



Truck Duty Cycle and Performance Data Collection and Analysis Program

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Project ID #
VSS002

Overview

Timeline

- Project Start Date: March 2008
- Project End Date:
 - MTDC FY2012
 - LSDC FY2015
- MTDC (50%)/LSDC (10%)

Budget

- Total project funding
 - MTDC
 - DOE share: \$1.76M (\$1.12M received to date)
 - Partner share: \$1.40M (\$1.17M received to date)
 - LSDC
 - DOE share: \$4.8M (\$0.15M received to date)
 - Partner share: \$1.2M (\$0.00M received to date)
- Funding received in FY10
 - MTDC (\$0.52M) - LSDC (\$0.15M)
- Funding for FY11
 - MTDC (\$0.52M)(\$0.11 Received to date)
 - LSDC (\$0.05M) (\$0.00 Received to date)

Technical Targets & Barriers

- Barriers addressed
 - By 2015 contribute to demonstrating a 50% improvement in freight hauling efficiency
 - Collaboration with other agencies on transportation vehicles in areas outside of DOE's purview
 - Increase heavy truck baseline performance data via fleet testing and analyze performance data

Partners

- DOT/FMCSA & DOT/FHWA/NHTSA
- Technology & Maintenance Council (TMC) of the ATA
- H. T. Hackney (Class-7 Combination Trucks)
- Knoxville Area Transit (Class-7 Transit Busses)
- Knoxville Utilities Board (Class-7 Utility Truck – for PTO data)
- Fountain City Wrecker Service
- Project lead: ORNL

Relevance

- **Objectives:**

- (1) Collect and analyze real-world heavy- and medium-duty truck duty cycle data and associated situational data to support:
 - A) Autonomie development/validation;
 - B) DOE research investment decisions;
 - C) heavy- and medium-truck fuel efficiency research requiring real-world performance data; and
 - D) conduct and support research at the intersection of heavy- and medium-truck energy efficiency, mobility and safety.
- (2) Develop tools for the assessment of fuel efficiency benefits of new technologies utilizing real-world performance data and disseminating results to the public.

- **Impacts:**

- Collected nearly 600 Gbytes of HTDC & MTDC data for analyses.
- Analyzed fuel savings when using Single Wide-based tires (showed 6-10% savings) (paper selected as winner of TRB's Pyke Johnson award).
- Facilitated effective cross-federal-agency joint project.
- Initiated LSDC feasibility study.

Milestones (FY10 & FY11)

- **MTDC**

- Complete MTDC Year-2 Test Plan (2/2010)
- Complete of MTDC Year-1 data collection (2/2010)
- Initiate Year-1 MTDC data analyses (3/2010)
- Complete of de-instrumentation of MTDC Year-1 test vehicles (4/2010)
- Year-2 MTDC partnerships in place (7-9/2010)
- Instrumentation of Year-2 MTDC test vehicles (7-9/2010)
- Year-2 MTDC test vehicles launched in field test (9-12/2010)
- Complete Year-1 MTDC data analyses and issuance of the Year-1 Report (1/2011)
- Adapt the DCGen Tool for Year-1 MTDC data (3/2011)
- Completion of MTDC Year-2 data collection (11/2011)

- **LSDC**

- Complete LSDC program scoping (1/2010)
- Complete LSDC final SOW (5/2010)
- Complete technology survey and data acquisition system options matrix (9/2010)
- Prepare a request for quotation to be sent to telematics suppliers (1/2011 – *delayed*)
- Complete final report for LSDC feasibility study (3/2011 – *delayed*)
- Go/no-go decision on LSDC Proof of Concept testing (3/2011)

Approach/Strategy

Collect real-world heavy- and medium truck duty cycle and associated situational data from operating fleets, develop tools for analyses and data/analysis dissemination, conduct analyses, and make data and information available to DOE and the research community.

1. Identify vocations of interest (class 8 & class 7)
2. Identify relevant performance measure (MTDC = 60 channels; LSDC = 5 channels)
3. Develop hardened data acquisition systems (6 DASs)
4. Find fleet partners (gratis participants)(value is in \$Ms)
5. Seek cross-agency sponsorship (FMCSA/FHWA/NHTSA)
6. Instrument test fleet (MTDC/6 per year; LSDC/1,000s per year)
7. Conduct field operational test (12 months for seasonal data)
8. Collect data (MTDC; expected 900Gbytes)
9. Develop tools (DCGenT; web-based data access (controlled); technology benefits analysis)
10. Conduct analyses (energy efficiency, driver performance, within-vocation duty cycle variance) to support DOE's needs in modeling, research investments, etc.
11. Conduct specialized studies
12. Set-up publically accessible (multi-agency = ?) National Truck Performance Data System. Integrate (as possible) other truck data/information sources.

MTDC Technical

Accomplishments and Progress

- The six participating vehicles logged about 95,000 miles (45,400 for the combination trucks and 49,400 for the transit buses) and consumed over 17,000 gallons of fuel (6,000 for the combination trucks and 11,300 for the transit buses)
- For the combination trucks, the largest proportion of idling time (61%) and fuel consumed (50%) while idling correspond to idling intervals that lasted between 0 and 5 minutes (i.e., traffic congestion and delay at traffic signals). (Note: for HTDC was overnight idling)
- The transit buses also spent most of their idling time and fuel consumed while idling (31%) in congestion and bus dwelling stops (0 to 5 minute idling interval). However, as opposed to the combination trucks, the transit buses spent 26% of their idling time in intervals that are longer than 4 hours, also consuming about 26% of the fuel spent while idling.

MTDC Technical

Accomplishments and Progress

- Fuel efficiency (FE) and payload level are closely linked. Using sensor information, ORNL developed a vehicle weight model that allowed estimation of vehicle weight for all the trips in the database.
- Overall, and as expected, the FE decreases as the payload increases for the combination trucks. However, because the payload categories are very narrow and low (those combination trucks never made any trips that were above 42,000 lbs, far below the legal weight limit for Class-7 trucks), the variation of the FE is not significant.
- In the case of the Transit Buses, the relationship between FE and vehicle weight is not as it would be predicted (i.e., decreasing FE with increasing payload). This is due, mainly, to the fact that when the vehicle is empty (lowest payload) it spends a considerable amount of time idling.

MTDC Technical

Accomplishments and Progress

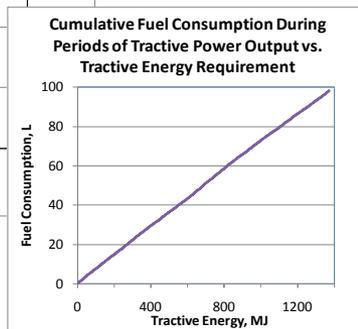
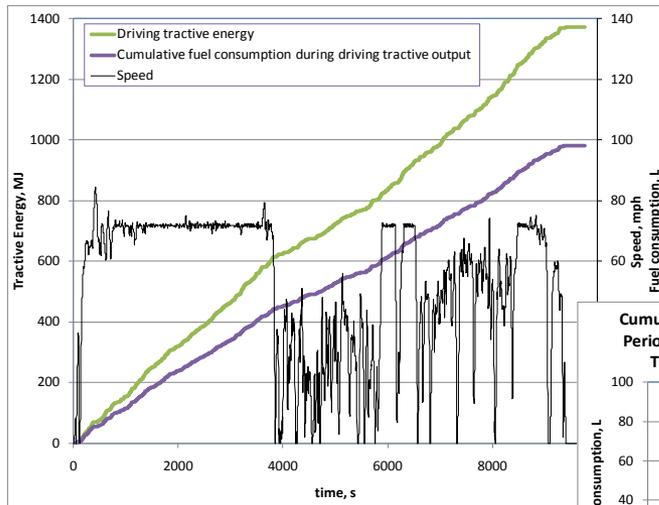
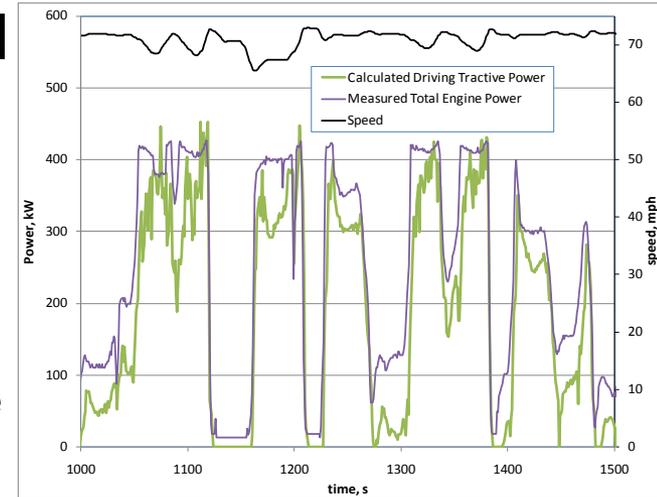
- ORNL collected and analyzed safety data (brake and tire sensors) and found that in some cases these sensors show a high percentage of “false alarms.” While these sensors can provide valuable advisory information, ORNL recommended to FMCSA that at this stage, such safety sensors should not be used to flag vehicles with brake problems.
- ORNL is currently conducting a study for FHWA using HTDC data to determine the effect of speed limits and payload on the FE of heavy trucks.

Large Scale Duty Cycle (LSDC) Project— Accomplishments and Progress

- Completed Data collection technology evaluations
 - Telematics/external data collection provider found to be only viable approach based on data needs, cost
 - GPS cell phone not accurate enough, very rapid battery depletion with frequent measurements
- Data analysis using HTDC measured data completed
 - Shows excellent results for ability to estimate fuel savings using calculated tractive energy
 - Channels planned for data collection demonstrated to be sufficient for all analysis
 - Interesting results for fuel savings potential of hybrid for the class 8 fleet analyzed: regenerative braking energy potential frequently seen to exceed 6% for duty cycles evaluated, even for exclusive highway operation
- Cost Assessment: RFQ development complete

LSDC Project—Accomplishments (ctd.)

- Data analysis has clearly demonstrated the merits of the approach
 - The calculated driving tractive force, based on relatively simple assumptions, predicts total engine power quite well
 - Fuel consumption during periods of positive tractive force correlates very well with the tractive force itself, even under very different driving conditions



- Mass estimation based on measured engine power and calculated tractive energy provides consistency/accuracy of about ± 1000 kg for class 8 combination vehicles. This is sufficiently accurate for the purposes of the tractive energy analysis for these trucks.

Collaboration and Coordination with Other Institutions

- **Partners**

- **USDOT (Interagency Agreements)** – sponsors work that interplays well with HTDC/MTDC/LSDC efforts
 - Federal Motor Carrier Safety Administration
 - Federal Highway Administration
 - National Highway Traffic Safety Administration
- **Industry (Memorandums of Agreement)** – provide resources for conducting HTDC/MTDC/LSDC efforts for early access to data, analyses, technology experience
 - H. T. Hackney
 - Knoxville Area Transit (KAT)
 - Knoxville Utilities Board
 - Fountain City Wrecker Service
 - Technology & Maintenance Council (TMC) of the American Trucking Associations (ATA)
- **Other National Laboratories** – support data needs; research collaboration discussions
 - ANL
 - NREL

Proposed Future Work

- FY2011

- Continue data collection on utility and towing & recovery vehicles
- Complete the analysis of MTDC Year-1 data
- Complete energy efficiency and weight/grade analyses for HTDC data (FHWA)
- Conduct data analyses – Driver Behavior and Fuel Efficiency for Heavy- and Medium-Duty Trucks
- Complete LSDC feasibility study
 - Issue RFQ to telematics providers
 - Identify willing telematics and fleet partners
- Perform Proof of Concept Testing for LSDC and develop/evaluate data automation tools

- FY2012

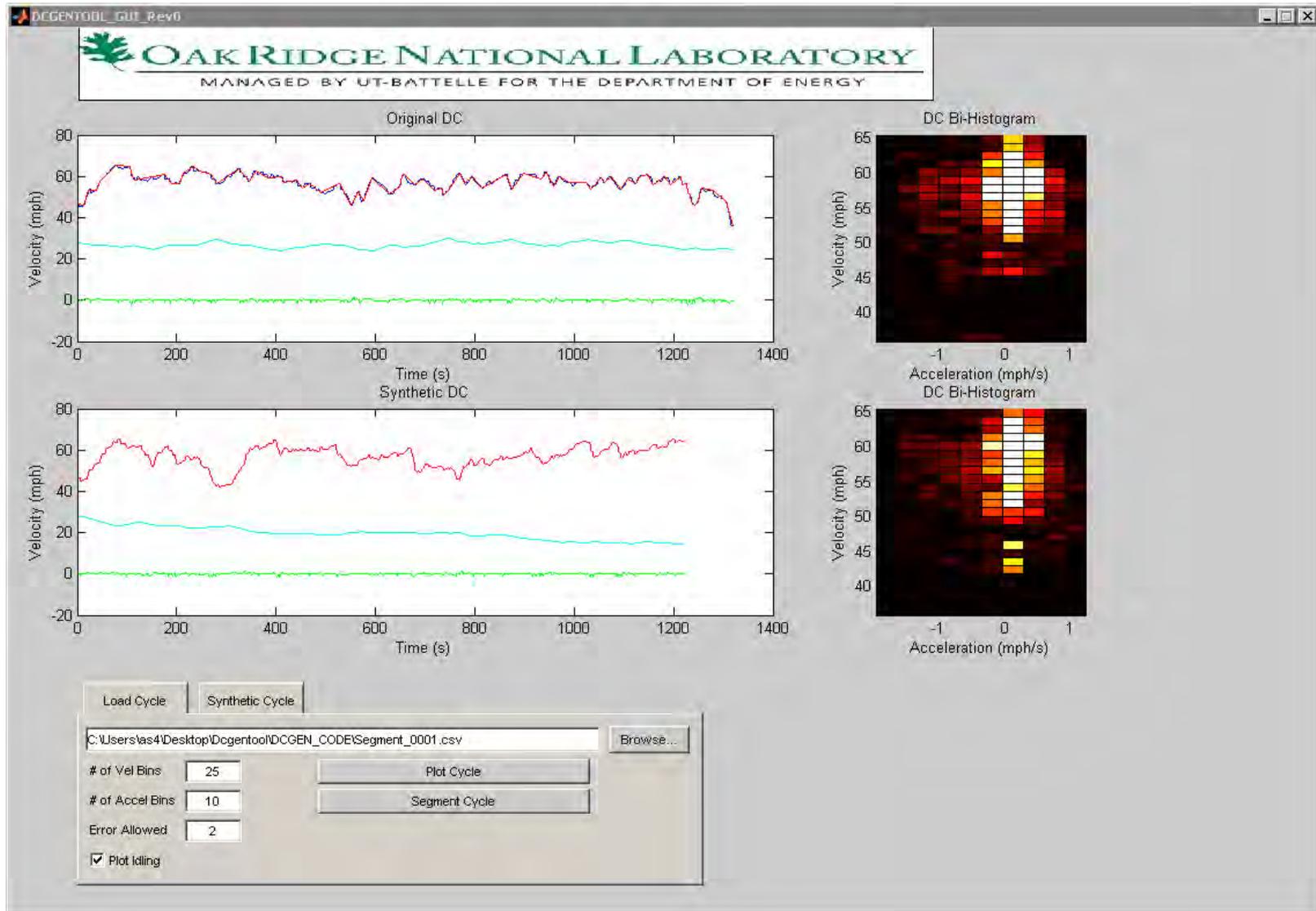
- Complete MTDC Year-2 efforts
- Analyze MTDC Year-2 data
- Complete development of technology benefits assessment tool
- Add the statistical evaluation of elevation in the synthetic duty cycles generated by DCGenT
- Initiate development of web-based access to HTDC/MTDC data, data analysis tools and research analysis results.
- Complete LSDC Pilot Test
- Continue to conduct regular energy efficiency analyses
 - Defined by DOE
 - NHTSA TTEA study – benefits of fuel efficiency technologies.
- Initiate stand-up of a National Truck Performance Data System (multi-agency = ?)

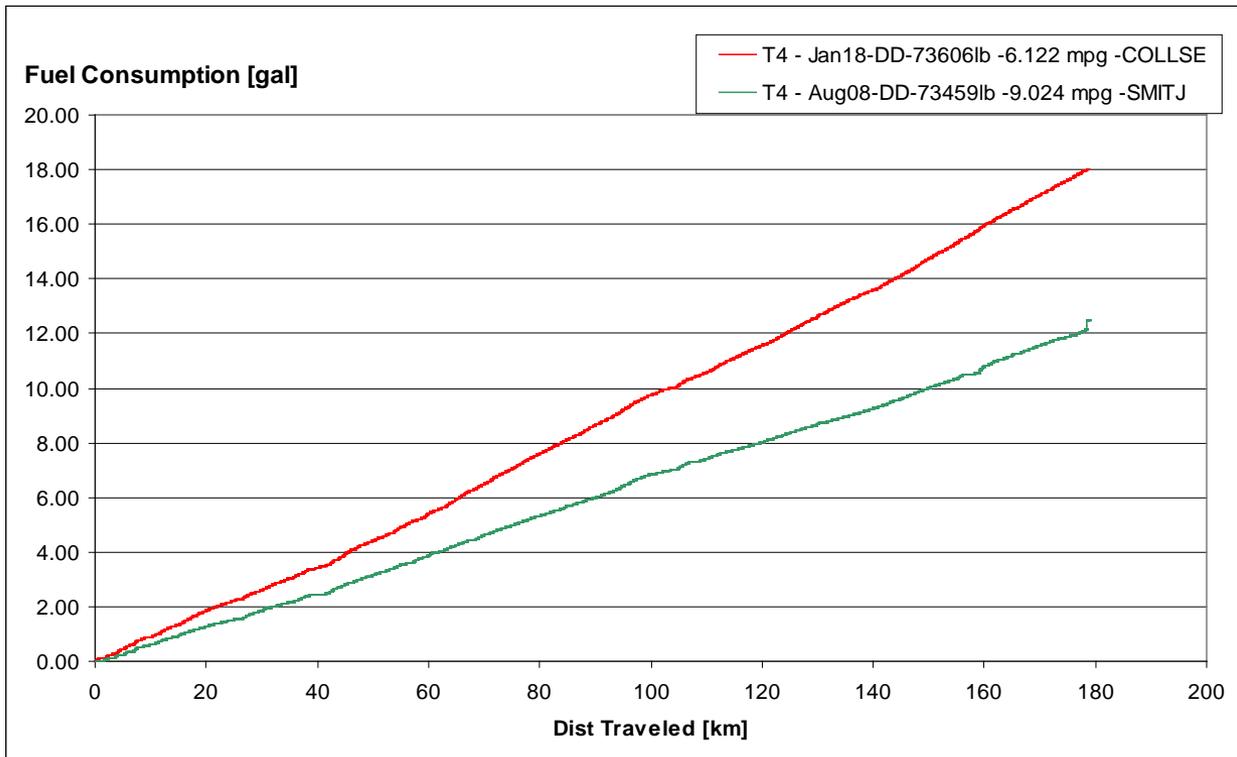
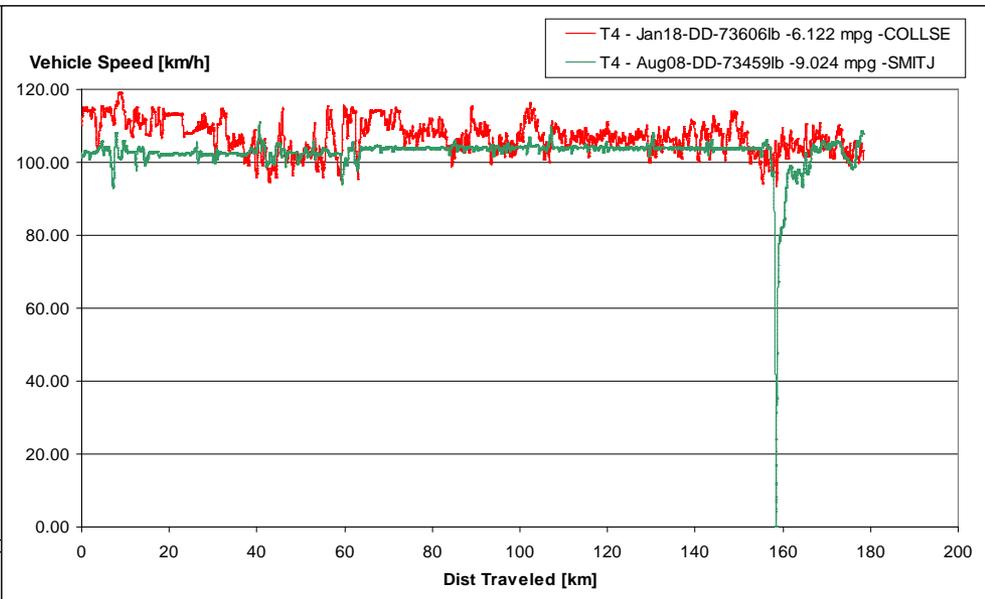
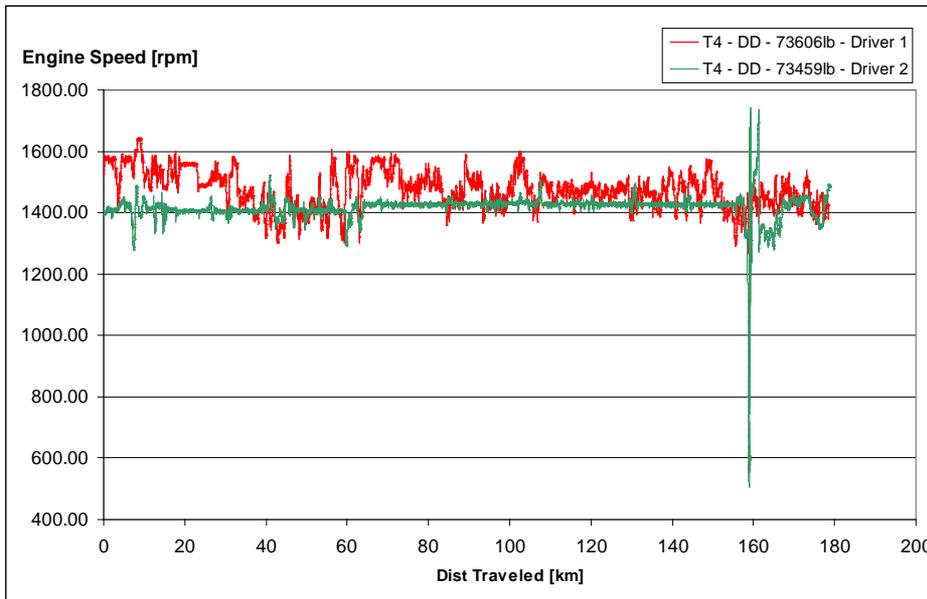
Summary

- The HTDC/MTDC data represent a rich plethora of heavy- and medium-truck performance data from real-world operating fleets.
- Data analyses of the HTDC/MTDC data sets are increasing, with more analyses to come.
- The LSDC effort will focus on the cost-effective collection of data from a large population of vehicles for a minimal and critical set of performance measures. Emphasis will be on developing characteristic duty cycles for different vocations and analyzing 1st order fuel savings potential of efficiency technologies for these vocations.
- The performance data efforts are well networked with industry and other federal agencies.
- There is a need for a national truck performance data system – possibly multi-agency. Such a system would:
 - Be a repository of heavy- and medium truck data (multiple sources)
 - Provide on-line tools for generating synthetic duty-cycles based on real-world data,
 - Provide tools for assisting in the determination of fuel efficiency benefits of new technologies based on duty cycles, and
 - Be a repository for heavy- and medium-truck performance analyses.

Technical Back-Up Slides

Matlab[®]-Based DCGenT Interface





Driver Behavior and Fuel Efficiency:

- Same Truck
- Same Route
- Same Load
- ~ Same Speed
- Different Season
- Different Driver

MTDC Vehicle Signals

Databus Signals

1 Total Vehicle Distance	15 Boost Pressure	29 Cruise Control Resume Switch
2 Road Speed Limit Status (On/Off)	16 Fuel Rate	30 Cruise Control Set Switch
3 Wheel-Based Vehicle Speed/Road Speed	17 Instantaneous Fuel Economy	31 Cruise Control Set Speed
4 Front Axle Speed	18 Actual Engine - Percent Torque	32 Power Takeoff Governor/Status Flags
5 Engine Speed	19 Percent Accelerator Pedal Position	33 Power Takeoff Set Speed
6 Current Gear	20 Percent Load at Current Speed	34 Total Power Takeoff Hours
7 Selected Gear	21 Driver's Demand Engine - Percent Torque	35 Actual Retarder - Percent Torque
8 Actual Gear Ratio	22 Nominal Friction Percent Torque	36 Retarder Torque Mode
9 Output Shaft Speed	23 Brake Switch	37 Engine Retarder Selection
10 Transmission Selected Range	24 Clutch Switch	38 Intended Retarder Percent Torque
11 Transmission Current Range	25 Cruise Control Accelerate Switch	39 Battery Voltage
12 Engine Oil Temperature	26 Cruise Control Active	40 Fan Drive State
13 Intake Manifold Temperature	27 Cruise Control Coast Switch	41 AC High Pressure Fans Switch
14 Engine Coolant Temperature	28 Cruise Control Enable Switch	42 Barometric Pressure

Signals from Other Sensors

43 Latitude	48 Longitudinal Acceleration	53 Distance
44 Longitude	49 Lateral Acceleration	54 Steer Axle Weight
45 Altitude	50 Heading	55 Drive Axle Weight
46 Vertical Velocity	51 Satellites	56 Wiper Switch Position (On/Off)
47 Velocity over Ground	52 Time UTC	

Safety Signals for FMCSA

57 Brake Actuator Status - Left Front	65 Tire Pressure - Left Rear Inside	73 Tire Temperature - Right Rear Outside
58 Brake Actuator Status - Right Front	66 Tire Pressure - Right Rear Inside	74 Tire Pressure Threshold Detection - Left Front
59 Brake Actuator Status - Left Rear	67 Tire Pressure - Right Rear Outside	75 Tire Pressure Threshold Detection - Right Front
60 Brake Actuator Status - Right Rear	68 Tire Temperature - Left Front	76 Tire Pressure Threshold Detection - Left Rear Outside
61 Brake Application Pressure	69 Tire Temperature - Right Front	77 Tire Pressure Threshold Detection - Left Rear Inside
62 Tire Pressure - Left Front	70 Tire Temperature - Left Rear Outside	78 Tire Pressure Threshold Detection - Right Rear Inside
63 Tire Pressure - Right Front	71 Tire Temperature - Left Rear Inside	Tire Pressure Threshold Detection - Right Rear
64 Tire Pressure - Left Rear Outside	72 Tire Temperature - Right Rear Inside	79 Outside