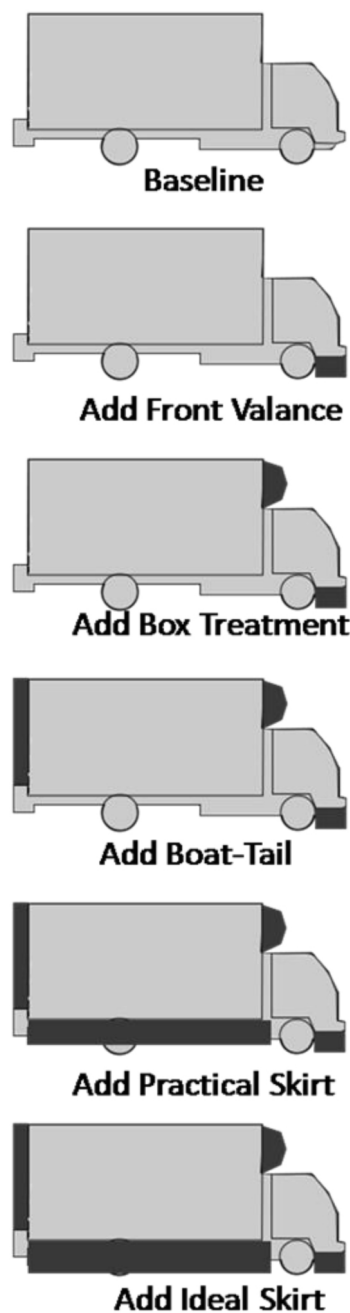


**Figure 4. Test Configurations**

#### Test Procedure and Data Reduction

##### Test Conditions and Drag Measurement

All configurations were tested at a nominal dynamic pressure of 10 psf over a yaw sweep of 0 to 9 degrees with data to 15 degrees for the baseline case. Two of the configurations were chosen at random to be run as replicates for uncertainty estimates. A PC-based data acquisition system with a 16-bit A/D samples automotive balance load cell forces as well as a differential pressure transducer dedicated to dynamic pressure measurement. The drag force measurement and wind tunnel