US Department of Energy DE-EE0001552:
Fleet Evaluation and Factory Installation of Aerodynamic Heavy Duty Truck Trailers

Final Scientific and Technical Report

Jason Beck
Test and Integration Engineer
Navistar Aerodynamics

Kambiz Salari, Jason Ortega
Lawrence Livermore National Laboratory

Andrea Brown
Fmr. Navistar Aerodynamics

December 18th, 2013

Executive Summary

The purpose of DE-EE0001552 was to develop and deploy a combination of trailer aerodynamic devices and low rolling resistance tires that reduce fuel consumption of a class 8 heavy duty tractor-trailer combination vehicle by 15%. There were 3 phases of the project:

Phase 1 – Perform SAE Typed 2 track tests with multiple device combinations.
Phase 2 – Conduct a fleet evaluation with selected device combination.
Phase 3 – Develop the devices required to manufacture the aerodynamic trailer.

All 3 phases have been completed. There is an abundance of available trailer devices on the market, and fleets and owner operators have awareness of them and are purchasing them. The products developed in conjunction with this project are at least in their second round of refinement. The fleet test undertaken showed an improvement of 5.5 – 7.8% fuel economy with the devices (This does not include tire contribution).

Table of Contents

1 Introduction

Navistar, Inc. partnered with Lawrence Livermore National Laboratory, Freight Wing, Frito-Lay, Kentucky Trailer, and Michelin to produce a commercially available tractor-trailer combination outfitted with trailer aerodynamic drag reduction devices and low rolling resistance tires in order to achieve the 15% fuel economy improvement target set forth by funding opportunity DE-EE0001552.

This project began with a Phase 0 full-scale wind tunnel test led by Lawrence Livermore National Laboratory (LLNL) at the National Full-Scale Aerodynamics Complex 80' x 120' wind tunnel. That test included the evaluation of a number of trailer aerodynamic devices, and the criteria for involvement in that test were as follows:

- Devices in or close to being in production
- Wind tunnel or SAE Type II, III, or IV fuel economy data

Following that test, we were able to use the acquired data to down-select a number of devices for Task 1.4 testing. Some configurations, however, required further evaluation. Thus, Freight Wing and Navistar led the Task 1.2 sub-scale evaluation of a select number of Freight Wing's devices. Using devices from the Phase 0 test along with components from Freight Wing and LLNL, along with a trailer from Frito-Lay, we were able to complete a 24 configuration test as described in Task 1.4. Using the results from Task 1.4 and a statistical analysis completed by a statistician at LLNL, the team completed its Task 1.5 device down-select in a face-to-face meeting on April 14, 2011.

Given that the testing undertaken in Task 1.4 is essentially at steady-state highway condition, there are considerations that should be made when interpreting the results and applying the performance data collected to what a fleet might see in actual operation. These considerations have influenced the fleet evaluation plan, and we expect to deliver information applicable to a wide cross-section of the industry as a result.

In addition to these tasks, the team commissioned a survey of the industry to better understand the barriers to widespread adoption of trailer aerodynamic devices and wide base single tires. The key outcomes of the survey are as follows:

- Fleets and owner operators that have used trailer aerodynamic devices and wide base single tires in service generally find that the devices deliver on performance claims
- The payback period for trailer fuel saving devices is approximately as expected, but the amount fleets and owner operators are willing to invest up front is less than expected.
- The allowable weight of the devices is lower than expected.
- There is a strong preference in the industry for Original Equipment Manufacturers (OEMs) to install fuel saving devices rather than have them installed as aftermarket equipment.

The team incorporated the information from the survey with the Phase 2 fleet test results in order to best meet the needs of the industry with the Phase 3 commercially available product.

2 Work Completed per Task

2.1 Task 1.1 – Gather Existing Performance Data

Prior to selecting trailer aerodynamic drag reduction devices for evaluation in the Phase 0 full-scale test, Navistar and LLNL developed a list of criteria upon which to judge various devices that met the following minimum qualifications:

- Devices in or close to being in production
- Wind tunnel or SAE Type II, III, or IV fuel economy data.

The criteria used in this evaluation were:

- Advertised/demonstrated fuel economy benefit
- Existence of wind tunnel or fuel economy data
- Cost
- Weight
- Level of driver involvement in device use
- Installation difficulty
- Required maintenance
- Expected years of life

Navistar and LLNL used that information to devise an attribute weighted scoring system to rank the overall priority of the devices.

Navistar solicited a number of device manufacturers to gather this data. Device manufacturers willing to participate in the full-scale evaluation provided the information on the devices they hoped to test. The resulting list included a representative sample of trailer gap treatments, underbody skirts, and boat tails for evaluation during Phase 0.

The Phase 0 test provided additional information on device performance. At the conclusion of that test, we were able to limit the devices to the top performing devices (regardless of manufacturer) and devices from Freight Wing and LLNL. Both of the partners' devices, however, required additional evaluation in the Task 1.2 sub-scale testing.

2.2 Task 1.2 – Sub-Scale Wind Tunnel Testing

The primary purpose of sub-scale wind tunnel testing for this project was to facilitate an upfront down-select of Freight Wing's and LLNL's proposed devices and device combinations. Sub-scale testing was conducted at Auto Research Center (ARC) in Indianapolis, IN September 2010. The facility includes a $1/8^{th}$ scale open jet tunnel with a top speed of 111.8 mph. The facility was selected because it is the most widely used by trailer aerodynamic device manufacturers. Results from this facility have a tolerance of +/-0.5% (fuel economy).

A total of 22 runs were made, and estimated fuel economy improvements were provided by ARC. The run matrix, Table 1, was as follows:

Table 1 – ARC Wind Tunnel Test Matrix

Run Number	Run Description
1	Baseline
2	Baseline
3	Square Front Angle Skirt, Angled Just over Landing Gear (Config 2)
5	Add Landing Gear Cover (Config 3)
6	Add Cross-Member Cover (Config 4)
7	Add Rear Panel (Config 5)
8	Angle Rear Panel (Config 6)
9	Return Rear Panel to Straight, Add Wheel Cover (Modification of Config 7)
10	Remove Wheel Cover and Rear Panel, Angle Skirt Straight (Config 8)
12	Best Skirt Combination and Gap Fairing (Config 17)
13	Add Aero Industries Aero Tail (Config 18 except different tail manufacturer)
14	Repeat Run 13
17	Freight Wing Short Skirts (Config 9)
18	Angle Freight Wing Short Skirts Inboard (Config 10)
19	Add Cross-Member Covers (Config 11)
20	LLNL Underbody Wedge (Config 12)
21	LLNL Short Skirts and Aft Skirts (Config 15)
22	Freight Wing Short Skirts Moved Forward with Cross-Member Covers

Run 9 provided the greatest estimated fuel economy improvement using only Freight Wing devices yielding 8.31%. Run 13 built on Run 9 (Figure 1 and 2) with the addition of the Aero Industries/AeroVolution Aero Tail and delivered an estimated 13.25% fuel economy improvement.

Figure 1 – Run 13, Front View

Figure 2 – Run 13, Rear View

Both of these configurations, along with the subcomponents thereof, were moved forward to the track test. The LLNL underbody devices did not perform as well as the Freight Wing trailer skirts, so they were not moved forward into the track test.

2.3 Task 1.3 – Fabricate Devices

Devices included in the track test either came from partners in the grant, or were recycled from Phase 0. Freight Wing and LLNL supplied material for all configurations ahead of the test and were on site to coordinate the installation and make modifications over the course of the test. Freight Wing variations were generally composed of modifications to their base system and materials while LLNL utilized their carpenters to fabricate devices ahead of the test and then modify as necessary on site. All devices from other suppliers were reused from Phase 0.

2.4 Task 1.4 – Track Testing

The team elected to conduct its track testing in accordance with SAE Recommended Practice J1321 Type II. This test requires vehicles to complete at least three runs of 40 miles or greater to evaluate fuel consumption within a tolerance of +/-1%. Since the procedure specifies the use of the weigh tank method, fuel consumption was measured by recording the weight of an auxiliary fuel tank before and after each run. As this form of fuel economy testing is completed on a track with a control vehicle ran simultaneously, and since each run is mostly at steady state highway speeds where aerodynamic improvements are best realized, this type of testing lends itself well to isolating the fuel economy improvements produced by trailer drag reduction devices and wide base single tires.

24 configurations were evaluated, and of those configurations, five delivered 15% or better fuel economy improvement on the straight frame trailer (Table 2):

Table 2 – Configurations over 15% Fuel Economy Improvement

Configuration	Description	Percent Improvement
10	Freight Wing Max Skirt with Rear Panel, Freight Wing Gap Fairing, and Aero Industries/AeroVolution Aero Tail	17.6%
11	Freight Wing Max Skirt with Rear Panel, Freight Wing Gap Fairing, Aero Industries/AeroVolution Aero Tail, and Michelin XOnes	22.3%
16	Freight Wing Gap Fairing, LLNL Skirts, and LLNL Boat Tail with High 4th Side	15.3%
17	Freight Wing Gap Fairing, LLNL Skirts, and LLNL Extended Length Boat Tail with High 4th Side	15.5%
18	Freight Wing Gap Fairing, LLNL Skirts, and LLNL Extended Length 3-Sided Boat Tail	16%

It is important to note that although these combinations delivered the 15% fuel economy improvement target, they did so under conditions that do not mirror fleet use. For example, if a fleet combination outfitted with configuration 16 devices were to spend only 60% of its day at highway speeds, 10% of its day at idle, and the remaining 30% in city traffic, the overall fuel economy improvement would be far less than the 15.3% achieved during the track test simply because it was not operating at steady state highway speeds. Conversely, however, a line haul combination outfitted with configuration 16 devices operating at highway speeds with a 20 mph crosswind is likely to see a fuel economy improvement in excess of the 15.3% reported for that combination. In short, it is important to keep in mind the impact of duty cycle when reporting results and interpreting in fleet fuel economy deltas.

Because Frito-Lay is primarily a drop deck trailer fleet, the team also evaluated drag reduction devices on their trailer (Table 3).

Table 3 – Drop Deck Trailer Fuel Economy Improvements

Configuration	Description	Percent Improvement
19	Frito-Lay Drop Deck Trailer with Freight Wing Skirts and Freight Wing Gap Fairing	2.1%
20	Frito-Lay Drop Deck Trailer with Freight Wing Skirts, Freight Wing Gap Fairing, LLNL Rear Skirts, and LLNL 4-Sided Boat Tail	6.1%
22	Frito-Lay Drop Deck Trailer with Freight Wing Skirts, Freight Wing Gap Fairing, LLNL Rear Skirts, and 3-Sided Boat Tail	5.4%

Although these combinations did not achieve the 15% improvement, the team feels there is a role for drop deck trailers in the fleet evaluation, namely to implement a novel boat tail design.

2.5 Task 1.5 – Down-Select

In addition to targeting device combinations that deliver 15% fuel economy improvement, the team answered the following questions:

- Would the sample size available be statistically significant?
- How many devices in service can the team support logistically and financially?
- How many trailers are available for retrofit in the Frito-Lay fleet?
- What types of trailers are available?
- Do those trailers spend enough time at highway speed?
- In addition to achieving the fuel economy improvement goal, what commercial criteria should be considered?

LLNL provided a statistical evaluation of information provided by Frito-Lay to determine what size sample would be required to have certain levels of confidence in the results. Unfortunately, this exercise yielded sample sizes well in excess of the 30 – 50 trailers the team originally committed to retrofit under this funding award.

Frito-Lay does not have a large number of straight frame trailers, and those trailers would not be considered high mileage. Their drop deck fleet, however, is a good candidate for boat tail evaluation.

Although boat tails are available on the market, their acceptance is lagging compared to underbody skirts and gap fairings, so the team felt it important to evaluate multiple boat tail designs in an effort to evaluate and address the in service issues with these devices. Freight Wing, which started as a boat tail manufacturer, has brought forward a new boat tail design that the team feels has potential. Since it will be built per the specifications LLNL made public following the Phase 0 test, the team is confident in its ability to compete with the performance of the two boat tails tested during the track test while possibly addressing operational issues its competitors do not. Thus, the team chose to add this product to the fleet evaluation.

Wide base single tires are not common in the Frito-Lay fleet today, so integrating them into the fleet evaluation will be financially burdensome.

Given the constraints, the team has decided to evaluate three combinations of devices:

1. Frito-Lay straight frame trailers fitted with Freight Wing skirts and gap fairing, the ATDynamics TrailerTail, and Michelin XOnes on the trailer only. This configuration differs from track test Configuration 11 in that the tractor will not be equipped with wide base single tires, and it uses the ATDynamics boat tail instead of the Aero Industries /AeroVolution Aero Tail.
2. Spirit Truck Lines straight frame trailers fitted with Freight Wing skirts and gap fairing, the Aero Industries/AeroVolution Aero Tail, and Michelin XOnes on the trailer only. This configuration differs from track test Configuration 11 in that the tractor may not be equipped with wide base single tires..
3. Frito-Lay drop deck trailers fitted with Freight Wing skirts, gap fairing, and boat tail (similar to track test Configuration 22). The primary purpose of this test will be evaluation of the operational capability of the new boat tail.

3 Survey Results

Navistar contracted a third party vendor to conduct an anonymous survey on tractor and trailer fuel saving devices. The web-based consisted of 32 questions, several of which intended to eliminate unintended respondents, with many questions accepting verbatim feedback. In the end, we received feedback from 256 respondents representing a mix of owner operators, small and large fleets. For the purpose of this survey, a small fleet was defined as having less than 25 tractors, and a large fleet was defined as having more than 25 tractors. The key feedback was as follows:

- The majority of respondents prefer performance measurements in miles per gallon.
- The majority of respondents require the initial investment in a device to be less than $1000, and a large portion of that group requires initial investment to be less than $500 per device.
- Purchase price is the main barrier to adopting devices while fuel costs are the main inducement.
- Despite the long life of a trailer, most respondents report the devices must pay back within 1 – 2 years.
- Approximately one half of respondents are not willing to add more than 149 lbs to their trailers due to add on devices.
- Most respondents would prefer their devices come as OEM installed equipment.
- Most respondents do not want their drivers to have to interact with the devices.
- Most respondents prefer to learn about devices via industry publications and word of mouth.
- Most of the respondents who are using devices today report that their performance is about what they expected.

In short, the survey confirmed the team's theory that devices are being successfully used in fleet operations today, but the economic equation is not ideal for widespread adoption. Thus, with the continued increase in fuel prices, fleets are likely to begin adopting trailer aero devices on a wider basis, assuming capital is available to do so. However, the benefit of a large scale fleet evaluation will be that data is coming out of a reputable industry source (Frito-Lay), so other fleets and owner operators are more likely to believe the results.

A complete list of questions and an executive summary are available in Appendix B.

4 Phase 2 Plan

As stated in subsection 2.5, the team has elected to include three device combinations in the fleet evaluation. All three combinations will require the establishment of baselines. The team has determined it will be necessary to run the baseline simultaneously with the fuel economy evaluation. This will contribute to the total number of devices put in service. For the first combination, we are targeting 10 baseline trailers and 10 retrofitted trailers. For the second

combination, we are also targeting 10 baseline trailers and 10 retrofitted trailers, although there is opportunity to increase that sample size. For the third combination, the target is 20 baseline trailers and 20 retrofitted trailers (facilitated by Frito-Lay's existing equipment). The team is confident these device combinations will allow for adequate evaluation of fuel economy performance improvements and operational challenges without creating undue financial or logistical burdens.

The team was able to execute a 1 year evaluation beginning in September 2011. The third item, the driver training program, is of primary concern as it has previously been demonstrated that driver behavior can have a multiple percent impact on fuel economy, so drivers must not be in the process of making changes to their behavior for the team to deliver valid results.

In order to establish additional statistical relevance of the Phase 1 and Phase 2 results, the team is planning a statistical evaluation of the fleet results. The statistical evaluation of the fleet results is meant to help quantify the in service performance variation of devices known to deliver a certain fuel economy improvement.

One of the key capabilities Frito-Lay brings to the table is the ability to capture highly accurate data from their operations namely fuel economy data, route information, and device information. Frito-Lay will be working with its distribution centers supporting the fleet evaluation to provide a range of information in these categories such that the team will know how the device performed, what uncontrollable circumstances may have impacted performance on a given day, and what in use issues arise. Therefore, the fleet evaluation will not only deliver performance information, but it will be able to qualitatively expand on the results as well.

5 Phase 2 Results

Data collection and post-processing of on-the-road fuel economy measurements was achieved for class 8 heavy vehicles from two commercial fleets, Frito Lay (76 tractors and 32 trailers tracked, 1.4×10^6 miles of fuel economy data) and Spirit Truck Lines (9 tractor-trailers tracked, 690,000 miles of fuel economy data). These vehicles were outfitted (Figures 1-2) with various combinations of tractor-trailer gap fairings (Freight Wing), trailer skirts (Freight Wing), trailer boattails (24" Freight Wing and 48" ATDynamics), and wide base tires (Michelin). Aside from the prototype Freight Wing boattail, all devices and tires functioned as expected. Unlike the ATDynamics boattail, which requires manual deployment and retraction, the Freight Wing boattail retracts as the trailer backs against the loading dock. When the trailer pulls away, the boattail automatically deploys. Partway through the test, the top plate of several of these Freight Wing boattails began to sag due to wear and tear on the supporting flexible members (see Figure 2). As a result, the optimum boattail angle was not maintained on the top plate. The failing flexible members were soon replaced and the test proceeded as planned. For the Freight Wing skirts and ATDynamics boattails, we received very positive feedback from the Spirit drivers, who observed better vehicle handling and ride quality for the vehicles outfitted with the devices.

For the heavy vehicles monitored within the Frito Lay fleet, the data collection and analysis presented several challenges and unique opportunities. We quickly learned that Frito Lay stores

very detailed information for each tractor and trailer on any given day. Mining meaningful fuel economy data for the 2011 and 2012 calendar years required several months of back and forth iterations with the technical staff at Frito Lay. We finally settled upon a group of sorting parameters (including a consistent latitude and longitude of the vehicle routes, average vehicle speed, and minimum miles driven per route), which made it possible to compare on-the-road fuel economy data of baseline and control vehicles outfitted with aerodynamic drag reduction devices. The results of this comparison are shown in Figure 3 over the course of a 12 month period. The rise and fall of the average fuel economy throughout the year is from seasonal temperature changes. We found a substantial level of noise in this dataset that made it particularly difficult to draw out any additional trends from that shown in Figure 3. This was, in part, due to variability in the route, vehicle driver, and fuel consumption uncertainty. For some drivers or vehicles, the drag reduction devices produced a higher mpg, but there were as many drivers or vehicles, for which the devices produced a lower mpg. So on average, there was no observable difference. More formal analyses of the data, which accounted for the effect of the driver and vehicle showed no difference either.

To mitigate these shortcomings in the Frito Lay data set, we suggest that future studies incorporate vehicles that have on-board data loggers, which will provide direct engine fuel economy measurements when the vehicle is traveling at highway speeds instead of an averaged value over the entire route. Additionally, we suggest controlling for the effects of the vehicle and driver by having the same driver and vehicle combination with each device, with a good number of replicates for each such combination.

On the other hand, data collection and post-processing of the Spirit Truck Lines dataset was very straightforward as this fleet had previously established data monitoring software (PeopleNet) to track their fuel consumption and driver behavior. The data output produced by this software were readily conducive to our analyses. Our team typically received updates on their fuel economy data on a monthly basis through a secure website portal. The resulting data sets extended from September 2011 to March 2012. It should be noted that since the Kenworth T600 has under-cab fuel tanks, it had a larger tractor-trailer gap by approximately 8". The Spirit vehicles utilized the Michelin XOne XTEs, which are Michelin's high mileage wide base single tire. Spirit stated that their drivers strongly prefer their XOnes to traditional duals because of improved traction. Spirit also uses soft top speed limiters to control their driver's speed and encourage good driving habits. The speed limiter is set to 65 mph, and assuming the driver exhibits good behavior during the run, they are able to run up to 67 mph for a certain period of time. Spirit also has limited their vehicles to operate only up to 60 miles without cruise control engaged. As a result of the speed limiters and Michelin XOnes, the baseline trucks used for the fleet test had an average fuel economy of approximately 7 mpg across their fleet. They currently have 300 trailers with Utility skirts. Spirit believes the Utility skirt improves their fuel economy approximately 0.3 mpg. They were also involved in an evaluation of the Transtex skirt. Spirit has been running these skirts for over three years, and they are pleased their performance and condition.

A basic analysis of variance (ANOVA) with miles per gallon as a response and the device as a predictor was performed on Spirit datasets that were separated either by vehicle, combined together across all vehicles, or filtered according to the average trip speed. The average fuel

economy for each of the vehicle is shown in Table 1. From this analysis, we determined that the fuel savings of the Freight Wing or ATDynamics boattails combined with the Freight Wing gap fairing and skirts and Michelin XOnes were on average 0.394 mpg (0.306 to 0.482 mpg as a 95% confidence interval) or 0.562 mpg (0.481 to 0.642 mpg as a 95% confidence interval), respectively, compared to the baseline vehicles with only the Michelin XOnes. The corresponding average percent increases in the average fuel economy relative to the baseline vehicle are 5.47% and 7.79%, respectively (Table 2).

These results are consistent with our fuel economy savings estimates previously made from CFD simulations and small- and full-scale wind tunnel tests. These results highlight the fact that fleets desiring to assess fuel economy changes of aerodynamic drag reduction devices must provide a series of controls to the driver, on-the-road vehicle performance, data collection, and data presentation in a manner similar to that of Spirit Truck Lines.

Freight Wing Skirts & ATD Boattail

Freight Wing Gap Fairing and Skirts

Figure 3. A Spirit trailer outfitted with Freight Wing skirts and an ATDynamics (ATD) four-sided boattail.

Freight Wing 3-sided boattail

Frito Lay trailer with a Freight Wing gap fairing

Figure 4. Freight Wing 3-sided boattail and a Frito Lay trailer outfitted with a Freight Wing gap fairing.

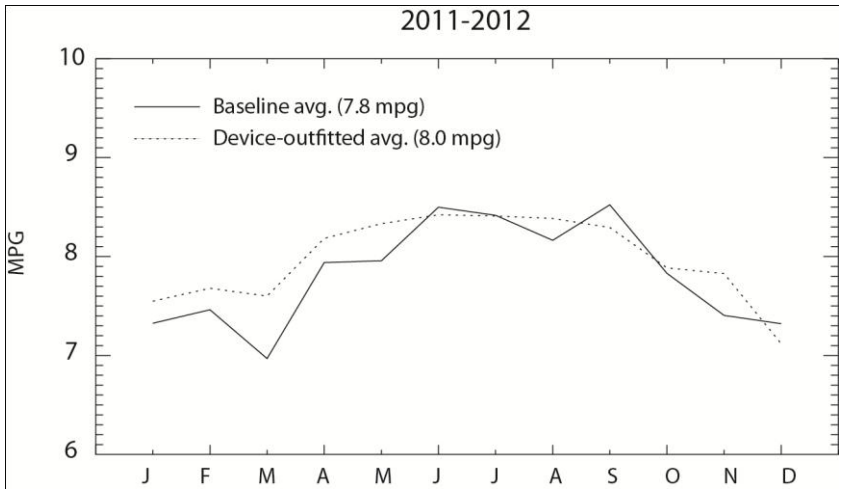


Figure 5. Average monthly fuel usage for the baseline vehicles and vehicles outfitted with aerodynamic drag reduction devices.

Vehicle	FW – Baseline		ATD - Baseline	
	Mean	95% CI	Mean	95% CI
2255	0.457	(0.253, 0.661)	0.46	(0.294, 0.626)
2273	0.5	(0.256, 0.735)	0.269	(0.037, 0.5)
2276	0.35	(0.174, 0.525)	0.404	(0.194, 0.614)
2317	0.237	(0.005, 0.468)	0.372	(0.153, 0.59)
2327	0.509	(0.242, 0.776)	0.988	(0.764, 1.211)
2337	0.439	(0.266, 0.611)	0.638	(0.492, 0.784)
Overall	0.394	(0.306, 0.482)	0.562	(0.481, 0.642)

Table 3. Change in fuel economy (mpg) for the six Spirit trailers outfitted with Freight Wing (FW) skirts and gap fairing, Michelin XOnes XTE tires, and either the Freight Wing or ATDynamics (ATD) boattails. Note that the baseline case also had Michelin XOnes XTE tires. CI: confidence interval.

Vehicle	(FW – Baseline)/Baseline		(ATD – Baseline)/Baseline	
	Mean	95% CI	Mean	95% CI
2255	6.32	(3.47, 9.22)	6.37	(4.02, 8.75)
2273	7	(3.58, 10.45)	3.79	(0.52, 7.11)
2276	5.27	(2.59, 7.99)	6.09	(2.89, 9.33)
2317	3.44	(0.07, 6.86)	5.41	(2.21, 8.67)
2327	7.13	(3.33, 11.01)	13.81	(10.51, 17.22)
2337	5.79	(3.48, 8.13)	8.43	(6.43, 10.48)
Overall	5.47	(4.24, 6.7)	7.79	(6.67, 8.92)

Table 4. Percent increase in fuel economy for the six Spirit trailers outfitted with Freight Wing (FW) skirts and gap fairing, Michelin XOnes XTE tires, and either the Freight Wing or ATDynamics (ATD) boattails. Note that the baseline case also had Michelin XOnes XTE tires. CI: confidence interval.

6 Phase 3

Phase 3 goal is to develop the engineering specifications and production requirements to manufacture the aerodynamic trailer. This was broken into 4 tasks:

Task 3.1: Refine device designs
Task 3.2: Design and tool-up final designs for 3rd party devices
Task 3.3: Publicly report results and advertise devices and device performance
Task 3.4: Factory-installed devices ready for sale by trailer manufacturer

Task 3.1, 3.2 and 3.4 were already commenced an in operation before the end of phase 2. The "Freight Wing Max Skirt", "Freight Wing gap fairing" and "ATD Trailer Tail" are available to the trucking industry for individual sale and through trailer manufacturers. All of these products are on their 2nd or 3rd iteration of design. They have been optimized and sales volumes have been increasing throughout the past few years. As reported by Wabash Trailer Company the sales of skirts installed on trailer over the last few years has been trending drastically up (Table 3). In the year of 2013 Wabash also installed 800 units of trailer tails, although tails have not been accepted by the industry as much as skirts, tail sales are also present and rising.

Table 5 - Wabash trailer skirt Installs

2010	16,802
2011	32,382
2012	26,00
2013	41,000

Freight Wing has also increased its sales of skirts and Aero devices over the last few years (Table 4).

Table 6 - Freight Wing Trailer Skirt Sales

2007	105
2008	878
2009	2,550
2010	8,068
2011	13,399

We have been able to achieve every, metric in tasks 3 and meet an overall objective of increasing industry awareness. The trend is that more devices will be sold in the future, and future legislation will also play a role in driving customers to trailer devices.

7 Project Conclusion

The purpose of DE-EE0001552 is to develop and deploy a combination of trailer aerodynamic devices and low rolling resistance tires that reduce fuel consumption of a class 8, heavy duty tractor trailer combination vehicle by 15%. There were 3 phases of the project:

Phase 1 – Perform SAE Typed 2 track tests with multiple device combinations.

Phase 1 was able to demonstrate a maximum of 22% Fuel Economy savings with a full complement of devices and tires. Without tires the same set of devices was able to demonstrate 17.6% Fuel Economy.

Phase 2 – Conduct a fleet evaluation with selected device combination.

Phase 2 was completed with two fleets of tractor trailers combinations and over 1.5 million miles of data collection. Without taking into consideration the effect of tires the demonstrated fuel economy benefit was 5.5 – 7.8%. This represents less than half of what was projected on the test track.

Phase 3 – Develop the devices required to manufacture the aerodynamic trailer.

Phase 3 was completed in step with phase 2. The devices of the combination that achieved 7.8% (Freight Wing Gap Fairing, Freight Wing Max Skirt, ATD Trailer Tail) are all available for sale and sales data indicates an upward trend.

All 3 phases have been completed. There is an abundance of availability of trailer devices on the market and fleets and owner operators have awareness of them and are purchasing them. The products developed in conjunction with this project are at least in their second round of refinement.

The target goal of 15% fuel economy improvement was not realized in the fleet test. This raises two issues: the variability of fleet operation and the accuracy of test track data. As stated in section 5 of this report the variability associated with the Frito Lay test fleet made the results inconclusive. Further study is needed in the fleets to understand duty cycles so that the aerodynamic, high speed contribution of the devices can be isolated from the rest of the duty cycle. Furthermore this highlights the issues inherent with track testing. Type 2 track testing is very wind sensitive and has relatively high error (+/-) 1%. Although there are wind limits in the procedure it is still possible to demonstrate a much greater fuel economy benefit than what is a real world simulation. These two factors contributed to the fleet test numbers. The fleet test undertaken showed an improvement of 5.5 – 7.8% fuel economy with the devices this does not include the contribution of low rolling resistance tires. Low rolling resistance tires would contribute another 3-5% in fuel economy savings.

Although the objective of 15% Fuel Economy savings was not met, the overall objective of increasing industry awareness of trailer devices was successfully met. We have demonstrated that within the current size envelope of a trailer, an aerodynamic trailer can reduce fuel consumption.

Appendix A: Task 1.4 Photos

Configuration 1: Baseline

Configuration 2: Aero Industries/AeroVolution Aero Tail

Configuration 3: Windyne Skirts

Configuration 4: Freight Wing Gap Fairing

No Photo

Configuration 5: Freight Wing Aeroflex Skirt

Configuration 6: Freight Wing Aeroflex Skirt – Trailer Axles Moved Rearward

Configuration 7: Freight Wing Max Skirt less Rear Panel

Configuration 8: Freight Wing Max Skirt with Rear Panel

Configuration 9: Freight Wing Skirt Outboard Landing Gear with Square Front Panel

Configuration 10: Freight Wing Max Skirt with Rear Panel, Freight Wing Gap Fairing, and Aero Industries/AeroVolution Aero Tail

Configuration 11: Freight Wing Max Skirt with Rear Panel, Freight Wing Gap Fairing, Aero Industries/AeroVolution Aero Tail, and Michelin XOnes

Configuration 12: Freight Wing Gap Fairing and LLNL Skirts

Configuration 13: Freight Wing Gap Fairing, LLNL Skirts, and LLNL 3-Sided Boat Tail

Configuration 14: Freight Wing Gap Fairing, LLNL Skirts, and LLNL 3-Sided Boat Tail with Bumper Filler Panel

Configuration 15: Freight Wing Gap Fairing, LLNL Skirts, and LLNL Boat Tail with Low 4th Side

No Photo

Configuration 16: Freight Wing Gap Fairing, LLNL Skirts, and LLNL Boat Tail with High 4th Side

Configuration 17: Freight Wing Gap Fairing, LLNL Skirts, and LLNL Extended Length Boat Tail with High 4th Side

Configuration 18: Freight Wing Gap Fairing, LLNL Skirts, and LLNL Extended Length 3-Sided Boat Tail

Configuration 19: Frito-Lay Drop Deck Trailer with Freight Wing Skirts and Freight Wing Gap Fairing

Configuration 20: Frito-Lay Drop Deck Trailer with Freight Wing Skirts, Freight Wing Gap Fairing, LLNL Rear Skirts, and LLNL 4-Sided Boat Tail

Configuration 21: ATDynamics Trailer Tail

Configuration 22: Frito-Lay Drop Deck Trailer with Freight Wing Skirts, Freight Wing Gap Fairing, LLNL Rear Skirts, and 3-Sided Boat Tail

Configuration 23: Frito-Lay Drop Deck Trailer (No Aero Devices)

Configuration 24: Michelin XOnes

Photo taken post-test

Appendix B: Survey Questions and High Level Results

The following images are the questions that were given in the survey. The yellow blocks are the background actions taken given various user inputs.

Trailer and Tractor Aerodynamic Fuel Saving Device Questionnaire

Draft

August 23, 2010

Prepared by:

National Analysts
WORLDWIDE
RESEARCH CONSULTING

Thank you for agreeing to take our survey! The purpose of this survey is to understand current and past experiences you may have had with fuel saving devices on both your tractors and trailers, and the criteria these devices would have to meet in order for you to install them throughout the majority of your fleet. We believe that you will find this survey both interesting and informative.

The survey will take approximately 12-15 minutes, and we will send you a check for $20 if you qualify and complete the survey.

If you encounter any problems while taking this survey, please contact XXX of National Analysts Worldwide at (800) 342-9102 or ____@nationalanalysts.com. Thank you!

Please click the "Forward" button to begin the survey.

Throughout the survey - do not display row letters, cell letters, or question numbers
For any open ends (including other-specify), force 2 characters

SECTION I – SCREENER

Before getting started, we would like to ask a few simple questions to determine if you qualify to take this survey.

S1. Are you the person in your organization who has primary or shared responsibility for purchasing or spec'ing trucks?

Select one

Yes	❍
No	❍

IF "No", terminate

Back | Forward | Stop | Help

S2. How many locations does your company have?

Enter a number between 1 and 99,999, then click Forward to continue

of locations

Allow values from 1- 99,999
Error message: "Please enter a value between 1 and 99,999"

Back | Forward | Stop | Help

S3. For how many of those locations are you involved in the purchasing and/or spec'ing of trucks?

Enter a number between 1 and <<insert number from S2>>, then click Forward to continue

of locations

Ask if S2 > 1
Answer must be <= S2

Back | Forward | Stop | Help

S4. What is your title?

Select one

[Randomize rows A-J]		
A	**President / CEO/ Owner**	❍
B	**Finance Manager/ Controller**	❍
C	**VP / Director Sales**	❍
D	**VP / Director Marketing**	❍
E	**Fleet manager**	❍
F	**Maintenance Manager/ Mechanic**	❍
G	**Purchasing agent**	❍
H	**Transportation Director**	❍
I	**Fire Chief**	❍
J	**EMS Director**	❍
k	**Other (specify): _____**	❍

Back | **Forward** | **Stop** | **Help**

S5. Which of the following *best* describes your organization's primary type of business?

Select one

A	**Agriculture/Farm**	❍
B	**Beverage Process/Distribution**	❍
C	**Bus Transportation**	❍
D	**Construction**	❍
E	**Emergency Services (fire, ambulance, etc.)**	❍
F	**Food Processing, Distribution or Delivery**	❍
G	**Forestry, Lumber**	❍
H	**Full-Service Lease or Maintenance Lease**	❍
I	**General Freight including hazardous (specify): _____**	❍
J	**Government (general)**	❍
K	**Road & Highway Maintenance**	❍
L	**Individual**	❍
M	**Landscaping/Horticulture**	❍
N	**Manufacturing**	❍
O	**Mining/Quarry/Coal**	❍
P	**Moving Storage**	❍
Q	**Petroleum Distribution / Propane Distribution including hazardous**	❍
R	**Sanitation/Refuse/Hazardous**	❍
S	**Services (security, driver training, etc.) (specify): _____**	❍
T	**Specialized Heavy Hauling**	❍

U	Towing	❍
V	Utility Services including hazardous	❍
W	Vehicle Transporter (on-highway – not including towing)	❍
X	Wholesale/Retail (specify): _____	❍
Y	Other (specify): _____	❍

Back | Forward | Stop | Help

S6. Which of the following *best* describes your organization?

Select one

[Randomize rows A-C]		
A	A company that primarily uses trucks for own business (e.g., private company or business but not an owner-operator business)	❍
B	A company that primarily transports freight for other companies (for-hire trucking company, but not an owner-operator business)	❍
C	An owner-operator: Own generally 1-2 trucks, drive at least one of the trucks, and manages a business in which the primary function of the business is for-hire transportation	❍
D	Other (specify):_____	❍

Back | Forward | Stop | Help

S7. Thinking only of locations in which you are involved in the purchasing or spec'ing of tractors, how many of each of the following weight classes are currently in use?

Enter a number between 0 and 99,999 in each row, then click Forward to continue

A	**_____**	**# of trucks GVW 10,000 lbs or less (e.g. Class 2/2C commercial vans, light step vans, pick-ups & small vans, not including cars etc.)**	
B	**_____**	**# of Class 3 (GVW 10,001 - 14,000) Light-Medium Duty Trucks**	
C	**_____**	**# of Class 4 or 5 (GVW 14,001 – 19,500) Medium Duty Trucks**	
D	**_____**	**# of Class 6 or 7 (GVW 19,501 – 33,000) Medium-Heavy Duty Trucks**	
E	**_____**	**# of Class 8 (GVW 33,001 and above) Heavy-Duty Trucks used for <u>vocational</u> purposes (e.g., construction, landscape, drilling, etc.)**	
F	**_____**	**# of Class 8 (GVW 33,001 and above) Heavy-Duty trucks used for <u>highway hauling</u> (e.g., tractor-trailer transport) [if = 0, TERMINATE]**	

Allow values from 0- 99999 in each cell
Error message: "Please enter a value or 0 in each row"
Sum of all rows > 0
<u>If level F = 0, TERMINATE</u>

S8. Does your company own trailers?

Yes	❍
No	❍

S9. Does your company haul trailers for other companies (e.g., contracted haulers)?

Yes	❍
No	❍

S10. How many of each of the following types of trailers does your company have in its fleet?

Show Col A if level a selected in S8. Show Column B if level a selected in S9.

Trailer Types	Trailers Owned	Trailers Hauled for Other Companies
Cargo Trailers	_____	_____
Tanker Trailers	_____	_____
Flatbed Trailers	_____	_____
Auto Transport Trailers	_____	_____
Dump Trailers	_____	_____
Utility Trailers	_____	_____
Tilt Trailers	_____	_____
Equipment Trailers	_____	_____
Stock (livestock) Trailers	_____	_____
Double Trailers	_____	_____
Hopper/Grain Trailers	_____	_____
Low boy	_____	_____
Open top	_____	_____
Logging, pole, pulpwood, or pipe	_____	_____
Tank, dry bulk	_____	_____
Tank, liquids or gasses	_____	_____
Van, basic	_____	_____
Van, drop-frame	_____	_____
Van, insulated refrigerated	_____	_____
Van, insulated non-refrigerated	_____	_____
Other (please specify)__	_____	_____

Welcome screen:

Thank you. You have qualified to participate in the survey! Please fill out the below information so that we can send your $20 honorarium check at the conclusion of the survey.

We strongly encourage you to provide an e-mail address so that we may contact you about future paid studies. You are under no obligation to participate and will never experience "spam" as a result of providing your e-mail address. National Analysts Worldwide is a founding member of CASRO (http://www.casro.org) and will never disclose your e-mail address to third parties.

Name:

Company (if a business address):

Address:

City:

State:

ZIP:

Phone (optional):

E-mail (strongly encouraged):

Please click "Forward" to begin the survey.

If e-mail not provided, prompt:

We would like for you to provide an e-mail address so that we may contact you once or twice per year about future paid studies. If you do not wish to provide an e-mail address, click "OK" to continue. Otherwise, please click "cancel" and enter your e-mail address.

Back	Forward	Stop	Help

Throughout the remainder of the survey, please refer to your Class 8 Highway Hauling tractors that carry a trailer.

SECTION II: General Fleet Info.

Q1. Please indicate the brand(s) of Class 8 highway hauling tractor(s) currently included in your fleet.

Select all that apply.

MANUFACTURER:	
Freightliner	❑
International	❑
Kenworth	❑
Mack	❑
Peterbilt	❑
Sterling	❑
Volvo	❑
Other manufacturer (please specify) _____	❑

Back | Forward | Stop | Help

Q2. Of your Class 8 Highway Hauling tractor(s), what percent are used for national, regional and local haul?

	Distance	Percentage
A	National Haul (500 + mile radius)	_____%
B	Regional Haul (101-500 mile radius)	_____%
C	Local Haul (within 100 mile radius)	_____%
	TOTAL	INSERT RUNNING TOTAL%
		100%

Back | Forward | Stop | Help

Q3. What percentage of your fleet is made up by each type of tractor listed below?

Conditions	Percentage
Long Sleepers	
Short Sleepers	
Extended Cabs	
Day Cabs	
TOTAL	INSERT RUNNING TOTAL%
	100%

Back | Forward | Stop | Help

Q4. What percent of the time do your Class 8 highway hauling tractor-trailer combinations operate in each of the following conditions (including both the tractor-trailer combinations you own and those contracted)?

Conditions	Percentage

On the highway	
In city traffic	
At Idle	
TOTAL	INSERT RUNNING TOTAL%
	100%

Back | Forward | Stop | Help

Show Q5 if level A, Q4 >0 and Q2, level a selected. Show Q5a if level A, Q4>0 and Q2, level B selected , else, SKIP to Q6.

Q5. What is your typical highway cruising speed of your Class 8 highway hauling tractor-trailer combinations used for National Haul? (e.g., 65 miles per hour highway)? _____ (open end)

Q5a. What is your typical highway cruising speed of your Class 8 highway hauling tractor-trailer combinations used for Regional Haul? (e.g., 65 miles per hour highway)? _____ (open end)

Back | Forward | Stop | Help

Q6. What is the annual number of miles that your Class 8 tractor-trailers average (e.g., 100,000 miles annually)? _____(open end)

Back | Forward | Stop | Help

Q7. What percent of trips do your Class 8 highway hauling tractor-trailer combinations operate in each of the following weight ranges?

Select all that apply.

Weight Ranges:	Truck Load Delivery	Less Than Truck Load Delivery
Less than 60,000 lbs GVW	❑	❑
60,000 – 65,000 lbs GVW	❑	❑
65,001 – 70,000 lbs GVW	❑	❑
70,001 – 75,000 lbs GVW	❑	❑
75,001 – 80,000 lbs GVW	❑	❑

Back | Forward | Stop | Help

Q8. What is your average tractor-trailer gap (back of cab to front of trailer), in inches (e.g., 45")? _____" (open end)

Back | Forward | Stop | Help

SECTION II: TRACTOR

Q10. Which of the following best describes your adoption of aerodynamic/fuel saving options for daily operation of your Class 8 highway hauling tractors: currently using, planning to use, would you consider using, would not consider using, have used in the past & discontinued use, or don't know?

Again, we are asking only about tractor aerodynamic devices.

Please select one per row.

Tractor Aerodynamic/Fuel Saving Devices	Currently Using Aerodynamic devices in my daily operations	Planning To Use Aerodynamic devices in my daily operations	Would Consider Using Aerodynamic devices in my daily operations within The *Next* 12 Months	Would Not Consider Using Aerodynamic devices in my daily operations	Have Used in the past and have decided to dis-continue use	Don't Know
a. Roof Air Fairings	❍	❍	❍	❍	❍	❍
b. Cab Side Extenders	❍	❍	❍	❍	❍	❍
c. Fuel Tank/Chassis Skirts	❍	❍	❍	❍	❍	❍
d. Wide-Base Single Tires	❍	❍	❍	❍	❍	❍
e. Electronic Speed Limiter	❍	❍	❍	❍	❍	❍
f. Aerodynamic Mirrors	❍	❍	❍	❍	❍	❍
g. Other (please specify___)	❍	❍	❍	❍	❍	❍

If levels a-g, column A selected in Q10, continue to Q11. If levels a-g selected, Col B-F in Q10, SKIP to Q12

Back | Forward | Stop | Help

Q11. You indicated that you have currently implemented <<insert devices selected in rows a-g, column a, (if level g, insert text entered here) Q10>> in your daily operations.

Q11a. What benefits have you realized from using these devices? (Please specify and be as specific as possible)_____ (open end)

Q11b. What challenges or difficulties have you encountered, if any? (Please specify and be as specific as possible) _____ (open end)

Back | Forward | Stop | Help

Section III: TRAILER

Q12. Which of the following best describes your adoption of aerodynamic/fuel saving options for daily operation of your Class 8 highway hauling trailers: currently using, planning to use, would consider using, would not consider using, have used in the past & discontinued use, or don't know?

Now, we are asking only about trailer aerodynamic devices.

Please select one per row.

Trailer Aerodynamic/Fuel Saving Devices	Currently Using Aerodynamic devices in my daily operations	Planning To Use Aerodynamic devices in my daily operations	Would Consider Using Aerodynamic devices in my daily operations within The *Next* 12 Months	Would Not Consider Using Aerodynamic devices in my daily operations	Have Used in the past and have decided not to use in the future	Don't Know
a. Wide-Base Single Tires	❍	❍	❍	❍	❍	❍
b. Wheel Shields	❍	❍	❍	❍	❍	❍
c. Trailer Skirts	❍	❍	❍	❍	❍	❍
d. Trailer Nose/Gap Devices	❍	❍	❍	❍	❍	❍
e. Trailer Rear Devices/Base Flaps	❍	❍	❍	❍	❍	❍
f. Aerodynamic Mud Flaps	❍	❍	❍	❍	❍	❍
g. Vortex Generators	❍	❍	❍	❍	❍	❍
h. Other (please specify____)	❍	❍	❍	❍	❍	❍

Back | Forward | Stop | Help

If levels a-h, column A selected in Q12, continue to Q13. If levels a-h selected, Col B/C selected in Q12, SKIP to Q14; If levels a-h, Col D selected in Q12, SKIP to Q16; If levels a-h selected in Q12, Col E, SKIP to Q15; If selected levels a-h, col F, SKIP to Q30

Q13. Previously, you indicated that you have currently implemented <<insert devices selected in rows a-h, column a, Q12>> in your daily operations.

Q13a. What benefits have you realized from using these devices?(Please specify and be as specific as possible) (open end)

Q13b. What challenges or difficulties have you encountered, if any? (Please specify and be as specific as possible) (open end)

Back	Forward	Stop	Help

If selected levels a-h, Col A/B show Q14.

Section IV: Device Requirements

Q14. What are main reasons that have prompted your use/consideration of TRACTOR aerodynamic devices?

Please select all that apply.

[Randomize levels a-f]

INDUCEMENTS:	
Fuel Economy	❑
Protection	❑
Increased road speed	❑
Appearance	❑
Increased durability	❑
Reduced Emissions	❑
Business focus to be more environmentally conscious	❑
Fuel Cost	❑
DOT Regulations	❑
Customer Focus on Environment	❑
Other (Please specify) _____	❑

Back	Forward	Stop	Help

Q15. Please elaborate on why you have decided TO DISCONTINUE using <<insert levels selected in Q10, rows a-g, col E OR Q12, rows a-h, Columns E>>.

Devices no longer using:	Reason
Wide-Base Single Tires	Please specify:
Wheel Shields	Please specify:
Trailer Skirts	Please specify:
Trailer Nose Devices	Please specify:
Trailer Rear/Base Flaps	Please specify:
Aerodynamic Mud Flaps	Please specify:
Vortex Stabilizers	
Roof Air Fairings	
Cab Side Extenders	
Fuel Tank/Chassis Skirts	

Electronic Speed Limiter	Please specify:
Aerodynamic Mirrors	Please specify:
Other (insert text from Q10, level g OR Q12, level h)	Please specify:
	Please specify:
	Please specify:

Back | Forward | Stop | Help

If selected levels a-g, Cols D or E in Q10 or levels a-h, Col D or E in Q12, show Q16. Else, SKIP to Q17.

Q16. What are main barriers that have prohibited you from using tractor aerodynamic devices?

Please select all that apply; if another reason is not listed here, please be sure to enter it in the space provided.

[Randomize levels a-m]

Barriers:	
Purchase price	❑
Expected return on investment (ROI)	❑
Installation costs	❑
Weight/payload Impact	❑
Expected performance/Fuel economy benefit	❑
Installation concerns	❑
Durability concerns	❑
Increased maintenance costs	❑
Driver operation of devices	❑
DOT compliance concerns	❑
Safety concerns	❑
Increased down-time as a result of devices malfunctioning/breaking	❑
Not enough available service locations to fix device issues	❑
Alck of sufficient support available for devices	❑
Other (Please specify) _____	❑

Q16a. Please feel free to elaborate on why the options you selected are barriers. _____ (open end)

Back | Forward | Stop | Help

If levels a-g, Q10, Col D-F OR levels a-g, Q12, Col D-F selected, SKIP to Q30; ELSE, CONTINUE to Q17

Q16b. How do/would you measure payback of your return on investment for aerodynamic devices? _____ (open end)

Q17. How do you measure the payback of your aerodynamic devices?

Please select all that apply.

Payback Measures	
Purchase Price	❑
Installation Costs	❑
Maintenance Costs	❑
Mileage	❑
Gas Price	❑
Other (Please specify) _____	❑

Back | Forward | Stop | Help

Q17a. What is your required payback period for aerodynamic add-on fuel efficiency devices for your trailers?

Please select one.

Required Payback Period (in years):	
1 year	❍
2 years	❍
3 years	❍
4 years	❍
5 years	❍
6 years	❍
7 years	❍
8 years	❍
9 years	❍
10 years	❍
More than 10 years	❍

Back | Forward | Stop | Help

Q18. Which of the following do you prefer?

Please select one. If your preference is not shown, please specify in the space provided below.

Drivers operate the devices (i.e. driver has to open/close boat tail before opening trailer doors)	❍
Devices to be fully automatic (no driver involvement)	❍
Other (Please specify) _____	❍

[Display dynamically to Q 18]

Q18a. If level a selected, "Why do you prefer drivers operate the devices? (Please specify and be as specific as possible) _____ (open end)

Q18b. If level b selected, "Why do you prefer the devices to be automated? (Please specify and be as specific as possible) _____ (open end)

Back	Forward	Stop	Help

Q19. Which of the following measures are the most meaningful to you for measuring the performance of trailer aerodynamic devices?

Please select all that apply.

Most meaningful measures:	
Miles per Gallon	❑
Ton-Miles per Gallon	❑
Freight Volume per Gallon	❑
Fleet Average Efficiency (Any of the above averaged across your fleet)	❑
Other (please specify) _____	❑
None of the Above [cannot select with other levels]	❍

Back	Forward	Stop	Help

Q19a. What is the maximum weight you would be willing to add to your trailers for all aerodynamic devices combined?

Maximum amount of weight would add to trailer for all aerodynamic devices combined:	[Drop-down menus containing]
	Less than 50 lbs.
	50 lbs.
	51-99 lbs.
	100-149 lbs.
	150-199 lbs.
	200-249 lbs.
	250-299 lbs.
	300-349 lbs.
	350-399 lbs.
	400-449 lbs.
	450-500 lbs.
	More than 500 lbs.

Back	Forward	Stop	Help

Q20. Please enter the maximum amount of US dollars (in hundreds) you would spend on tractor-trailer aerodynamic devices (per tractor-trailer combination):

Q20b. Maximum Amount Would Spend: $_____

Back	Forward	Stop	Help

Q21. How much time would you expect would be required to maintain tractor-trailer aerodynamic devices?

Please select one.

1 – 2 hours per trailer annually	❍
3 – 5 hours per trailer annually	❍
6 – 10 hours per trailer annually	❍
More than 10 hours per trailer annually	❍
Other (Please specify) _____	❍

Back	Forward	Stop	Help

Q22. How would you most prefer to purchase/implement tractor-trailer aerodynamic devices?

Please select one.

As factory/manufacturer installed components	❍
As add-on aftermarket devices installed by a third-party vendor	❍
As aftermarket devices installed by your internal fleet maintenance personnel	❍
As dealer installed components	❍
Other (Please specify) _____	❍
None of the Above [cannot be selected with other levels]	❍

Back	Forward	Stop	Help

If levels a-h, column A selected in Q10 or Q12, show Q22a; Else, SKIP to Q23.

Q22a. What is the average increase (in miles per gallon) of fuel consumption you've seen as a result of using aerodynamic devices? (Your best estimate is sufficient (e.g., 2.0 MPG savings)) _____ (numeric open end)

Q23. Taking into account of all the tractor-trailer aerodynamic devices that you have implemented, how would you rate your fuel economy results on a scale of 1 to 5, where "1" signifies "Worse than Expected", "3" signifies "About the Same as Expected", and "5" signifies "Better than Expected"?

Please select one.

	Worse than Expected		About the Same as Expected		Better than Expected
	1	2	3	4	5
Fuel	❍	❍	❍	❍	❍

Economy Results					

Q23a. If levels 1 or 2 selected, please show, "Please explain why you rated your aerodynamic fuel economy results as worse than expected." Please be as specific as possible. _____ (open end)

Back	Forward	Stop	Help

Q24. Taking into account of all the tractor-trailer aerodynamic devices that you have implemented, how would you rate your return on Investment (ROI) using a scale of 1 to 5, where "1" signifies "Worse than Expected", "3" signifies "About the Same as Expected", and "5" signifies "Better than Expected"?

Please select one.

	Worse than Expected		About the Same as Expected		Better than Expected
	1	2	3	4	5
ROI Results	❍	❍	❍	❍	❍

Q24a. If levels 1 or 2 selected, please show, "Please explain why you rated your aerodynamic ROI results as worse than expected." Please be as specific as possible. _____ (open end)

Back	Forward	Stop	Help

Q25. Again, taking into account of all the tractor-trailer aerodynamic devices that you have implemented, how would you rate the overall operational performance of these devices using a scale of 1 to 5, where "1" signifies "Worse than Expected", "3" signifies "About the Same as Expected", and "5" signifies "Better than Expected"?

Please select one.

	Worse than Expected		About the Same as Expected		Better than Expected
	1	2	3	4	5
Operational Performance	❍	❍	❍	❍	❍

Q25a. If levels 1 or 2 selected, please show, "Please explain why you rated your aerodynamic operational performance as worse than expected." Please be as specific as possible. _____ (open end)

Back	Forward	Stop	Help

Q26. How would you rate the overall maintenance of aerodynamic devices using a scale of 1 to 5, where "1" signifies "Worse than Expected", "3" signifies "About the Same as Expected", and "5" signifies "Better than Expected"?

Please select one.

	Worse than Expected		About the Same as Expected		Better than Expected
	1	2	3	4	5
Maintenance	❍	❍	❍	❍	❍

Q26a. If levels 1 or 2 selected, please show, "Please explain why you rated your aerodynamic operational performance as worse than expected." Please be as specific as possible. _____ (open end)

Back | Forward | Stop | Help

Q27. What are your preferred channels for receiving information about aerodynamic devices before implementing them into your daily routine?

Please select all that apply.

[Randomize levels a-j]

Information Sources:	
Tractor OEM/Manufacturer	❑
Tractor Dealer	❑
Trailer Dealer	❑
Internet	❑
Seminar	❑
Word of Mouth	❑
Device Manufacturer Information from Representatives, Websites, etc.	❑
Industry Publications (e.g., Heavy Duty Trucking)	❑
Technical Organization Publications (e.g., SAE, TMC)	❑
Independent Testing Publications (e.g., Energotest)	❑
Other (please specify) _____	❑
None of the Above [cannot select with other levels]	❍

Back | Forward | Stop | Help

If select level L (None of the Above) in Q27, SKIP to Q29

Back | Forward | Stop | Help

Q29. The California Air Resource Board (CARB) has mandated that fleets reduce their C02 emissions beginning in the next couple of years. If you operate in California, what are your CARB compliance plans?

Use SmartWay certified tractors	❍
Retrofit existing fleet/equipment	❍
Not applicable – My company does not operate in California	❍

SECTION IV: Firmographics

Q30. What is your age?

Select one

A	20 or younger	❍
B	21-30	❍
C	31-40	❍
D	41-50	❍
E	51-60	❍
F	61-70	❍
G	71 or older	❍
H	I prefer not to disclose	❍

Back | Forward | Stop | Help

Q31. Including yourself, how many people work for your company at your location?

Select one

A	1-4	❍
B	5-9	❍
C	10-24	❍
D	25-49	❍
E	50-99	❍
F	100-249	❍
G	250-499	❍
H	500-999	❍
I	1000-4999	❍
J	5000+	❍

Back | Forward | Stop | Help

Show Q32 if S2>1

Q32. Again, including yourself, how many employees work for your company at all locations combined?

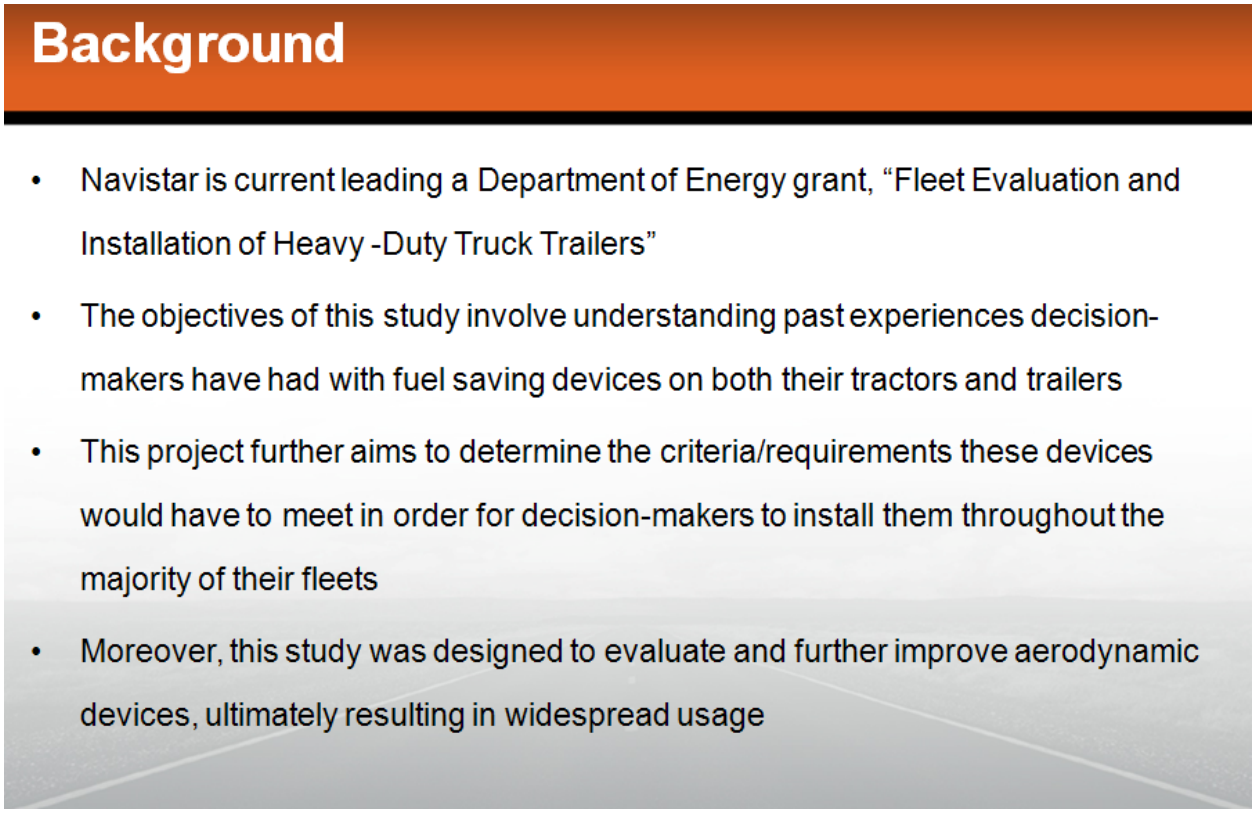
Select one

A	1-4	❍
B	5-9	❍
C	10-24	❍
D	25-49	❍
E	50-99	❍
F	100-249	❍
G	250-499	❍
H	500-999	❍
I	1000-4999	❍
J	5000+	❍

Back | Forward | Stop | Help

That concludes our survey, thank you for your participation!

The following images were taken from the high level results overview provided by National Analysts, the third party who administered the survey, and Navistar's competitive intelligence team.



Methodology

Participants	• Navistar Class 8 Tractor/Trailer Owner/Operators, Small & Large Fleets
Markets Covered	• US
Sample Sources	• Navistar-provided customer and prospect lists
Interviewing	• e-mail recruitment • 12-minute Web-based survey • 256 completed interviews
Time Period	• August-September 2010
Incentive	• $20 US

Executive Summary

- About half of all decision-makers have adopted cab side extenders and roof air fairings for their tractors
  - Most are planning to use/would consider using aerodynamic mirrors and wide-base single tires
  - Those currently utilizing tractor aerodynamic devices have most frequently noted increased fuel mileage, better wind control, and enhanced appearance as the most beneficial results of usage
    - Challenges involved with using aerodynamic devices mostly include the costs to repair, driver discontent and product durability
- More than one-third of respondents are planning to use /would consider aerodynamic mud flaps, trailer skirts, and trailer nose devices (most are currently using mud flaps)
  - Most of the individuals currently utilizing trailer aerodynamic devices report increased fuel economy, wind control, and decreased debris as the most salient benefits
  - Installation costs, costs/downtime associated with damages/repair, and durability of equipment were the most cited challenges encountered

Executive Summary

- Fuel economy and fuel cost are the most significant inducements to utilizing tractor-trailer aerodynamic devices
  - In fact, almost half of all decision-makers currently utilizing aerodynamic devices have noticed an average increase of 1 mpg of fuel economy since implementation
  - More than two-thirds of those using aerodynamic devices report fuel economy results are about what they expected
- About 50% of all decision-makers require payback on add-fuel efficiency devices for their trailers within 1-2 years
  - More than two-thirds of respondents measure the payback of their ROI for aerodynamic devices with mileage (purchase price and maintenance costs follow closely behind)
    - Decision-makers cite payback is usually recognized through increased fuel savings/mileage and ROI in conjunction with maintenance costs and installation price
    - Almost three-quarters of those using aerodynamic devices rate (ROI) also about the same as they expected

Executive Summary

- Approximately two-thirds of respondents report purchase price as the main barrier that has prohibited them from adopting (some/all) aerodynamic devices
  - More than half cite increased maintenance costs as a significant barrier
  - Product durability, current economic conditions, lack of available service locations and weight sensitivity are also frequently cited as substantial barriers to adoption
  - More than 75% of those using these devices report the operational performance is about what they expected
- In comparison to fuel economy, ROI, and operational performance, decision-makers rated maintenance of aerodynamic devices highest, with almost one in five rating it better than expected
  - However, some decision-makers have discontinued using certain aerodynamic devices as a result of increased downtime/costs to repair and poor device durability

Executive Summary

- More than two-thirds of respondents prefer that aerodynamic devices be fully automatic
  - Automatic devices eliminate driver error and decrease the possibility of accidents/injuries
    - However, about one-quarter do prefer drivers to operate aerodynamic devices, claiming this lends to a decreased chance of device malfunction and lower purchase/maintenance costs
- Almost two-thirds of all respondents prefer to have tractor-trailer aerodynamic devices installed by the manufacturer
  - In addition, more than half of all decision-makers would not be willing to spend more than $1,000 on aerodynamic devices per tractor-trailer combination (29% of those would not be willing to spend more than $500
  - About half of all respondents are only willing to add 149lbs. or less to their trailers for these devices
  - 36% of respondents would expect 1-2 hours per trailer, annually, be required for aerodynamic device maintenance
  - Most prefer to learn about the devices through industry publications and word of mouth