U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

www.nhtsa.gov

DOT HS 810 035 **September 2008**

The Drowsy Driver Warning System Field Operational Test: Data Collection Methods

Final Report

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank) DOT HS 811 035	2. REPORT DATE September 2008	3. REPORT TYPE AND DATES COVERED Final Report October 2002-September 2005
4. TITLE AND SUBTITLE The Drowsy Driver Warning System Field Operational Test: Data Collection Methods		5. FUNDING NUMBERS DTNH22-00-C-07007
6. AUTHOR(S) Richard J. Hanowski, Myra Blanco, Akiko Nakata, Jeffrey S. Hickman, William A. Schaudt, Maria C. Fumero, Rebecca L. Olson, Julie Jermeland, Michael Greening, G. Thomas Holbrook, Ronald R. Knipling, and Phillip Madison.		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Center for Truck and Bus Safety Virginia Tech Transportation Institute 3500 Transportation Research Plaza (0536) Blacksburg, Virginia 24061		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Department of Transportation National Highway Traffic Safety Administration 1200 New Jersey Avenue SE. Washington, DC 20590		10. SPONSORING/MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES This project was managed by Dr. Paul Rau, National Highway Traffic Safety Administration.		
12a. DISTRIBUTION/AVAILABILITY STATEMENT This report is free of charge from the NHTSA Web site at www.nhtsa.dot.gov		12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

A Drowsy Driver Warning System (DDWS) detects physiological and/or performance indications of driver drowsiness and provides feedback to drivers regarding their state. The primary function of a DDWS is to provide information that will alert drivers to their drowsy state and motivate them to seek rest or take other corrective steps to increase alertness. The system tested in this study was the Driver Fatigue Monitor (DFM) developed by Attention Technologies, Inc., which estimates PERCLOS (percent eye closure). The primary goal of this field operational test (FOT) was to determine the safety benefits and operational capabilities, limitations, and characteristics of the DFM. The FOT was conducted in a naturalistic driving environment and data were collected from actual truck drivers driving commercial trucks. During the course of the study, 46 trucks were instrumented with a Data Acquisition System (DAS). Over 100 data variables such as the PERCLOS output from the DFM and driving performance data (e.g., lane position, speed, and longitudinal acceleration) were collected. Other collected measures included video, actigraphy, and questionnaires. The FOT had 103 drivers participate. Drivers were randomly assigned to either control (24 drivers) or experimental groups (79 drivers). The data collected include the following: approximately 46,000 driving-data hours; 397 load history files from 103 drivers; approximately 195,000 hours of activity/sleep data; questionnaires from all drivers; fleet management surveys from each company; and focus group results collected from 14 drivers during two post-study focus group sessions. The focus of this report is the description of the data collection procedures.

14. SUBJECT TERMS actigraph, commercial vehicle, driver behavior, driver fatigue monitor, drowsy driver, human factors, naturalistic, sleep, truck, warning system.			15. NUMBER OF PAGES 295
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT

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ACKNOWLEDGEMENTS

This research was funded by the National Highway Traffic Safety Administration under Contract # DTNH22-00-C-07007 (Task Order #14). Dr. Paul Rau was the Task Order Manager and provided much appreciated advice and support throughout the project. The authors thank Dr. Rau for his insight, careful reviews, and prompt attention in administrative matters.

Support was also provided by the Federal Motor Carrier Safety Administration (FMCSA); Tim Johnson (now with NHTSA) oversaw the project for FMCSA. The Federal Highway Administration (FHWA) Intelligent Transportation System (ITS) Joint Program Office (JPO) provided funding for this study. Virginia Tech also provided funding to support this effort. Dr. Tom Dingus, director of the Virginia Tech Transportation Institute (VTTI), facilitated this process.

Dr. Bruce Wilson, Dr. Stephan Popkin, and Dr. Heidi Howarth at the Volpe Center, Independent Evaluator for this FOT, were instrumental in the success of this effort and provided support to VTTI throughout the contract. Dr. Richard Grace of Attention Technology, Inc. (ATI), provided the systems used in the testing and also led the post-study focus groups.

This very large, complex study could not have been conducted without the dedication and determination of the staff at VTTI. The authors wish to especially thank the VTTI hardware staff (led by Andy Petersen and Andy Alden) that built, installed, and serviced the instrumentation used in the data-gathering vehicles. Brian Leeson, Craig Bucher, and John Howard played key roles in the software development for the instrumented vehicles and the data reduction/analysis software. A crew of data-download staff were instrumental in meeting drivers and servicing vehicles, which often required working evenings, nights, weekends, and holidays. Similarly, a crew of data reduction staff helped ensure that the data requirements were being met and the time-intensive data reduction and analysis was conducted.

This study could not have been conducted without the support of the safety-conscious trucking companies that participated: J. B. Hunt Transport Services, Inc. (Greer Woodruff), Pitt Ohio Express (Jeff Mercadante), and Howell’s Motor Freight, Inc. (Tim Shephard). The authors thank these gentlemen and their support staff at the fleet locations. Finally, this study could not have been conducted without the participation of the 103 drivers. These three companies and their drivers are dedicated to the trucking profession and have safety as a core value.

EXECUTIVE SUMMARY

OVERVIEW

Each year, more than 5,000 people are killed and an additional 130,000 injured in crashes involving commercial motor vehicles (CMVs) (NHTSA, 2005b). Truck driver fatigue is believed to be a prominent factor in many of these crashes. As cited by Advocates for Highway and Auto Safety (2001), the Federal Motor Carrier Safety Administration estimates that 750 deaths and over 20,000 injuries each year can be attributed to fatigued truck drivers. The U.S. Department of Transportation recognizes the importance of this problem. Agencies within the U.S. DOT, including NHTSA and FMCSA, have programs in place to address the drowsy driver problem. For example, FMCSA has sponsored a number of research projects to investigate fatigue in CMV operations. In two such projects, Hanowski, Wierwille, Garness, and Dingus (2000) investigated fatigue in local/short-haul operations, and Dingus et al. (2002) examined fatigue in sleeper berth operations. FMCSA's sponsored research related to truck driver fatigue has led to the development and implementation of a change to the hours-of-service (HOS) regulations for CMV drivers.

In addition to changes to the HOS regulations, other means of addressing truck driver fatigue include technological innovation. NHTSA and FMCSA have sponsored research directed at the development of technologies aimed at reducing fatigue. The principal technology identified by the DOT as a countermeasure to driver drowsiness is a vehicle-based Drowsy Driver Warning System (DDWS). A DDWS detects physiological or performance indications of driver drowsiness and provides feedback to drivers regarding their state of drowsiness. The primary function of a DDWS is to provide information that will alert drivers to their drowsy state and motivate them to seek rest or take other corrective steps to increase alertness (e.g., drink a cup of coffee).

Attention Technology, Inc. (ATI), with support from the DOT, developed a DDWS called the Driver Fatigue Monitor (DFM). The DFM is mounted on the dash of a vehicle and monitors the percent closure (PERCLOS) of the driver's eyelids by using infrared technology. PERCLOS has been demonstrated to be a reliable measure of alertness (Wierwille, 1999a) and is considered the gold standard of drowsiness measures (Knipling, 1998). DOT has funded research to test and further develop the DFM (e.g., Wierwille et al., 2003), and the system was determined to be ready for testing in a field operational test (FOT).

The primary goal of this FOT was to determine the safety benefits and operational capabilities, limitations, and characteristics of a DDWS that monitors drivers' drowsiness. To meet this goal, three general requirements were identified. First, the evaluation must occur in a naturalistic driving environment and data must be collected from actual truck drivers driving commercial truck. Second, the participant population must be representative of the CMV truck driver population. Third, the drivers must use the DFM in normal operating conditions (i.e., actual delivery runs).

To determine how the DDWS works in a naturalistic environment, in-service commercial vehicles were instrumented with a state-of-the-art data acquisition system (DAS). More than 100 data variables such as the PERCLOS output from the DFM and driving performance data (e.g., lane position, speed, and longitudinal acceleration) were collected. Also, four video cameras were installed to continuously record the drivers' faces and the driving conditions around the vehicles. This approach resulted in an extremely large dataset, approximately 12 terabytes (TB). Data collection occurred whenever the trucks were turned on and in motion. This helped ensure that episodes of interest (e.g., drowsiness episodes) were captured and saved for analysis.

METHOD

Participants

The FOT had 103 drivers with Class-A Commercial Driver's Licenses (CDLs) as participants. These drivers were employed at one of three trucking companies: Pitt Ohio Express, J.B. Hunt Transport Services, Inc., or Howell's Motor Freight, Inc. Line-haul (out-and-back) and long-haul (out for approximately one week) operations were represented. Drivers were selected based upon the "operational envelope" of the DDWS being tested. That is, the particular device did not effectively operate during the daytime or with drivers who wore eyeglasses at night. Drivers were volunteers and were selected based on the following qualifications: (1) engaged in night driving, (2) did not wear glasses while driving, (3) had a low risk of dropping out or leaving the company, and (4) passed vision and hearing tests.

Experimental Design

Drivers were randomly assigned to either the control group or the experimental group. The control group had 24 drivers, whereas the remaining 79 drivers were in the experimental group. The final experimental design used in the study was A^9 for the control group and A^2B^9 for the experimental group; note that additional weeks for each driver were added to the A^2B^9 design to account for technical problems (e.g., truck out of service). In this design, *A* refers to the baseline condition and *B* refers to the treatment condition. The superscript numbers indicate the number of weeks (minimum) that a driver was in any particular condition. With this design, drivers in the control group have a baseline sequence lasting 9 weeks, whereas drivers in the experimental group have a pre-treatment baseline sequence for 2 weeks and a treatment sequence lasting 9 weeks. In the baseline sequences, the DDWS monitors the driver but does not provide any alerts (auditory or visual). In the treatment sequence, auditory and visual alerts are provided when the driver's eye closure exceeds the threshold.

Data Collection

A diverse set of measures were collected during the study, including driver input/performance measures (e.g., lane position, headway), video (four camera views), actigraphy (wrist-worn Actigraphs), and questionnaires (pre-study, post-study, and focus groups). The DAS instrumented in the vehicles included five major components: DDWS, sensors, vehicle network, incident box, and video cameras. Each component was active when the ignition system of the vehicle was initiated. A software program called Loki was developed to coordinate the data collection from the different DAS components and to integrate the data into a specific DAS output file linked to the video. During the course of the study, 46 trucks were instrumented.

The system tested in this study was the DFM developed by ATI. The device estimates PERCLOS, which has been shown to highly correlate with a subject's performance degradation under varying conditions of sleep deprivation (Wierwille, 1999a, 1999b; Wierwille et al., 2003). When the DFM estimates that PERCLOS reached a pre-defined threshold, visual and auditory alerts are presented to the driver. The DFM was mounted near the center of the dashboard, and the DFM camera (upper part of the DFM) was pointed toward the driver's face.

SUMMARY

Please note that the focus of this report is the description of the data collection procedures used for this study. As the data collector for this study, VTTI successfully conducted the FOT by creating a very large, comprehensive dataset in which to investigate the safety benefits and operational capabilities, limitations, and characteristics of a DDWS that monitors drivers' drowsiness. To meet this goal, the FOT met three general requirements:

1. The evaluation occurred in a naturalistic driving environment, and data were collected from actual drivers driving a CMV.

2. The participant population was representative of the CMV driver population.

3. The drivers used the DFM in normal operating conditions (i.e., actual delivery runs).

VTTI has provided the Volpe Center with a dataset that surpasses initial expectations (in terms of the number of drivers, trucks, operations, and completed drivers). It is noteworthy that in terms of the amount of data collected, this study is the largest ever conducted by the U.S. DOT. The following list provides an overview of the data collected.

- Approximately 46,000 driving-data hours covering 2.3 million vehicle miles traveled (VMT) (equivalent to almost 96 trips around the world or 770 coast-to-coast trips across the United States);
- More than 250,000 data, video, and ASCII text files (278,900 files total);
- Approximately 11.8 TB of data from video and dynamic sensor files;
- A total of 397 load history files from 103 drivers who participated in the FOT;
- A total of 598 actigraphy data files and 356 data recording sheets from over 8,000 days' worth of actigraphy data (or approximately 195,000 hours of activity/sleep data);
- Pre-participation, pre-study, post-study, and debriefing questionnaires from drivers;
- Fleet management surveys from each company; and
- Focus group results collected from 14 drivers during 2 post-study focus group sessions.

All of the itemized datasets have been delivered to the Volpe Center for detailed analyses. The Volpe Center and VTTI will analyze this very large dataset to develop:

1. A detailed understanding of the DDWS's safety benefits;
2. A characterization of the DDWS's performance and capability;
3. An assessment of driver acceptance of a DDWS;
4. An assessment of fleet management acceptance of a DDWS;
5. An assessment of the deployment prospects of a DDWS;

6. Recommendations for DDWS design changes directed at optimizing safety benefits and increasing driver and fleet management acceptance; and
7. An assessment of how a DDWS fits within a comprehensive fatigue-management program.

The results of this data collection effort provide the necessary data to carry out these analyses.

FUTURE RESEARCH IDEAS

Though the primary focus of this study was to assess the safety benefits of a DDWS, the resulting dataset provides a unique opportunity to re-analyze the data for additional purposes. A preliminary list of follow-on research ideas is presented below and highlights a benefit of the naturalistic data collection methodology: the ability to use the dataset in ways beyond the initial purpose of the FOT.

A sample of potential data mining topics includes:

- A meta-analysis comparing light-vehicle and CMV driving behavior using data from the 100-Car Naturalistic Driving Study (Dingus et al., 2006) and DDWS FOT data;
- The relationship between seat vibration, sleep quantity, and fatigue;
- Activity/rest patterns as a function of the type of operation;
- Activity/rest differences between work days and off days;
- Activity/rest patterns in periods (e.g., 24 hours prior, week prior) before critical incidents;
- Distractions due to cell phones, CB radios, and other secondary in-vehicle tasks;
- Models of CMV actions in work zones;
- Characteristics of safety-critical areas by mapping GIS data and GPS data collected in the FOT;
- Evaluations of crashes, near-crashes, and safety-critical incidents across all the DDWS FOT data;
- Improvements to the current observer rating of drowsiness (ORD) method (subjective drowsiness assessment) and an exploration of new methods;
- Criteria for characterizing high-risk drivers versus low-risk drivers and use of these criteria to improve driver training and selection;
- Patterns of seat belt use in CMV drivers;
- Models of CMV lane-change and back-up behavior;
- Driver parking habits relating to space available for parking on the roadways and rest stops;
- Crash countermeasure modeling using FOT data as system/algorithm input; and
- Driver behavior in deer strikes.

CHAPTER 1. INTRODUCTION

PROJECT OVERVIEW

Each year, more than 5,000 people are killed and an additional 130,000 are injured in crashes involving commercial motor vehicles (NHTSA, 2005b). In 2004, the number of people killed in crashes involving CMVs was 5,190, an increase of 3.1 percent from the previous year (NHTSA, 2005a). CMV driver fatigue is believed to be a prominent factor in many of these crashes. CMV drivers may drive up to 11 hours continuously before taking a break, often drive at night, and sometimes have irregular and unpredictable work schedules. Moreover, much of their mileage is compiled during long trips on interstates and other divided highways. Because of these factors and greater mileage exposure, CMV drivers have a greater risk of being involved in a fatigue-related crash than non-commercial drivers. As cited by Advocates for Highway and Auto Safety (2001), FMCSA estimates that 750 deaths and over 20,000 injuries can be attributed to fatigued truck drivers each year. In addition, laboratory, simulator, and instrumented-vehicle studies have consistently shown that drowsiness contributes to driver inattention and decision errors while driving (Moller, 2005).

The Department of Transportation recognized the importance of CMV driver fatigue in crashes and the associated fatalities and injuries. Agencies within the DOT, including NHTSA and FMCSA, have programs in place to address the drowsy driver problem. For example, FMCSA has sponsored a number of research projects to investigate fatigue in CMV operations. In two such projects, participants drove instrumented trucks on their normal delivery runs: Hanowski, Wierwille, Garness, and Dingus (2000) investigated fatigue in local/short haul operations, and Dingus et al. (2002) examined fatigue in sleeper berth operations.

These studies and other research funded by FMCSA (Balkin et al., 2000; O'Neill, Krueger, Van Hemel, & McGowan, 1999) led to the development and implementation of a change in the hours-of-service (HOS) regulations for CMV drivers. The new regulations are based on a 24-hour circadian clock, instead of an 18-hour clock as used in the previous regulations. Based on its analyses, FMCSA concluded the new rule will keep drivers healthy and reduce the 5.5 percent of fatal truck crashes that are caused by driver fatigue (FMCSA, 2005).

In addition to changes in the HOS regulations, technological innovations addressing driver fatigue were also studied. The principal technology identified by NHTSA, FMCSA, and the Federal Highway Administration Intelligent Transportation Systems Joint Program Office (ITS JPO) as a countermeasure to driver drowsiness/fatigue was a vehicle-based Drowsy Driver Warning System. A DDWS detects physiological and/or performance indications of driver drowsiness/fatigue and provides feedback to drivers regarding their state of drowsiness. Such feedback might include continuous indices of driver alertness and/or warnings activated at threshold levels of drowsiness and associated crash risk. The primary function of a DDWS is to alert drivers to their drowsy states and to motivate them to seek rest or take other corrective steps to increase alertness, such as drinking a cup of coffee). However, since the driver-alerting effects of any in-vehicle stimuli are likely to be transient, the system must, in the long run, motivate drivers to obtain more sleep both in their principal sleep periods and in naps.

For CMV drivers, the DDWS is expected to be implemented in the context of an overall fleet fatigue-management program. Such programs educate drivers and fleet managers about the physiology of fatigue and effective means for improving sleep and, consequently, alertness. Driver dispatching and scheduling is conducted in a manner sensitive to the daily and weekly sleep and rest needs of drivers. The DDWS should function within the framework of carrier fatigue management to prevent fatigue-related crashes and to encourage and support long-term improvements in driver sleep hygiene and driving performance.

In controlled environments such as simulators and on test tracks, a variety of DDWSs have shown great promise. One particularly relevant study was sponsored by NHTSA, FMCSA, and FHWA ITS JPO to examine, validate, and design a particular DDWS called Co-Pilot (Wierwille et al., 2003). The Co-Pilot monitored the PERCLOS of the driver's eyelids by using infrared technology (the driver was considered drowsier as the amount of PERCLOS increased). PERCLOS is mathematically defined as 80-percent eye closure. This measure has been demonstrated to be a reliable measure of alertness (Wierwille, 1999a) and is considered the gold standard of drowsiness measures (Knipling, 1998). The Co-Pilot produced an output that was intended to estimate or measure PERCLOS.

In the Wierwille et al. (2003) study, the Virginia Tech Transportation Institute, Carnegie-Mellon University, and the University of Pennsylvania developed driver-vehicle interface designs, fabricated and evaluated mockups, and conducted limited pilot testing and assessments on the road using CMV driver participants with the Co-Pilot. The studies also examined the system logic for generating signals to the driver based on sensor data stream inputs captured from the Co-Pilot camera.

Based on the findings and recommendations from the Wierwille et al. (2003) study, the next generation of the Co-Pilot, called the Driver Fatigue Monitor (DFM), was developed by Attention Technologies, Inc., with support from the DOT. The DFM also employed the PERCLOS concept as a measure of drowsiness and produced an output that was intended to estimate or measure PERCLOS. Based on the results from the Wierwille et al. (2003) study in which the Co-Pilot was tested in a controlled environment, the DOT determined the DFM was ready to be tested in a real-world commercial driving situation. The Wierwille et al. (2003) research laid the groundwork for the current research that tested the DFM in a field operational test.

An FOT evaluates various aspects of a new product or device in the actual setting of its intended use. As the DFM is a new safety device, its usability, reliability, and effectiveness need to be assessed in real-world situations. In the DDWS FOT, a total of 41 DFM units were instrumented in 46 in-use CMVs driven by 103 truck drivers while conducting their regular deliveries. The data collection for the DFM evaluation lasted over 17 months, with each driver in the DDWS FOT driving an instrumented vehicle for approximately 10 to 14 weeks. To conduct such a large-scale FOT, several research partners were involved from the government, industry, and a university research institute.

Research Partners Involved in Conducting the FOT

There were several research partners involved in conducting the DDWS FOT. Figure 1 displays a flow chart of the research partners. The first partner was the government sponsor. Dr. Paul Rau of NHTSA served as the Task Order Manager (TOM). The second partner was the Volpe Center, which served as the independent evaluator; Dr. Bruce Wilson served as the lead researcher from the Volpe Center. The third partner was ATI, which served as the DDWS vendor; Richard Grace was the primary ATI researcher involved in the DDWS FOT. The fourth partner, and author of this report, was VTTI. VTTI was responsible for all data collection in the DDWS FOT. Dr. Richard Hanowski served as the lead investigator from VTTI. More specifically, VTTI collected all the data in the DDWS FOT and submitted this data to the Volpe Center for analysis. The Volpe Center used these data to evaluate the DFM. Of course, the DDWS FOT would not have been possible without the truck companies and drivers who agreed to participate in the DDWS FOT, including Pitt Ohio Express, J.B. Hunt, and Howell's Motor Freight.

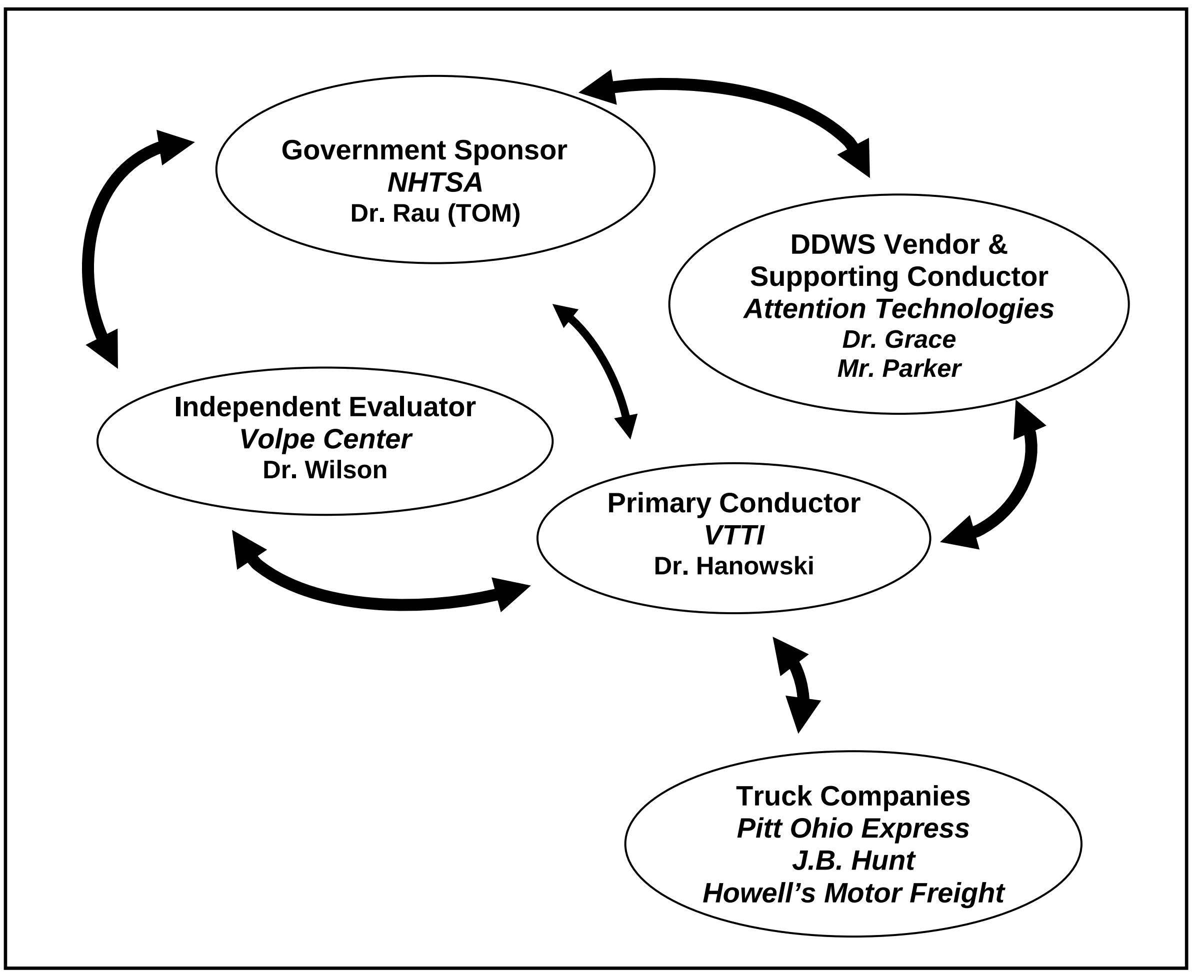

Figure 1. Flow Chart of the Primary Research Partners Involved in the DDWS FOT

PROJECT OBJECTIVE AND GENERAL REQUIREMENTS

The primary objective in the DDWS FOT was to collect data to evaluate the effectiveness, operational capabilities, limitations, and characteristics of a DDWS. More specifically, in accordance with Volpe's detailed research and implementation plan (Wilson & Popkin, 2002), the DDWS FOT had seven goals:

1. Achieve a detailed understanding of DDWS safety benefits;
2. Characterize DDWS performance and capability;
3. Assess the driver acceptance of the DDWS;
4. Assess the fleet management acceptance of the DDWS;
5. Assess the deployment prospects of a DDWS;
6. Develop recommendations for DDWS design changes directed at optimizing safety benefits and increasing driver and fleet management acceptance; and
7. Assess how DDWSs fit within a comprehensive fatigue management program.

As can be seen above, each of these seven goals refers to an assessment of a DDWS. To perform these analyses, which the Volpe Center led, on-road naturalistic driving data and other supporting data were collected. VTTI's primary goal under the DDWS FOT contract was to collect this data to support the Volpe Center's analyses. More specifically, VTTI had five goals (which involved 24 tasks across 2 phases) associated with the DDWS FOT:

1. Facilitate the collection of on-road data and other data necessary to conduct the DDWS FOT analyses;
2. Collect these data;
3. Provide these data in a form that could be reduced and used in the analyses;
4. Support the DDWS FOT goals by conducting two analyses; and
5. Document the work performed by VTTI during the course of the DDWS FOT.

In addition to the DDWS FOT goals listed above, there were four general requirements associated with meeting the project objectives:

1. The evaluation occurred in a naturalistic driving environment, and data was collected from actual CMV drivers.
2. The participant population in the DDWS FOT was representative of the target population performing overnight express and long haul operations.
3. The participants (CMV drivers) in the DDWS FOT operated their vehicles under normal operating conditions (i.e., actual delivery runs).
4. The evaluation protocol focused on operational measures to determine system benefits, liabilities, and user acceptability.

CHAPTER 2. OVERVIEW OF PHASE I: PREPARATION FOR THE FOT

The tasks in Phase I were directed at preparing the DDWS FOT data collection (Phase II). Phase I comprised three different tracks that were performed in parallel (Figure 2):

- Track 1 (Tasks 1 through 5): Develop the DAS;
- Track 2 (Tasks 6 through 9): Develop the DDWS; and
- Track 3 (Tasks 10 through 13): Recruit participants for the DDWS FOT.

The sections below briefly describe the work conducted in each task.

TASK 1: VALIDATE THE VOLPE-RECOMMENDED DATA NEEDS

The purpose of Task 1 was to review the measures recommended by the Volpe Center to be included in the DAS for the DDWS FOT. An initial list of measures was included in a report prepared by the Volpe Center entitled "Drowsy Driver Warning System Field Operational Test Implementation Requirements" (Wilson & Popkin, 2002). This initial list was modified based on discussions with Dr. Wilson. Although major components of the DAS were determined in Task 1, improvements were continued to the individual sensors in the DAS until data collection started in May 2004. A complete table of the final DDWS FOT DAS measures is presented in Appendix A.

Measures Collected from DDWS FOT DAS

The DAS in the DDWS FOT was composed of four general groups of measures: (1) DAS measures used in the 100-Car Naturalistic Driving Study (Dingus et al., 2005), (2) additional Volpe Center-requested measures, (3) truck network measures, and (4) DDWS measures. These measures are shown in Figure 3.

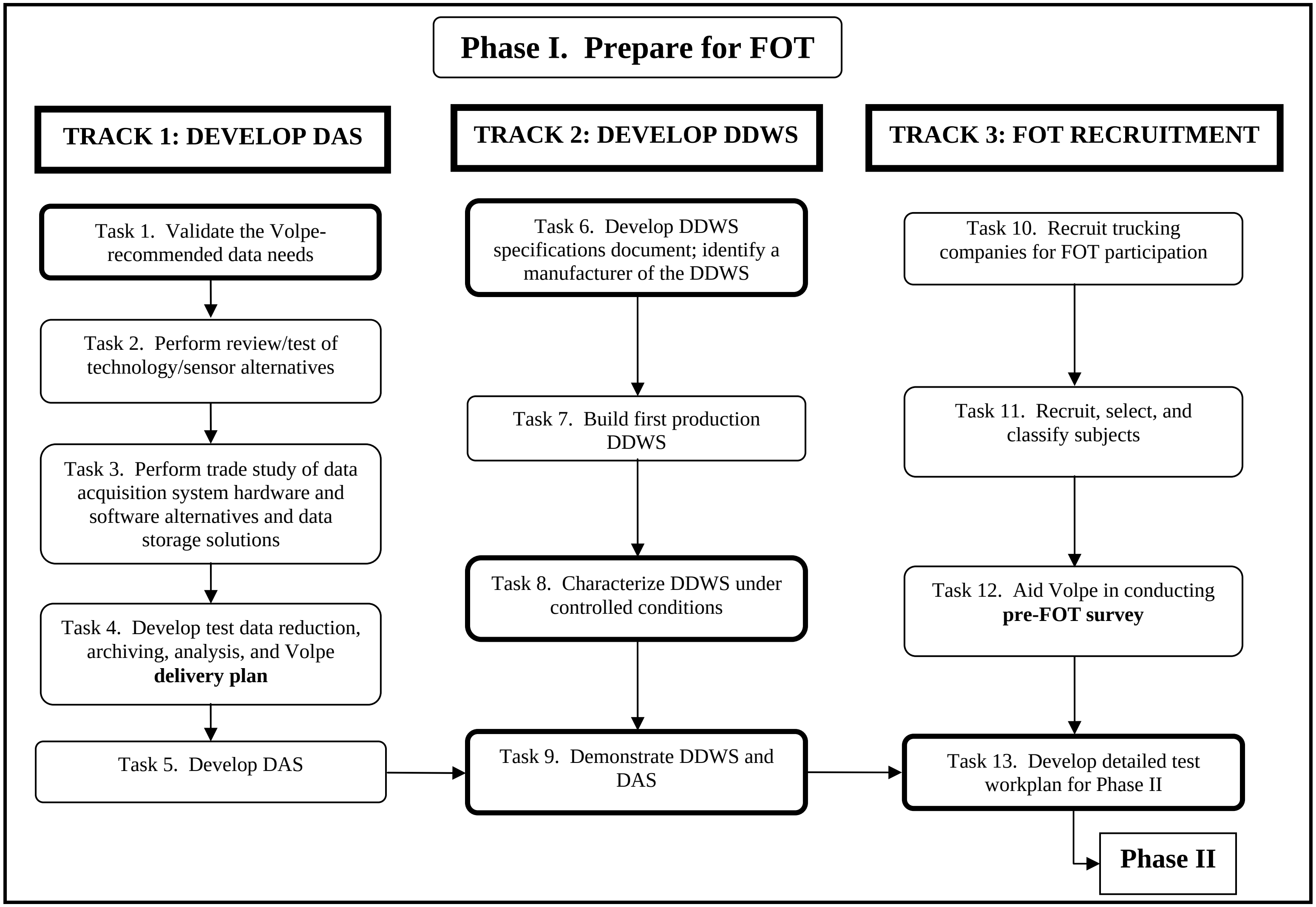

Figure 2. Overview of the Tasks in Phase I (bolded tasks indicate deliverables/milestones)

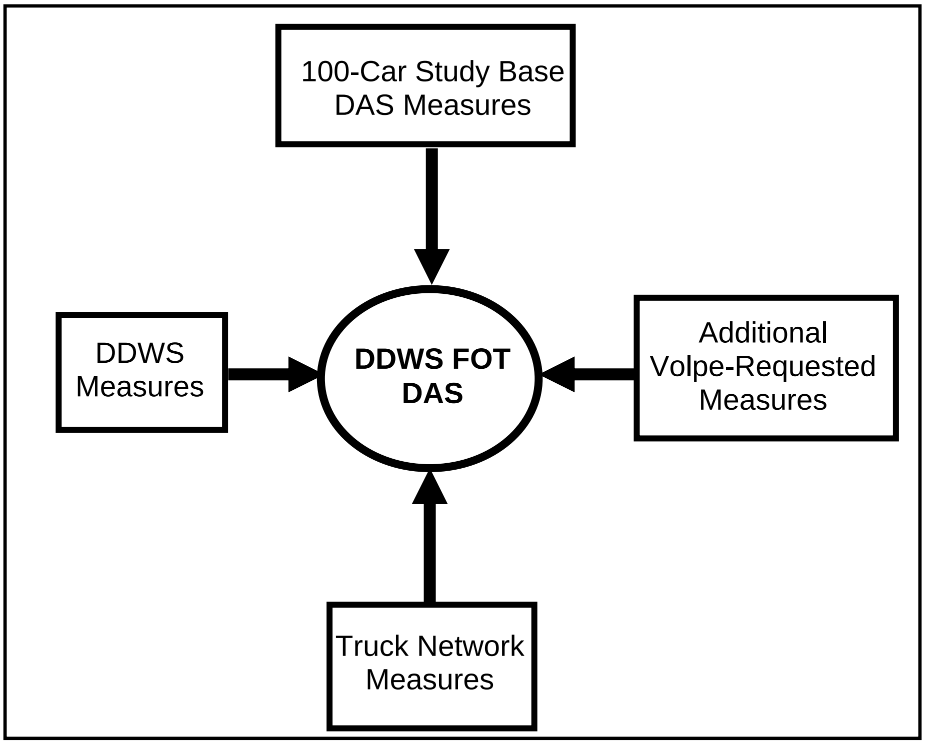

Figure 3. Component Measures of DDWS FOT DAS

"Base" DAS Measures from the 100-Car Study

The DAS from the 100-Car Study is referred to as the "base" system because most of the measures that were collected in the DDWS FOT are based on the 100-Car Study's DAS. Note that a complete table of the DAS measures in the 100-Car Study is presented in Dingus et al. (2006).

Additional Volpe-Center-Requested Measures

To facilitate the Volpe Center's planned analyses, a number of additional measures were considered (and implemented in Task 5), including:

- Vertical acceleration at the driver's seat (*g*'s);
- Sound level; and
- In-cab temperature (ºC/ºF).

Truck Network Measures

Additional measures were available from the truck's on-board data communication network (J1587). Appendix B shows the measures that could be collected from the J1587 communication network extracted from a 1994 Peterbilt 379 Class-8 tractor owned by VTTI. Note that the measures available from the truck's network varied depending on the manufacturer and the model of each truck.

DDWS Data Stream Variables

The DDWS used in the DDWS FOT was the DFM developed by ATI. Variables produced from the DFM and recorded to the DAS are listed in Appendix A. Additional information is also presented in the Methods chapter.

Characteristics of Data from the DDWS FOT DAS

In addition to the measures recommended by the Volpe Center, the data collected from the DDWS FOT DAS had the following characteristics:

- Data was recorded continuously; the system recorded when the ignition was turned on and the vehicle was in motion.
- The video data were collected at ~30 Hz, and driver and truck performance data were collected at 10 Hz. The resulting total data rate was ~4 MB/min.
- Data was compressed in MPEG 1 format.

Actigraphy Data

In addition to the measures collected by the DDWS FOT DAS, actigraphy data were also collected. The Volpe Center provided VTTI with Actigraph monitors and was responsible for analyzing the actigraphy data.

The original Actigraph watch (Figure 4) provided was a wristwatch-type activity-monitoring device used to assess a participant's quantity and quality of sleep. A newer version of the watch was used for the actual data collection. It provided an indication of whether or not the wrist was in motion and stored the data as a function of time. In effect, it indicated whether a participant tossed and turned while sleeping. During the day, the device also provided an indication of a participant's activity level. The Actigraph unit was self-contained and made no electrical contact with the participant.

Figure 4. Actigraph Watch

A letter report outlining the results of Task 1 was submitted to the TOM in November 2002. An updated version of the report was presented in the DDWS FOT Task 13 report (Hanowski et al., 2003).

TASK 2: PERFORM REVIEW/TEST OF TECHNOLOGY/SENSOR ALTERNATIVES FOR THE DATA ACQUISITION SYSTEM

The primary purpose of Task 2 was to identify the sensors required to support the collection of specific data in the DDWS FOT. As described above in Task 1, the DDWS FOT DAS was composed of five groups of measures:

- 100-Car Study DAS measures (with a few exceptions);
- Volpe Center requested measures;
- Measures from truck communication network;
- DFM data stream variables; and
- Actigraphy data.

Discussions with the TOM and the Volpe Center helped determine that many of the measures collected in the 100-Car Study were the same as those necessary to conduct the evaluation of the DFM in the DDWS FOT. As such, NHTSA, Volpe, and VTTI agreed to use the 100-Car Study DAS as the core DAS and to add components and sensors as needed for the FOT. Thus, a decision was made to refurbish the DASs from the 100-Car Study and use them as the DASs in the current DDWS FOT. From a budgetary standpoint, leveraging the 100-Car Study DASs and using them in the DDWS FOT appeared to be the most prudent approach.

To use the 100-Car Study DAS in the DDWS FOT, the system needed to be tested for the ability to withstand the ruggedness of a trucking environment. As part of the DAS development in the 100-Car Study, NHTSA required that a DAS-equipped vehicle be crashed. NHTSA conducted a 35-mph, 30-*g* crash (partial front hit) with the DAS-equipped vehicle. The results from the crash test showed that the DAS survived, did not break loose, collected data during the crash, and continued to collect data after the impact. These results indicated that the DAS had been designed and constructed to withstand significant jolts. As such, it was not expected that the anticipated rough terrain and rugged conditions of the on-road portion of the DDWS FOT would negatively impact the data collection capability of the DAS. Moreover, the DAS's ability to withstand a significant impact was demonstrated in the DDWS FOT when a rollover crash occurred with one of the trucks in the DDWS FOT. Therefore, the DAS is considered rugged enough to withstand normal day-to-day truck conditions and even a rollover crash.

A letter report describing the work conducted in Task 2 was submitted to the TOM in January 2003. An updated version of the report was presented in the DDWS FOT Task 13 report (Hanowski et al., 2003).

TASK 3: PERFORM TRADE STUDY OF DAS HARDWARE AND SOFTWARE ALTERNATIVES AND DATA STORAGE SOLUTIONS

The original purpose of Task 3 was to conduct a trade study on DAS hardware and software alternatives and to investigate data storage solutions. Because a decision was made early in the project to use the DAS from the 100-Car Study, most of the DAS hardware and software configurations had already been determined by the start of the DDWS FOT. Therefore, the remaining issue for Task 3 was to determine optimal data storage in the DAS (within the truck) and at VTTI.

When the updated version of the original letter report was submitted to the TOM in October 2003, a 40- GB removable hard drive was selected for the DAS's storage method. During the DDWS FOT, the size of the removable hard drive ranged from 40 to 100 GB. In fact, as the DDWS FOT progressed, the 40-GB removable hard drives were replaced with 60- or 100-GB removable hard drives. The data storage at VTTI was a storage area network (SAN) system (the Data Management section provides a more detailed description of the SAN).

A letter report outlining the results of Task 3 was submitted to the project TOM in March 2003. An updated version of the Task 3 report was presented in the Task 13 DDWS FOT Work Plan (Hanowski et al., 2003).

TASK 4: TEST DATA REDUCTION, ARCHIVING, ANALYSIS, AND VOLPE DELIVERY PLAN

Task 4 had three different goals: (1) estimate the number of hours for data reduction, (2) identify future uses of the dataset created in the DDWS FOT, and (3) develop a plan for delivering the data to the Volpe Center. Task 4 was conducted in consultation with a representative of the Volpe Center.

The primary goal of Task 4 was to estimate the number of hours required for data reduction. It was estimated that it would take approximately 18 months for 8–10 data reductionists, working roughly 20 hours per week, to complete the required data reduction in the DDWS FOT. This estimation was based on two prior naturalistic driving studies completed at VTTI that used data reductionists to reduce continuous data: the local/short haul (L/SH) study (Hanowski et al., 2000) and the 100-Car Study (Dingus et al., 2006).

The method for delivering the data to the Volpe Center is delineated in the Data Management section. VTTI sent the first dataset shipment to the Volpe Center in June 2004. A letter report outlining the Task 4 work was submitted to the TOM on June 30, 2003. An updated version of the report was presented in the DDWS FOT Task 13 report (Hanowski et al., 2003).

TASK 5: DEVELOP DAS

In Task 5, VTTI developed a heavy-vehicle-based DAS that was used to support the objectives and associated data requirements in the DDWS FOT. The final version of the DAS components is described later in this report.

TASK 6: MODIFY DDWS SPECIFICATION DOCUMENT, IDENTIFY A MANUFACTURER OF THE DDWS

ATI was identified as the manufacturer of the DDWS and was responsible for conducting Task 6. The goal of this task was to develop a modified and improved version of the Generation 2 Co-Pilot, which is referred to as the DFM in this report. ATI conducted preliminary field tests of the Co-Pilot (Wierwille et al., 2003). The field tests provided information on the optimal placement of the DFM to minimize false alarms. ATI was also responsible for updating the DFM system functions and specifications.

TASK 7: BUILD FIRST PRODUCTION DDWS

ATI was also responsible for Task 7, which was to manufacture a DDWS that could be used in Tasks 8 and 9. Upon completion of the field tests referred to in the previous section, ATI shipped DFM units to VTTI for evaluation and integration into the DDWS FOT experimental apparatus. In Task 8, VTTI tested the DFM in the lab and in a truck with a static setting (without driving). In Task 9, the DFM was tested under normal driving conditions (i.e., two 10-hour trips at VTTI's Smart Road facility and two 10-hour-long on-road trips). The test setting for Tasks 8 and 9 are described below.

TASK 8: CHARACTERIZE DDWS UNDER CONTROLLED CONDITIONS

The purpose of Task 8 was to assess the functionality of the DFM and determine if the various DFM functions worked as designed by ATI. The DFM in Task 8 was the original DFM (Figure 5), also called the Generation 2 Co-Pilot. Details about the assessment procedures and results were included in the DDWS FOT Task 13 Report (Hanowski et al., 2003). The instructions for operating the DFM in Task 8 are included in Appendix C.

Figure 5. The Original DFM

There were two primary assessments made in Task 8:

1. DFM's sensing capabilities and field-of-regard. (For example, does the DFM sense when the driver's eyes are closed? How does the DFM respond when the driver performs common in-vehicle tasks?)
2. DFM activation capabilities based on the defined DFM settings. (For example, does the DFM produce alerts at the predetermined time for the selected sensitivity level?)

The assessment of the DFM in Task 8 was conducted in a controlled, static setting. To conduct system assessment close to the actual setting in the DDWS FOT but without driving, the DFM was instrumented in one of VTTI's Class-8 tractors (1994 Peterbilt). Six volunteers of various ages served as research participants.

The DFM assessment in Task 8 uncovered several issues, which were relayed to ATI for modification of the DFM before the DDWS FOT began. These issues included:

- *Operating mode:* Only two operating modes were required in the DDWS FOT, as opposed to the six operating modes built into the DFM. One of the two required modes operated under baseline conditions (i.e., the DFM interface was not lit) while the other mode operated under experimental conditions (i.e., the DFM interface was lit and the auditory alarm was presented).
- *Premature alerts:* The DFM tested in Task 8 consistently alerted participants earlier than it should have.
- *DFM brightness measure:* The scale of the DFM interface illumination is measured from dark (0) to bright (254). This scale is not related to an actual luminance measure. The 0–254 scale should be mapped to a measurement of luminance (e.g., cd/m^2).
- *Potential data stream software bug:* During several alerts, no record was marked in the data when the alert sounded. A copy of the video and data were sent to ATI for further investigation.

TASK 9: DEMONSTRATE DDWS AND DAS

The goal of Task 9 was to ensure that the DDWS FOT had a fully functioning DFM and DAS. More specifically, Task 9 had the following three goals:

1. Ensure that the DFM and DAS worked reliably in a dynamic driving setting.
2. Generate a dataset that could be used by the Volpe Center in preparation for data analysis.
3. Ensure that drivers understood the questionnaires to be administered during the FOT.

Task 9 was divided into two phases: (1) Task 9A, which involved a 10-hour data collection run at night on the Smart Road at VTTI, and (2) Task 9B, which involved driving within Virginia for 10 hours on 2 consecutive nights (20 hours total). Each of the Task 9 studies involved drivers with a Class-A Commercial Driver's License (CDL) driving one of VTTI's Class-8 tractors with an empty 48-ft trailer. The tractor-trailer was instrumented with the DFM and DAS.

All drivers in Task 9 went through the identical screening test as drivers in the DDWS FOT, including a DFM test, a visual acuity test, and a hearing level test. The DFM testing was conducted in a static setting (e.g., parking lot) in order to ensure that the candidate driver's eye closure was reliably detected by the DFM. All four drivers completed a pre-participation survey, pre-study survey (Appendix D), post-study survey (Appendix E), and debriefing survey (Appendix F). Drivers in Task 9B were also required to wear the Actigraph watch selected by the Volpe Center.

During data collection, three types of files were created: (1) driving data file (in binary code), (2) MPEG files for video images, and (3) error file (in text format; the file was created only if an error occurred on the DAS during data collection). Over the 10 hours of driving, approximately 2.8 GB of data were recorded (approximately 58 MB for the driving data file and 2.2 GB for the MPEG file). VTTI converted the driving data file from binary code to text format before sending the data to the Volpe Center for analysis. Actigraphy data was also copied and sent to the Volpe Center for analysis.

Data checking was conducted for the driving data files and MPEG files. VTTI verified the data distribution of the variables collected by the DAS and ensured that the data were within the logical range (e.g., speed should be recorded under 100 mph). The MPEG files were checked to ensure that video images were continuously recorded.

After completing the Task 9A 10-hour drive and associated surveys, participants made verbal comments regarding both the DFM and the surveys. Drivers thought the alarm was helpful and kept them awake but that it became annoying after a few hours. Drivers also reported the survey questions were not easy to understand and needed to be rephrased; the survey language was “too academic” and “not driver friendly.”

In Task 8, VTTI uncovered an issue regarding the reliability of the DFM: eye closure was not reliably detected if drivers wore glasses. For example, the DFM recorded both of the driver’s eyes as open when the driver had both eyes closed. VTTI conducted a series of static and dynamic DFM reliability tests to investigate potential problems such as type of glasses and DFM calibration and location on the truck dashboard. Based on these reliability tests, VTTI recommended that drivers who were required to wear glasses while driving at night be disqualified from participating in the DDWS FOT.

Based on the drivers’ comments on the survey, VTTI recommended that Volpe (1) revise the original surveys and reword them to improve the readability of the document for the target users and (2) create different pre-study, post-study, and debriefing surveys for drivers in the control group because those drivers would not be exposed to the DDWS alerts referred to in the original surveys. Based on these recommendations, the Volpe Center made changes to several items on the surveys to obtain a lower score on the Flesch-Kincaid readability test. The Volpe Center also created separate surveys for the drivers in the control group by removing the questions that referred to the DDWS device in the original surveys.

After data collection was completed, VTTI sent the following materials to the Volpe Center: (1) four sets of 10-hour driving data in text format (two sets from two drivers), (2) four sets of 10-hour video images, (3) copies of the surveys drivers completed, and (4) actigraphy data collected from the two drivers in Task 9B.

TASK 10: RECRUITING TRUCKING COMPANIES FOR FOT PARTICIPATION

In Task 10, VTTI identified potential line- and long-haul truck companies for participation in the DDWS FOT. It was anticipated that these companies would be able to provide the necessary 102 drivers required in the DDWS FOT.

The fleets recruited in the study had the following characteristics:

- Enthusiastic cooperation and support from top management and first-line management;
- Well-organized operations that supported systematic and reliable data collection;
- Drivers who were generally representative of the long-haul and line-haul industries;

- Sufficient night driving (estimated to be at least 6 hours per night) to permit assessment of current PERCLOS sensory technology (which requires darkness). Note: VTTI personnel did not control the number of hours a driver drove at night; however, driving at night was used as a selection criterion.
- An existing fleet fatigue management plan or management practices to provide a supportive framework for the DDWS;
- A fleet with a proven record of low driver turnover; and
- A fleet that was located within a 5-hour drive of VTTI (Blacksburg, VA).

A list of potential fleets was developed and initial contact with managers from select companies was made in October 2003. VTTI representatives made several site visits to potential fleets to discuss the DDWS FOT and the fleet's potential involvement and responsibilities. The recruitment process was finalized in December 2003.

Three truck companies were selected and agreed to participate in the DDWS FOT: Pitt Ohio Express (line-haul operation), Howell's Motor Freight (long-haul operation), and J.B. Hunt (both line- and long-haul operations).

TASK 11: RECRUIT, SELECT, AND CLASSIFY SUBJECTS

Following recruitment of the participating fleets and briefing of fleet management personnel on the details of the DDWS FOT, VTTI began to recruit a representative sample of drivers who were willing to serve as participants in the FOT. More specifically, the goals in Task 11 included: (1) recruit and screen drivers for the DDWS FOT, (2) provide fatigue management training to all the participating drivers, and (3) provide DFM training to the drivers in the experimental group. Driver recruitment in the DDWS FOT was conducted from March 2004 to June 2005. VTTI recruited drivers who reported driving at night and did not need to wear glasses while driving at night.

TASK 12: AID VOLPE IN CONDUCTING PRE-FOT SURVEY

Both ATI and VTTI worked on Task 12. The goal of Task 12 was to develop surveys to administer to drivers and fleet management. As part of this effort, ATI and VTTI aided the Volpe Center in developing 8 surveys, including: (1) pre-participation survey, (2) pre-study survey for the experimental group, (3) pre-study survey for the control group, (4) post-study survey for the experimental group, (5) post-study survey for the control group, (6) debriefing survey for the experimental group, (7) debriefing survey for the control group, and (8) fleet management survey. These surveys went through several iterations; the latest versions are outlined in the Methods chapter.

TASK 13: DEVELOP DETAILED TEST WORKPLAN FOR PHASE II

The Task 13 report was submitted to the TOM in October 2003. The report outlined the detailed work completed in Tasks 1–12 and the workplan for Tasks 14–24. The remaining chapters in this final report outline the work completed in Phase II: Conducting the FOT.

CHAPTER 3. OVERVIEW OF PHASE II: CONDUCT THE FOT

Whereas Phase I was directed at planning and preparing for the DDWS FOT on-road data collection, Phase II of the DDWS FOT involved carrying out the Phase I plans described in the Task 13 report. There were a total of 11 tasks in Phase II:

- Task 14: Refurbish data collection systems for 34 trucks.
- Task 15: Build 36 DDWSs.
- Task 16: Install DASs and DDWSs.
- Task 17: Brief driver participants and carrier management.
- Task 18: Collect on-road data.
- Task 19: Provide stored data to Volpe Center.
- Task 20: Reduce and archive DDWS data.
- Task 21: Remove the instrumentation packages.
- Task 22: Analyze DDWS data.
- Task 23: Aid Volpe in conducting post-FOT focus groups.
- Task 24: Write final report.

Figure 6 shows a diagram of the tasks in Phase II. The current report provides a detailed description of Phase II (Tasks 14–24).

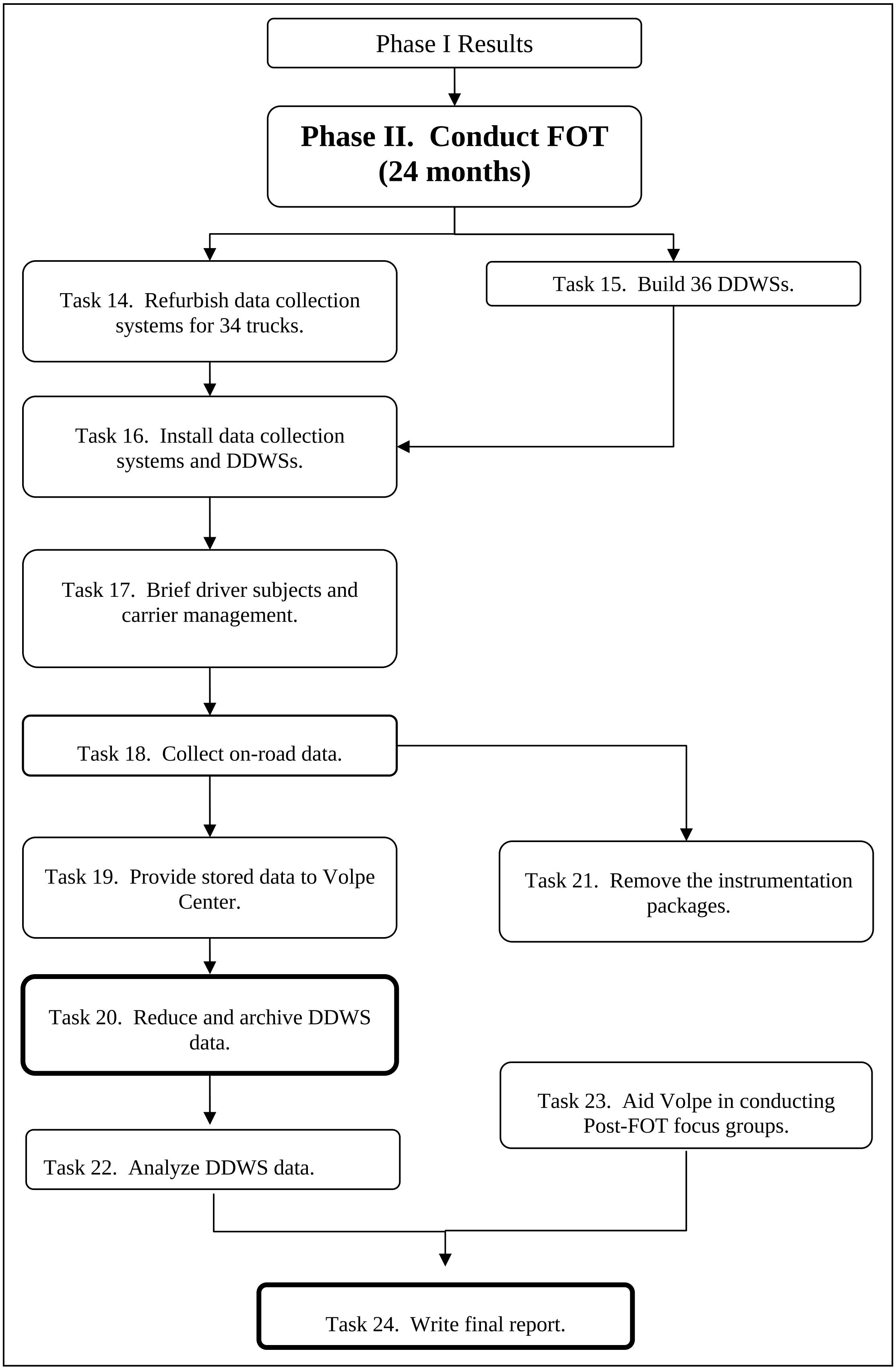

Figure 6. Phase II Task Overview (bolded tasks indicate deliverables/milestones)

CHAPTER 4. METHODS

The following sections describe how the DDWS FOT data collection was performed to support Volpe's analyses. It provides information about the experimental design, apparatus for the study (DFM and DAS), participants, and procedures.

EXPERIMENTAL DESIGN

Original Experimental Design

In preparation for the data collection effort for the DDWS FOT, the Volpe Center provided VTTI with instructions on the experimental design that needed to be implemented for the study. The original experiment submitted to VTTI by Volpe Center was an A^3B^9 for Group 1 and an $A^2B^8A^2$ for Group 2, which was based on a trade study by Popkin, Wilson, and Howarth (2003). With this design, 75 percent of the drivers would have had a baseline sequence (A) lasting 3 weeks and a treatment sequence (B) lasting 9 weeks. A baseline sequence was defined as a sequence where the DDWS would monitor the driver but not provide any alerts. A treatment sequence was defined as providing the auditory and visual alerts to the driver. For Volpe to have the statistical power necessary to conduct its analyses, a core sample of 34 drivers was needed (26 drivers for Group 1, 8 drivers for Group 2) for line-haul operations and another 34 drivers for long-haul operations, making the total 68 drivers. A power analysis, conducted by Volpe, was used to calculate this number. This core sample required that data be collected for a total of 12 weeks. Applying these numbers to the Volpe-recommended design, the baseline-treatment sequence shown in Figure 7 was developed, creating two distinct experimental groups of drivers (i.e., Group 1 and Group 2). In Volpe's design, an additional 4 weeks per driver were included after the original 12 weeks of data collection were finished to compensate for any data missed due to truck or other system breakdowns.

A	**A**	**A**	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**B**	+	+	+	+	**Group 1**
A	**A**	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**A**	**A**	+	+	+	+	**Group 2**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	

Total Weeks Truck is Driven per Participant

A = Baseline (No Alert)
B = Treatment (Alert)
+ = Additional weeks (if needed)

Figure 7. Original Experimental Design

Modified Experimental Design

During the data collection process the original experimental design was changed twice under direction from Volpe. The first modified experimental design was composed of a control group (baseline for 12 weeks) and an experimental group (i.e., A^{12}; A^3B^9). The experimental group had a baseline (A) sequence for the first 3 weeks and a treatment (B) sequence for the last 9 weeks (Figure 8). Similar to the original experimental design, Modification 1 allowed up to 4 additional weeks per driver after the original 12 weeks of data collection were finished for additional data collection, if needed, to compensate for data missed due to truck or other system breakdowns.

The second experimental design modification (i.e., A^9; A^2B^9) prescribed by the Volpe Center was a similar design to the one used in Modification 1. Modification 2 kept a control group but for only 9 weeks, with the potential of an additional week of data collection if needed. The experimental group for Modification 2 had a 2-week baseline sequence (A) and kept the treatment sequence (B) of 9 weeks (Figure 8). The experimental group for Modification 2 included 3 additional weeks. A similar proportion of line-haul and long-haul participants were recruited for each group.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Modification 1	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**+**	**+**	**+**	**+**	**Control Group 1**
	A	**A**	**A**	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**+**	**+**	**+**	**+**	**Experimental Group 1**
Modification 2	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**+**							**Control Group 2**
	A	**A**	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**+**	**+**	**+**			**Experimental Group 2**

Total Weeks Truck is Driven per Participant

A = Baseline (No Alert)
B = Treatment (Alert)
+ = Additional weeks (if needed)

Figure 8. Modified Experimental Design

Overall, the instrumented trucks were driven on average 13.72 weeks per participant (*SD* = 4.78 weeks). The weeks marked as "additional weeks" were used for all the participants due to different technical problems encountered during data collection, and in multiple instances even more weeks were needed to obtain the required weeks of data to support the Volpe Center's analyses. A comprehensive description of the technical problems encountered during the study is presented in Chapter 7.

One of the general restrictions of this FOT was that the sample of drivers must reflect "the envelope of operation" of the DFM. The predetermined limitations of the system used for the FOT include: (1) low reliability for drivers wearing glasses and (2) low reliability for determining drowsiness during daytime hours. Therefore, the driver sample was restricted to drivers from the companies that participated in the study who did not wear glasses and had the potential to be exposed to nighttime driving.

Measurements

A myriad of measurements can be derived from the data obtained from this FOT to evaluate the DDWS as well as for future research/analysis purposes. The following are the measurements used for VTTI analyses as well as examples of measurements that can be obtained from the data collected for this study for future data mining efforts. Appendix A presents a list of variables available in raw form from the DAS.

- **PERCLOS:** The DFM monitors the eyelid drop (PERCLOS) by using infrared technology. The driver is considered drowsier as the amount of PERCLOS increases.

High Sensitivity

PERCLOS calculation period	1 min
Initial advisory tone alert	8 percent (4.8 s)
Full warning alert	12 percent (7.2 s)

Medium Sensitivity

PERCLOS calculation period	3 min
Initial advisory tone alert	9 percent (16.2 s)
Full warning alert	12 percent (21.6 s)

Low Sensitivity

PERCLOS calculation period	5 min
Initial advisory tone alert	10 percent (30 s)
Full warning alert	12 percent (36 s)

- **DFM output:**
  - Eyes found: 0 = no eye, 1 = one eye, 2 = both eyes
  - Sensitivity level: 0 = high, 1 = medium, 2 = low
  - Operating mode: 0 = DFM unplugged; 1 = active mode, alerts presented to the driver; 2 = dark mode, alerts not presented to the driver
  - Display status: 1 = on, 0 = off
  - Longest eye closure (bar graph): 0–4 s
  - Warn flag: 0 = not triggered, 1 = full triggered, 2 = initial triggered
  - Warning sound: 0, 1, 2, 3, 4, 5
  - Mode: 0 = standby, 1 = active, therefore are controls lit and active in active mode; 2 = warn 1, meaning full-warning is presented; 3 = warn 2, reporting that the warning response button has been pressed
- **Light level:** Light level measured (lux) from illuminance meter.
- **Sound level:** Measure of the cab interior sound level in decibels (dBA) recorded from DAS sound level meter.
- **Temperature:** The ambient temperature of the air surrounding the vehicle recorded by the in-vehicle network communication system reported in degrees Celsius (°C).
- **Vehicle speed:** Vehicle speed recorded from the in-vehicle network communication system in kilometers per hour (km/h).
- **Throttle position:** The position of throttle pedal recorded from the in-vehicle network communication system in a normalized range of 0–1 (0 = pedal up, 1 = pedal down).
- **Cruise control status:** Status of the vehicle velocity control system recorded from the in-vehicle network communication system. System status reported as active or not active, and also reports when system switch is on or off.
- **Vehicle component information:** All vehicle component operation recorded from the in-vehicle network communication system measuring the presence and absence of right- and left-turn signal (1 = present, 2 = absent), brake usage (1 = brake was pressed, 0 = brake not pressed), headlight status (1 = headlights on, 0 = headlights off), and ignition signal (1 = on, 0 = off).
- **Seat acceleration:** Data collected from accelerometer to receive Z-acceleration (vertical travel up and down) of driver's seat reported in 1/100 *g*.

- **Vehicle angle:** Angle of vehicle with respect to the lane measured in 1/100,000 radians (rad) recorded by lane-tracker system.
- **Lane offset:** Distance of vehicle to the center of the lane. Measurements reported in 1/100 inch recorded by lane-tracker system.
- **Lane width**: Lane width measured in 1/100 inch recorded by lane-tracker system.
- **Road curvature**: Radius of road curvature is reported as the inverse of radius of road curvature reported in 1/100,000 ft and referred to as RhoInverse. Information collected by lane-tracker system.
- **Road incline:** The incline of road with respect to baseline measured in 1/100,000 rad recorded by lane-tracker system.
- **Left-lane characteristics:** Lane-tracker system records characteristics in the immediate left lane and reports the type of line (0 = none, 1 = double, 2 = single), leftmost and rightmost line color (0 = light lines, 1 = dark lines), contrast level in a range of 0–7 (0 = sharp contrast between lines and background, 7 = little contrast between lines and background).
- **Immediate left lane - left distance:** Distance from the lane’s center to the left side of the marker measured in 1/100 in recorded by lane-tracker system.
- **Immediate left lane - right distance:** Distance from the lane’s center to the right side of the marker measured in 1/100 in recorded by lane-tracker system.
- **Right lane characteristics:** Lane-tracker system records characteristics in the immediate right lane and reports the type of line (0 = none, 1 = double, 2 = single), leftmost and rightmost line color (0 = light lines, 1 = dark lines), contrast level in a range of 0–7 (0 = sharp contrast between lines and background, 7 = little contrast between lines and background).
- **Immediate right lane - left distance:** Distance from the lane’s center to the left side of the marker measured in 1/100 in recorded by lane-tracker system.
- **Immediate right lane - right distance:** Distance from the lane’s center to the right side of the marker measured in 1/100 in recorded by lane-tracker system.
- **Global positioning system (GPS):** GPS records all location information, which includes latitude and longitude measured in degrees, altitude measured in 1/100 ft, horizontal and vertical velocity measured in 1/10 mph, vehicle heading measured in 1/10 deg, month reported in a range of 1–12, day of the month, hour of day reported in a range of 0–24, and minute of the hour reported in a range of 0–59.
- **Lateral acceleration (Y acceleration):** Data recorded from system accelerometer measuring acceleration readings reported in 1/100 *g* (positive = right, negative = left).
- **Longitudinal acceleration (X acceleration):** Data recorded from system accelerometer measuring acceleration readings reported in 1/100 *g* (positive = accelerating, negative = braking).
- **Rotation:** Data recorded from gyro system to report rotation in deg/s of driver. A positive rotation rate is in a clockwise motion.
- **Range to target or targets:** Distance measurement reported as 1/10 ft from vehicle to target object or target objects. A total of seven targets may be tracked at one time.
- **Road and lane characteristics:** Size availability of road structure both on left and right side of vehicle, measured by three video camera feeds: one forward camera, one located on the left mirror, and one located on the right mirror. Also includes road characteristics

such as junctions, interchanges, traffic flow, number of lanes, roadway alignment, roadway profile, surface condition, lane marker type, and traffic density.

- **Driver comments:** Audio comments recorded by drivers by way of the incident box microphone. All audio clips are 30 seconds long and recorded in MP3 format.
- **Sleep:** Sleep quantity calculated by use of actigraphy data recorded by way of a wrist collection device (watch). MicroMini Motionlogger systems were used, which utilize a precision piezoelectric bimorph-ceramic cantilevered beam, which generates a voltage each time the watch is moved (Motionlogger User's Guide, n.d.). The number of times the signal voltage crosses the reference voltage is then accumulated in temporary memory storage for a 1-minute epoch and creates a frequency of movement data point. Sleep frequency and quantity can then be determined. Drivers wore these watches 24 hours a day, 7 days a week while participating in the FOT.
- **Observer rating of drowsiness (ORD):** Subjective judgment on driver level of drowsiness by analyzing driver face and body language from video captured from a face camera. Indications of drowsiness can include rubbing face or eyes, facial contortions, restless motion in the seat, and slow eyelid closures. A 100-point continuous rating scale was used where a number from 0 to 100 is assigned based on the linear position chosen by the analyst (0 = not drowsy, 100 = extremely drowsy).
- **Driver behavior video analysis:** Multiple measures can be obtained through analysis of captured video:
    - **Behavior video analysis**
        - Eyeglance analysis
        - Phone use
        - Passenger interaction
        - Use of Citizens Band (CB) or other technological devices
        - Instrument panel adjustment
        - Mirror glance
        - Shifting
        - Viewing other incident
        - Viewing construction or other objects such as vehicles, people, animals, etc.
        - Eating or drinking
        - Smoking or other habitual distractions
        - Removal of personal hygiene equipment (eye glasses, contacts, etc.)
        - DFM distraction
    - **Vehicle position video analysis**
        - Lane deviation status
        - Intersection maneuvers
        - Other vehicle position and encroachment
    - **Road structure**
        - Road type (pavement, gravel, interstate, highway, etc.)
        - Road condition (wet, icy, etc.)
        - Road shoulder descriptions (ditches, walls, etc.)
        - Number of lanes
        - Road characteristics (straight, curvature, etc.)
        - Road incline (grades, hills, etc.)

        - Lane marker profiling (dashed, solid, etc.)
    - **Traffic**
        - Flow
        - Amount
        - Types of vehicles
    - **Weather**
        - Presence of adverse conditions
        - Rain, sleet, snow, fog, rain, or combinations of all
    - **Light condition**
        - Daylight, dark, dawn, dusk, or combination of light

APPARATUS

DDWS–DFM Specifications

The DDWS is intended to detect drowsiness and warn drivers when their drowsiness exceeds a pre-determined level. The DDWS used in the FOT is called the DFM (Figure 9). This PERCLOS monitoring device has undergone extensive research and modifications based upon empirical data collection (Wierwille et al., 2003). PERCLOS is a mathematically defined eye-closure measure that has been demonstrated to highly correlate with a participant's performance degradation under varying conditions of sleep deprivation (Wierwille, 1999a; 1999b; Wierwille et al., 2003). The DFM estimates PERCLOS or the percentage of eyelid closure over the pupil over time and reflects slow eyelid closures ("droops") rather than blinks. This drowsiness metric was established in a 1994 driving simulator study as the proportion of time in a minute that the eyes are at least 80 percent closed. When the DFM estimates that PERCLOS has reached a pre-defined threshold, visual and auditory alerts are presented to the driver. The DFM is mounted as close to the centerline of the steering wheel as feasible, and the DFM camera (on the upper part of the DFM) is pointed toward the driver's face. The primary function of a DDWS is to provide information that will advise drivers to their drowsy states and motivate them to seek rest or take other corrective steps to increase alertness. The investigation of safety benefits of a DDWS was the primary focus of this FOT. The evaluated system was provided by ATI. The ATI system is an updated version of the Generation 2 PERCLOS monitor (Wierwille, 1999a; 1999b; Wierwille et al., 2003). The specifications of ATI's test system, the DFM, are presented next.

Figure 9. The DFM Used in the FOT

The DFM provides an estimate of the proportion of time that the driver's eyes are closed or nearly closed over a specified time interval (i.e., 1, 3, or 5 min). As mentioned previously, PERCLOS reflects slow eye closures that can be construed as both a physiological indicator of drowsiness as well as an indicator of an interruption in visual information gathering. The DFM consists of an infrared (IR) camera, signal-processing electronics, and a DVI. The IR camera is mounted on top of the DVI and is used to monitor the driver's eyes. The DVI provides an audio-visual alert to the driver when PERCLOS reaches a predetermined level. The DFM was placed on the dashboard to the right of the driver for all trucks used for data collection. All the DFMs were placed as close to the centerline as possible taking into consideration the physical constraints of the area available for placement (Figure 10). Due to the different types of dashboards and configurations, the placement of the DFM varied. Some DFMs had to be placed at an angle larger than the desired angle (i.e., 20°) in order to: (1) avoid blocking the driver's forward view, (2) avoid interfering with the steering wheel, and (3) leave the existing CB radio on the dashboard. Moreover, special brackets were made for trucks where the dashboard was too narrow to place the DFM or for split dashboards (Figure 11). Nonetheless, for all trucks, the DFM was positioned as close as possible to the centerline of the steering wheel.

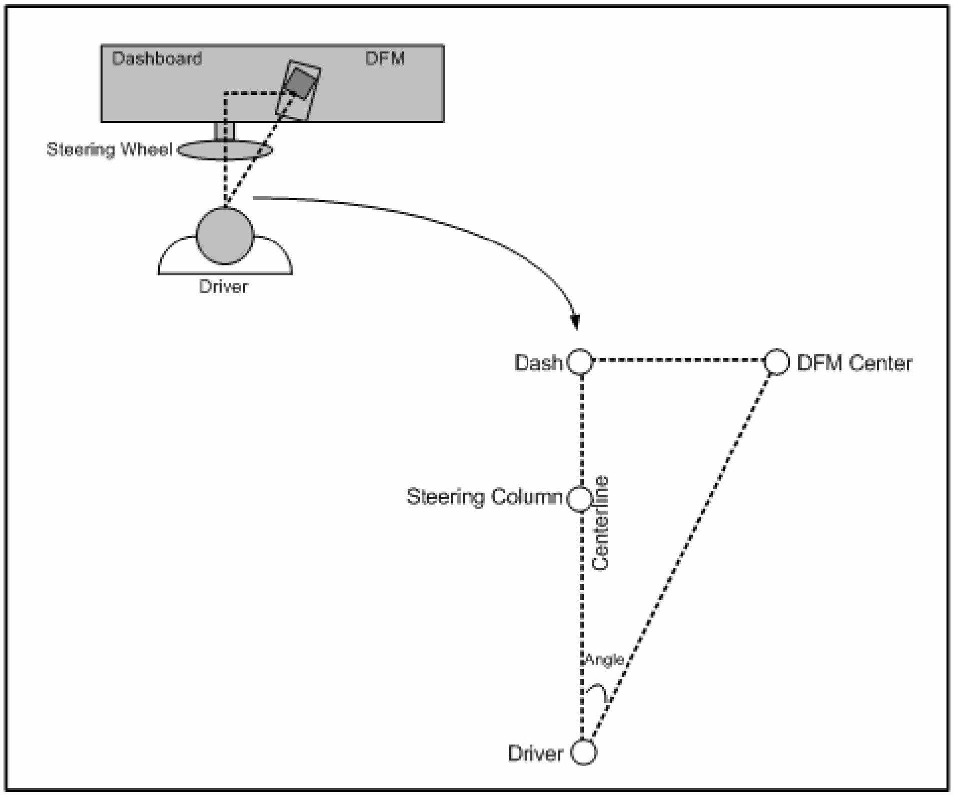

Figure 10. Example DFM Position Relative to the Driver (not to scale)

(a) Original DFM position with space available; position is too far to the right

(b) Modified DFM position with bracket to get DFM closer to (in front of) driver

Figure 11. DFM Position Modifications

The DFM allowed the driver to control several aspects of system operation. Two rotary knobs allowed the driver to adjust the warning volume and the display brightness. A push button allowed the driver to select the preferred warning sound from among five sounds. Another button allowed drivers to select the warning sensitivity (i.e., low, medium, or high). The PERCLOS calculation was re-initialized with each change to the sensitivity level. The three sensitivity levels were operationally defined in the Measurements section.

Figure 12 shows the DFM. The following is a short description of each of the controls shown in the figure.

1) Warning response button: Located on the top of the interface. This button was used to stop an alert and obtain feedback of potential drowsiness after an alert.
2) Display luminance control: Turn knob that controls the luminance for the display of the interface. The display luminance output ranges from 0–254. Display luminance levels were tested at five different dial settings (see Figure 13) for the sound selection switch and the sensitivity selection switch. All measurements were taken with the dash lights off (Table 1) and with the dash lights on (Table 2).
3) Volume control: Turn knob to adjust audible part of the warning. The sound level from the DFM was checked using a sound level meter positioned approximately at the ear location of a driver. Measures were taken at each of five dial locations (Figure 14). The sound levels, with and without the truck running, are shown in Table 3 and Table 4.
4) Sound selection button: Switch that allows user to choose from five different alerts.
5) Sensitivity Selection Switch: Switch that allows user to choose between three different sensitivity levels: low, medium, and high. Low sensitivity would allow for higher percentage of closure of the eyelids, and high sensitivity would allow for much lower percentage.
6) Operation mode selection key: Key lock switch used to switch the DFM between dark and active modes. This switch was used only by the experimenter. This switch is located on the right side and not visible while viewing the DFM straight on.
7) Data collection output: Small serial port located on the back of the DFM connected to the DAS (not shown in Figure 12).

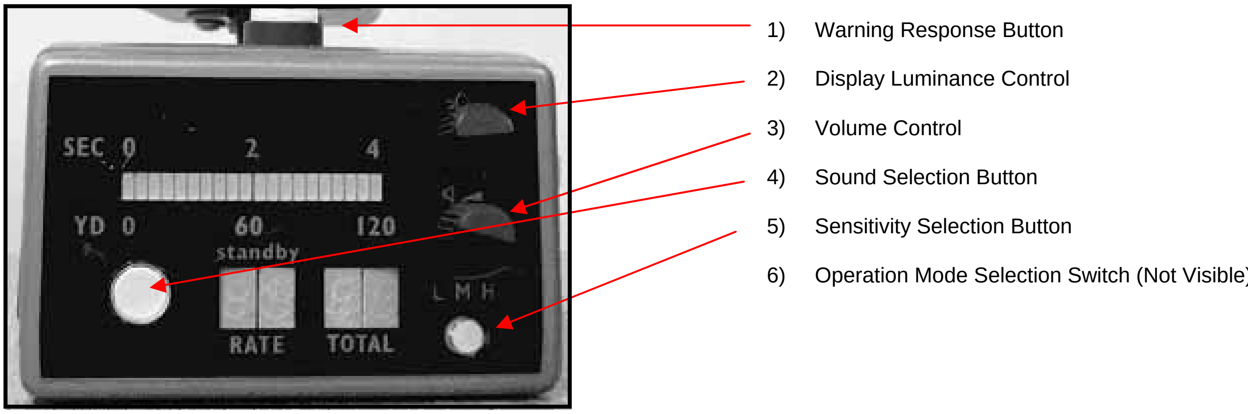

Figure 12. DFM User Interface and Controls

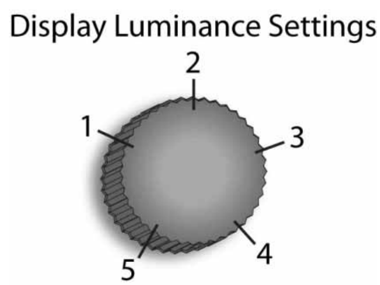

Figure 13. Display Luminance Control Settings

Table 1. Display Luminance With Dash Lights Off (in footcandles [fc])

DFM Setting	1	2	3	4	5
Info Button	0 fc	0.2 fc	1.6 fc	3.7 fc	4.6 fc
Sensitivity Button	0 fc	1.2 fc	3.4 fc	6.6 fc	9.2 fc

Table 2. Display Luminance With Dash Lights On (in footcandles)

DFM Setting	1	2	3	4	5
Info Button	0 fc	0.4 fc	2.0 fc	3.8 fc	4.6 fc
Sensitivity Button	0 fc	1.3 fc	3.5 fc	6.8 fc	9.6 fc

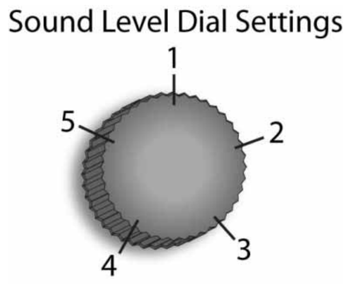

Figure 14. Sound Level Settings on the Volume Control

Table 3. Measured Sound Level Without the Truck Running
Ambient Noise: 35.8 dBA

DFM Setting	1	2	3	4	5
Sound 1	59.9 dBA	62.0 dBA	65.3 dBA	73.1 dBA	76.2 dBA
Sound 2	45.8 dBA	57.5 dBA	61.1 dBA	64.2 dBA	65.6 dBA
Sound 3	66.4 dBA	77.2 dBA	79.6 dBA	80.1 dBA	81.9 dBA
Sound 4	66.7 dBA	68.8 dBA	79.3 dBA	80.0 dBA	81.2 dBA
Sound 5	64.5 dBA	79.2 dBA	79.9 dBA	81.9 dBA	82.5 dBA
Sound 6	63.3 dBA	76.2 dBA	76.4 dBA	78.1 dBA	79.1 dBA

Table 4. Measured Sound Level With the Truck Running
Ambient Noise: 66.5 dBA

DFM Setting	1	2	3	4	5
Sound 1	66.8 dBA	70.6 dBA	71.9 dBA	75.4 dBA	75.9 dBA
Sound 2	66.7 dBA	68.1 dBA	70.8 dBA	71.6 dBA	71.8 dBA
Sound 3	71.1 dBA	77.2 dBA	79.1 dBA	81.1 dBA	81.4 dBA
Sound 4	70.5 dBA	79.0 dBA	79.5 dBA	80.3 dBA	80.5 dBA
Sound 5	70.6 dBA	77.3 dBA	80.2 dBA	81.8 dBA	82.8 dBA
Sound 6	69.3 dBA	76.6 dBA	79.7 dBA	81.7 dBA	82.8 dBA

As previously noted, the DFM could operate in two different modes, active mode and dark mode. In the active mode the driver received feedback from the DFM and was able to interact with it. During the active mode, the DFM would react based on several inputs. The DFM would switch between a standby state and active state based on ambient illumination and vehicle speed. When speed was below 30 mph and ambient illumination was above 100 lux, the DFM was in standby state. An indicator light signified by the word “standby” was lit in red in the center of the screen and the driver controls were not lit (Figure 15). During the standby state there was no audio-visual feedback to the driver.

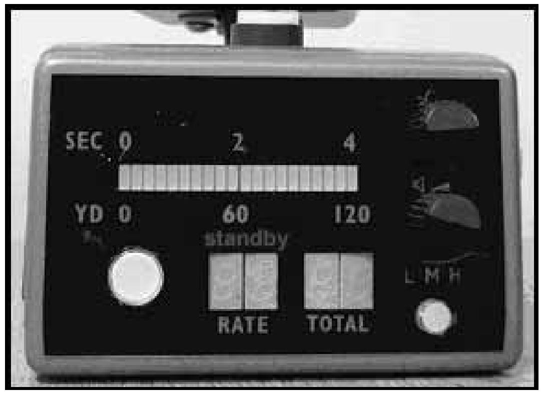

Figure 15. Standby State for DFM in Active Mode

The active mode was operational for speeds above 35 mph and ambient illumination of less than 50 lux. Active mode was indicated by a green light on the display (Figure 16). In active mode, the driver could interact with the system through the DVI controls and adjust display brightness, warning volume, and warning sensitivity as well as select a warning sound.

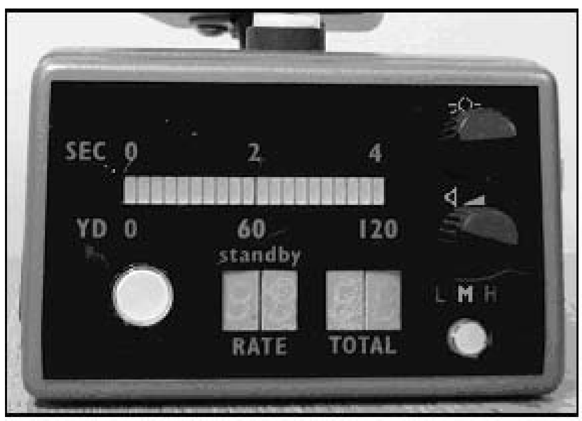

Figure 16. Active Mode Operating in DFM

If PERCLOS rose above the initial warning threshold, a single advisory tone was sounded, but the PERCLOS calculation was not reset. If the PERCLOS continued to rise to the full warning threshold, the selected warning sound was repeated at a 1-Hz rate and a visual warning was produced (Figure 17) until the driver responded by pressing the warning response button.

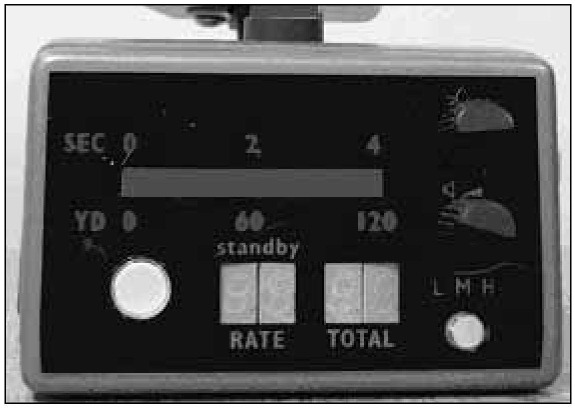

Figure 17. Visual Warning Produced After PERCLOS Reaches Full Warning Threshold

This action silenced the warning tone and displayed information relevant to the warning and warning history. The bar display showed the duration of the longest eye closure identified during the PERCLOS calculation period. The total number of warnings and the warning rate in units of warnings per hour was also displayed numerically (Figure 18). The information display cleared automatically 15 s later, or by pressing the warning response button one more time.

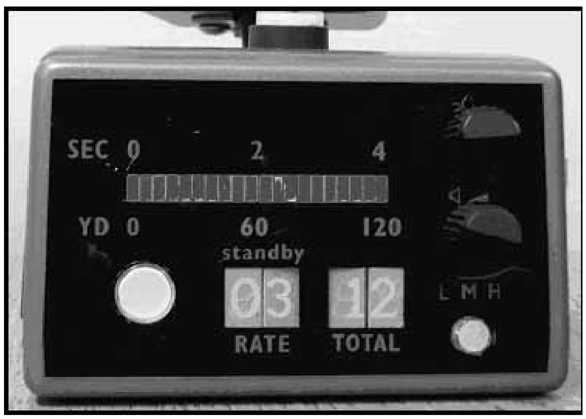

Figure 18. Information Displayed After a Warning Was Recognized

The other operation mode was the dark mode, activated by positioning the key-locked switch to the dark mode position (only experimenters performed this change). In dark mode operation, the user interface was disabled but data collection and calculations from the DFM remained active. While in dark mode the DFM operated in medium sensitivity mode as a default. Warnings were generated internally and the DFM responded to the warnings automatically after a 1-second delay. The driver was not aware of these virtual warnings but all data records were the same as when the warnings were actually delivered.

Data Acquisition System

The DDWS FOT instrumentation package was designed and developed over the past 15 years by VTTI personnel. Previous versions of the system have been used in several on-road studies. The system used for the FOT consisted of a Pentium-based computer that received and stored data from a network of sensors distributed around the vehicle. Data were stored on the system's external hard drive, which could store several weeks of driving data before requiring replacement.

System Capabilities

Each of the sensing subsystems within the instrumented vehicle was independent; thus, any failure was restricted to the faulty sensor. Sensors included a DFM, a box that obtained data from the vehicle network, an accelerometer box for longitudinal and lateral acceleration, a system that provided information on distance to lead vehicles, an incident box that allowed drivers to flag incidents for the research team, a video-based lane-tracking system that measured lane-keeping behavior, and video to validate any sensor-based findings. The video subsystem was particularly important as it provided a continuous display of the events and situations that occurred in and around the truck and trailer. Camera views monitored the driver's face, forward road view, and each side of the tractor trailer to observe the traffic actions of other vehicles behind and around the truck. The video system was digital, with software-controllable video compression capability. This feature allowed synchronization, simultaneous display, and efficient archiving and retrieval of DDWS FOT data. The DAS had other capabilities that provided the research team with additional important information. These capabilities included system initialization equipment to automatically control system status and a GPS positioning subsystem to collect information on vehicle position.

Data Acquisition System

The main DAS unit was mounted under the passenger seat for the day-cab trucks and trucks with sleeper berths without an air-ride equipped seat or an air conditioning unit under the seat (Figure 19). For those trucks with sleeper berths and no room under the passenger seat, the systems were mounted in a compartment on the side of the truck (Figure 20).

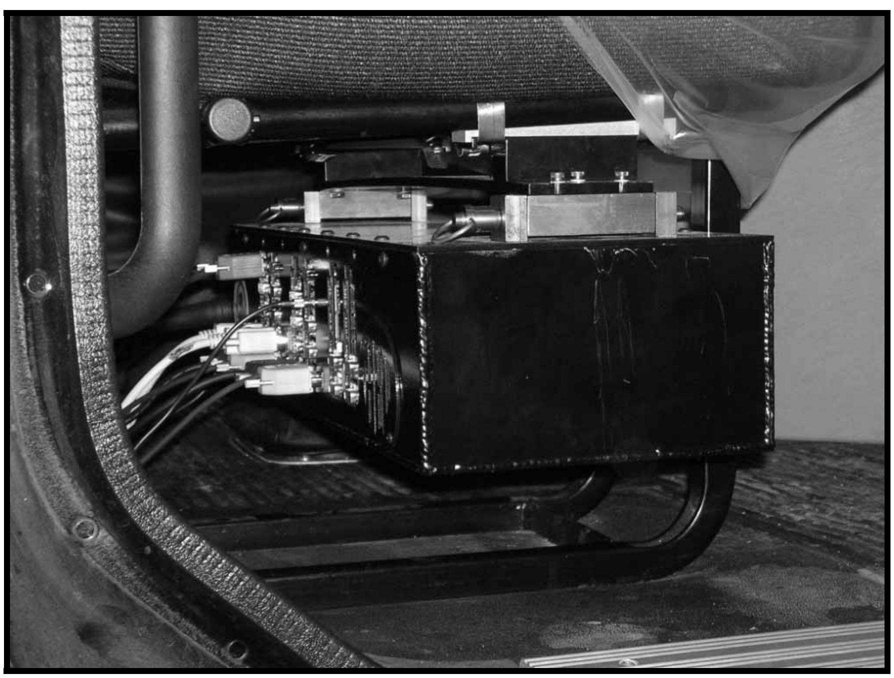

Figure 19. The Main DAS Unit Mounted Under the Passenger Seat

Figure 20. The Main DAS Unit Mounted in a Compartment Located on the Side of the Truck

Some components were mounted in the center of the windshield as far up on the glass as possible without being obscured by the sun visors. Some visors were specially designed with a cutout. DAS components included an incident push button that the driver could press whenever an unusual driving event occurred. An unobtrusive miniature camera for the driver face view was also contained in the housing for the pushbutton. The camera, mounted behind a smoked Plexiglas® cover, was invisible to the driver. The forward-view camera and the glare sensor were mounted near the incident box (Figure 21). The two rearward-facing side cameras were mounted on the outside rear-view mirrors on each side of the truck (Figure 22).

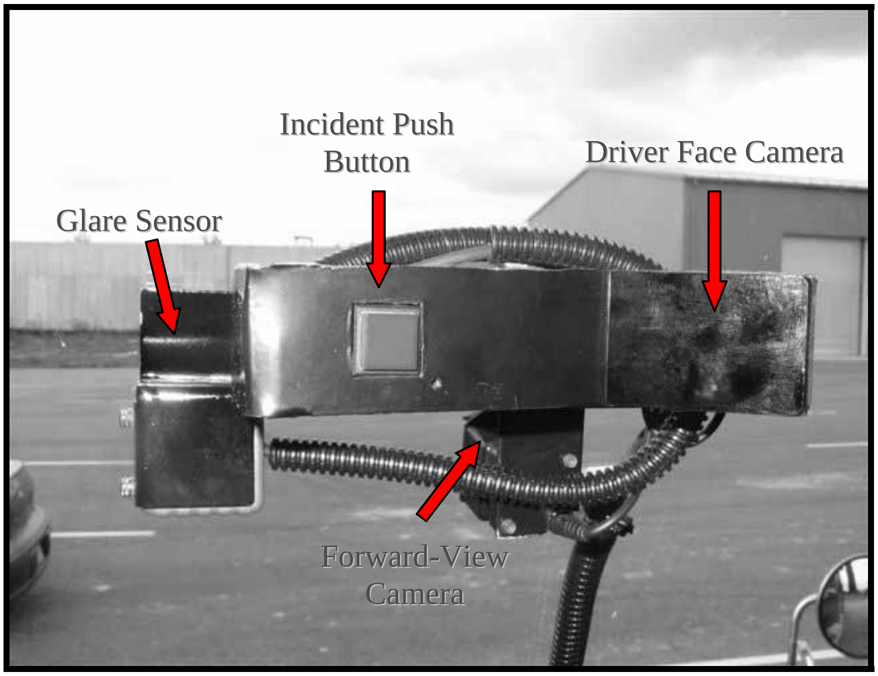

Figure 21. The Incident Push Button Box with Glare Sensor and Forward Camera

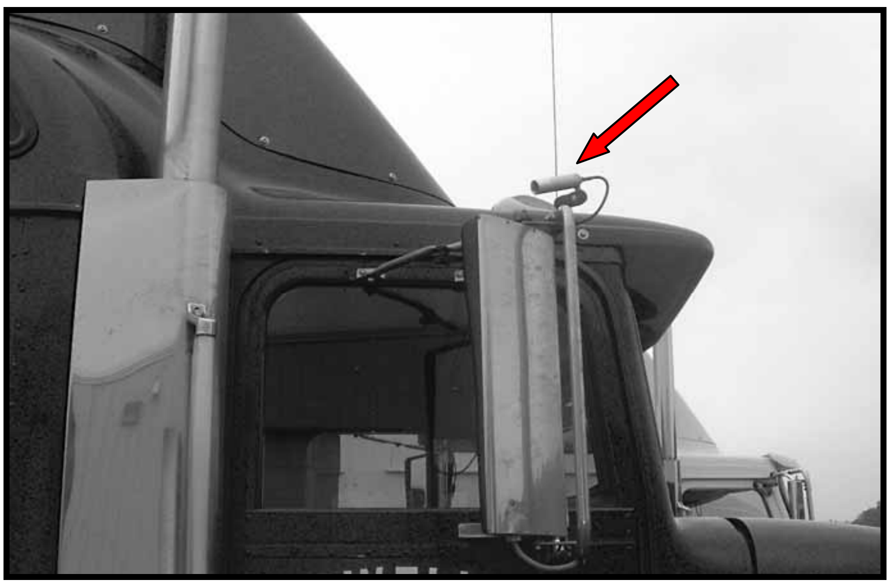

Figure 22. A Rearward Facing Side Camera Mounted on the Outside Rear-view Mirror

A description of each of the DAS components in the DDWS FOT is provided in the sections below.

Additional Sensors

Seat acceleration. An accelerometer was instrumented on the underside of the driver's seat. This accelerometer measured the vertical acceleration (*g*) of the driver's seat and logged it as synchronized data at a rate of 10 Hz. This method was consistent with the latitudinal and longitudinal acceleration data collection techniques included in the 100-Car Study (Dingus et al., 2006).

Glare sensor. The outside ambient illumination level was recorded by a glare sensor as part of the incident box mounted to the windshield facing out toward the front of the truck (Figure 21). Note that the ambient light level inside the truck was measured by the DFM.

Incident push button. When the driver was involved in a critical incident, he or she would push a red button on the incident box (right red arrow in Figure 23). Pushing this button allowed the driver to record a 30-s verbal report.

Microphone. A microphone was instrumented as part of the incident box to record the utterances of the driver when the incident push button was activated.

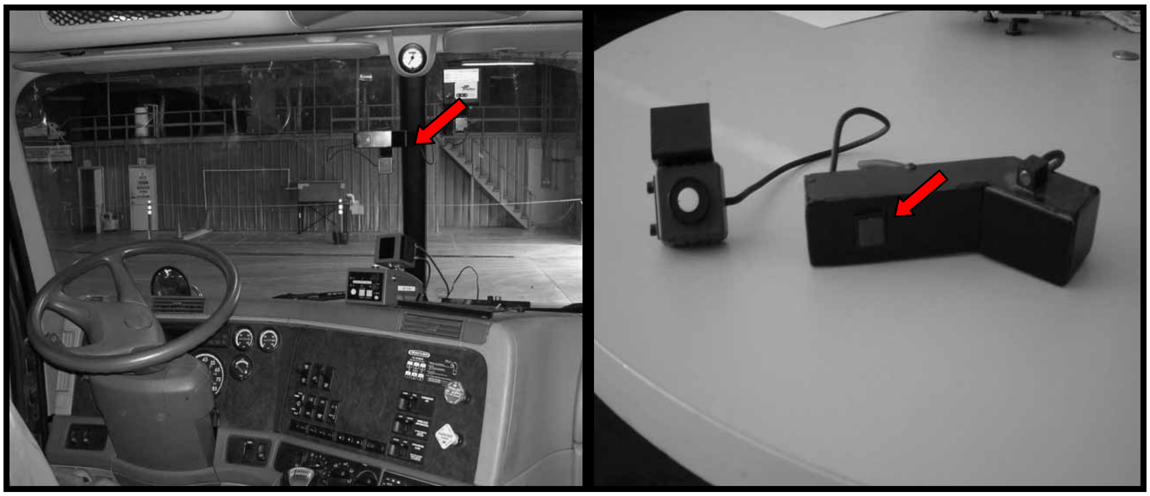

Figure 23. Incident Box ith Glare Sensor Shown Mounted on the Windshield (Left) and on a Tabletop (Right). In the Close-up, Note the External Microphone Mounted on Top of the Incident Box

Front VORAD. A radar-based VORAD unit installed on the front of the truck (Figure 24) provided a measure of range to lead vehicles. From the range measure, range rate and time-to-collision (TTC) could also be derived.

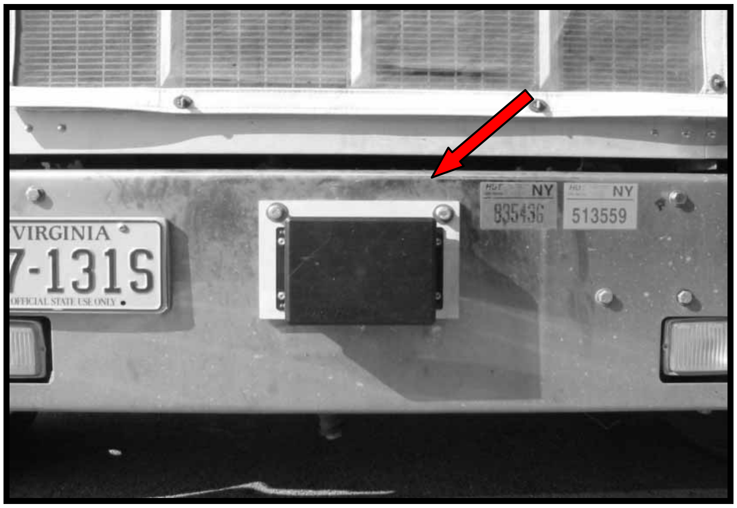

Figure 24. VORAD Unit on the Front of the Truck

Sound level. For measuring sound level, a Technika Detachable Probe Sound Meter (Figure 25) was used. Originally, VTTI's proposed design was to use a microphone interfaced to an analog circuit and then digitized. This approach would have been capable of classifying the ambient noise into three levels: low, medium, and high. The revised approach used an actual sound level meter that collected sound levels in dBA.

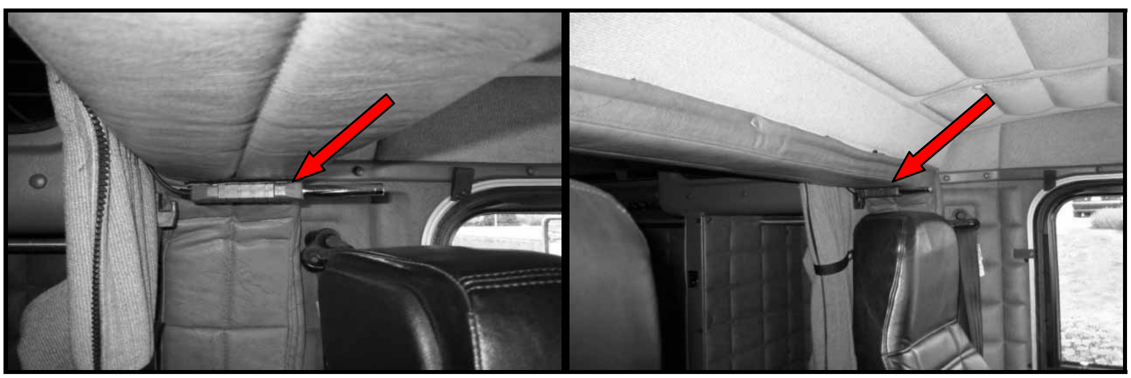

Figure 25. Sound Level Meter Instrumented in the Tractor

DFM. The DDWS that was used in the FOT was the DFM developed by ATI. A detailed description of the DFM can be found in the previous section. The DFM consisted of an IR camera, signal-processing electronics, and a DVI. The IR camera was mounted on top of the DVI and was used to monitor the driver's eyes. Shown in Figure 26, the DFM was mounted on the dash of the cab and positioned to the right of the center line of the driver (using the point between the driver's eyes as a reference point) as close as possible to the driver.

Figure 26. The DFM Mounted on the Dashboard of a Truck

GPS. The GPS device included in the DAS was used primarily for tracking the instrumented vehicles. Data output included measures of latitude, longitude, altitude, horizontal and vertical velocity, heading, and status/strength of satellite acquisition.

Lane tracker. A VTTI-developed lane tracker called Road Scout was included in the DAS. The Road Scout consisted of a single analog black-and-white camera, a PC with a frame grabber card, and an interface-to-vehicle network for obtaining ground speed (Figure 27). Note that the grabbed video frames were not stored but processed algorithmically in real time to calculate the vehicle position relative to road lane markings.

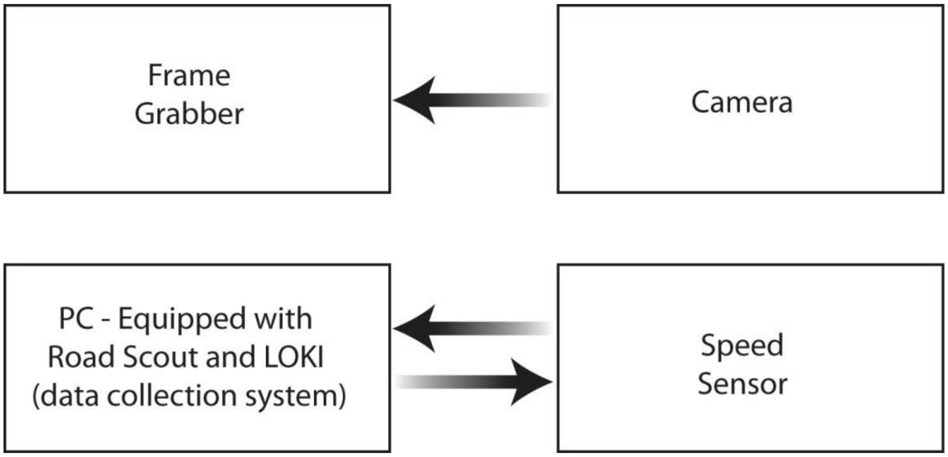

Figure 27. Overview of Road Scout

Road Scout could be configured to operate at 10 Hz on a 266 MHz Pentium PC or up to 30 Hz on an 800 MHz (or better) PC. The following variables were reported by Road Scout:

- Distance from center of truck to left and right lane markings (estimated max error < 6 in average error < 2 in);

- Angular offset between truck centerline and road centerline (estimated max error < 1°);
- Approximate road curvature;
- Confidence in reported values for each marking found;
- Marking characteristics, such as dashed versus solid and double versus single; and
- Status information, such as in lane or solid line crossed.

Once installed, Road Scout's software automatically calibrated to determine camera position; no elaborate calibration procedure was required.

Yaw rate. A yaw rate (gyro) sensor included in the DAS provided a measure of steering instability (i.e., jerky steering movements).

X/Y accelerometer. Accelerometers instrumented in the truck were used to measure longitudinal (x) and lateral (y) accelerations.

Vehicle network. SAE J1587 (SAE, 2002) defined the format of messages and data collected by on-board microprocessors. These microprocessors were installed on the vehicle at the truck manufacturing facility—not by VTTI. That is, the vehicle network refers to a from-the-factory on-board data collection system. Depending on the truck model, year, and manufacturer, there were several data network protocols or standards used with heavy vehicles, including those defined by J1939 (SAE, 2001), J1587 (SAE, 2002)/J1708 (SAE, 1993). After assessing the data requirements associated with the DDWS FOT, and in an effort to tap into a microprocessor network common to most trucks, it was decided that the data defined by J1708 would be accessed. An interface was developed by VTTI to access the data and bring it into the DAS dataset. Some of the measures accessed from the truck's vehicle network depended on the make, model, and year of the vehicle.

Video Cameras

Digital video cameras were used to record continuous video of the driver and the driving environment. Four video camera views—(1) forward, (2) driver's face camera, (3) rearward left and (4) rearward right—were multiplexed into a single image. Figure 28 shows the directions and approximate fields of view of the four video cameras. The forward and rearward camera views provided good coverage of the driving environment. The face view provided coverage of the driver's face and allowed researchers to conduct eyeglance analysis and manual drowsiness assessment.

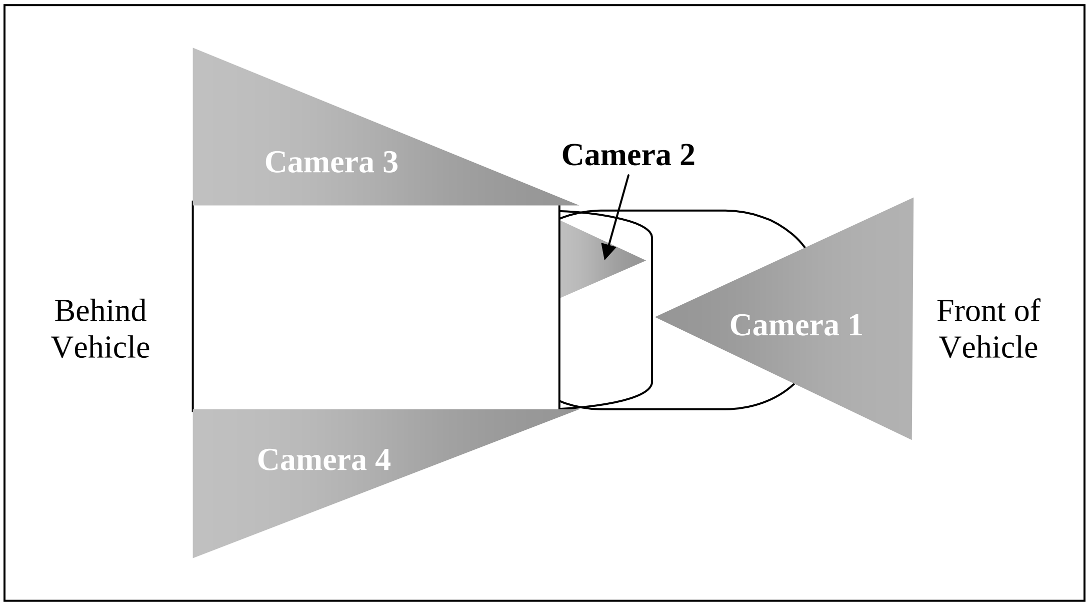

Figure 28. Camera Directions and Approximate Fields of View

The four camera images were multiplexed into a single image, as shown in Figure 29. A timestamp (MPEG frame number) was also included in the data file but was not displayed on the screen. The frame number was used to time-synchronize the video (in MPEG format) and the truck/performance data (in DAT format).

Figure 29. Split-Screen Presentation of the Four Camera Views

The digital video files did not contain continuous audio. However, as noted previously, the DAS was designed so that the drivers could press an incident push button and record a verbal comment lasting 30 s. This audio recording was contained in a separate PCM file, later to be converted to an MP3 file.

DAS Installation Process

The DDWS FOT DAS was highly capable and complex, yet had to be installed in company-owned vehicles without any permanent vehicle modifications. To achieve this, VTTI engineers developed customized brackets to utilize existing mounting holes in the frame of each vehicle. The brackets were designed individually based on bumper style, type of seat, dashboard, different placement of previously installed location units (e.g., Qualcomm), etc. Each installation was customized according to the make, model, and year of the vehicle.

Installation was completed by VTTI staff in 5–11 h. The trucks were chosen by the company's management based on reliability and accessibility to the participants. In general, sensors were mounted in different locations inside and outside the truck, with all cables running to the main system unit mounted somewhere inside the truck. All sensors were mounted as discreetly as possible, and all cables ran through ceilings, under floors and carpeting, and through plastic molding and compartments to be as unobtrusive as possible.

The trucking companies were accommodating to VTTI staff during equipment installation and removal and allowed covered garage space when possible. This contributed to a more efficient process due to protection from the elements and access to electricity when needed (for extra lighting or charging of portable tool batteries, for example). On occasion, VTTI staff members were granted access to welders, cutting torches, or air-driven tools on-site if a bracket needed modification.

Equipment Removal Process

De-installation consisted of removing all of the equipment associated with the DAS as if it were never installed and leaving the truck with all of its original equipment intact. The de-installation process was much quicker than the installation process as testing procedures, such as aiming cameras, terminating cables, and preparing the system box did not have to be performed. Again, the trucking companies allowed for covered space when possible.

PARTICIPANTS

Companies and Trucks

Three for-hire companies participated in this study. A for-hire company transports goods for several customers for a fee. The three companies that participated were Pitt Ohio Express, J.B. Hunt, and Howell's Motor Freight. Drivers were recruited in terminal locations throughout Virginia and North Carolina. One of these companies hauled mostly perishable items and used refrigerated trailers. The other two companies hauled primarily dry goods and used standard trailers. None of the companies had a union affiliation. See Appendix G for profiles of the participating companies. At the end of the study a fleet management survey (Appendix H) was sent to the terminal managers whose drivers participated in the FOT. This survey was filled out by four terminal managers.

A total of 46 trucks were instrumented for this research effort. Figure 30 shows the proportion of trucks per company. Figure 31 shows the proportion of trucks by make.

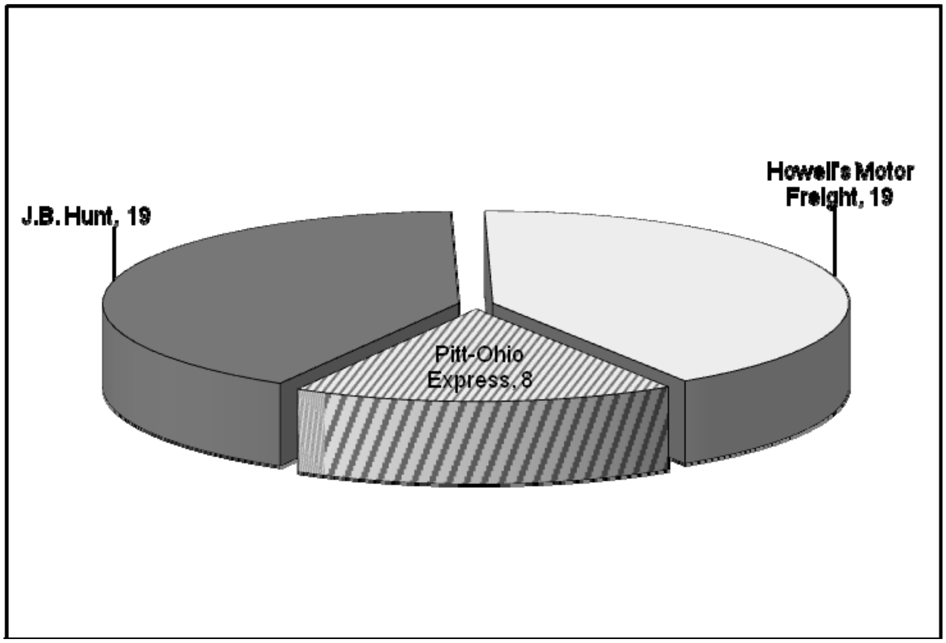

Figure 30. Proportion of Instrumented Trucks for Each Participating Company

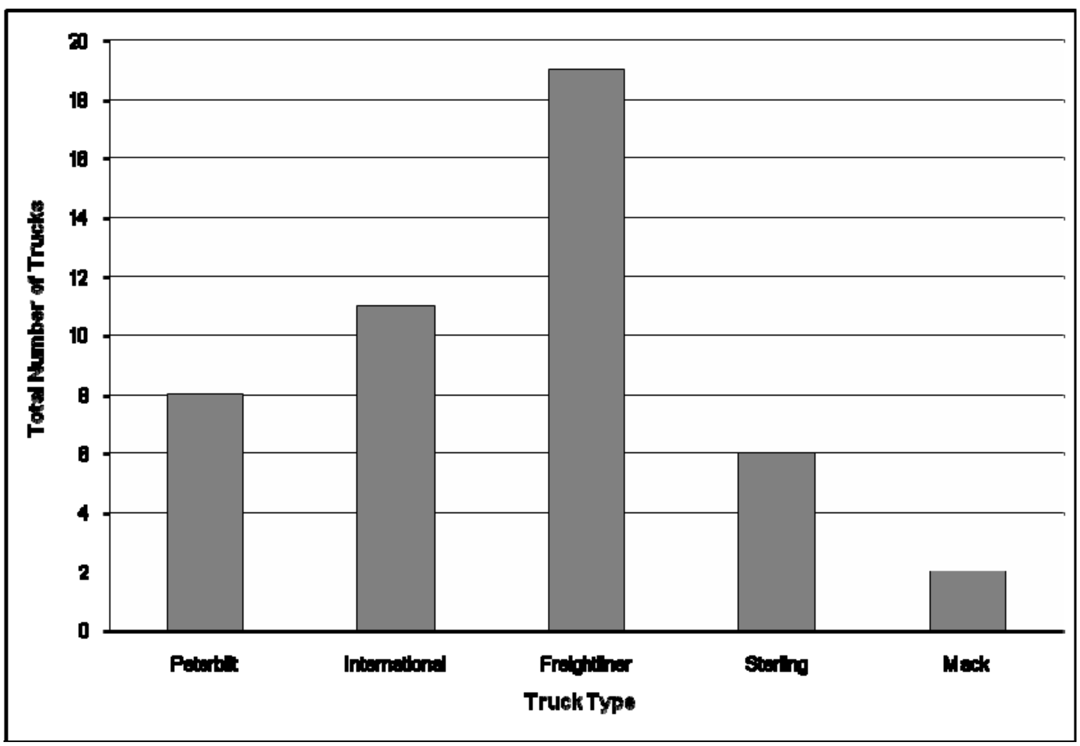

Figure 31. Proportion of Instrumented Trucks by Make

Drivers

The study involved 103 drivers: 102 males and 1 female. All participant drivers were recruited from one of three for-hire commercial trucking companies. Sixteen drivers from two Pitt Ohio Express locations participated in the study. Forty-six drivers from J.B. Hunt participated across six terminal locations. Howell's Motor Freight had 41 drivers participating in the study from two terminal locations. Figure 32 shows the proportion of drivers for each of the terminal locations.

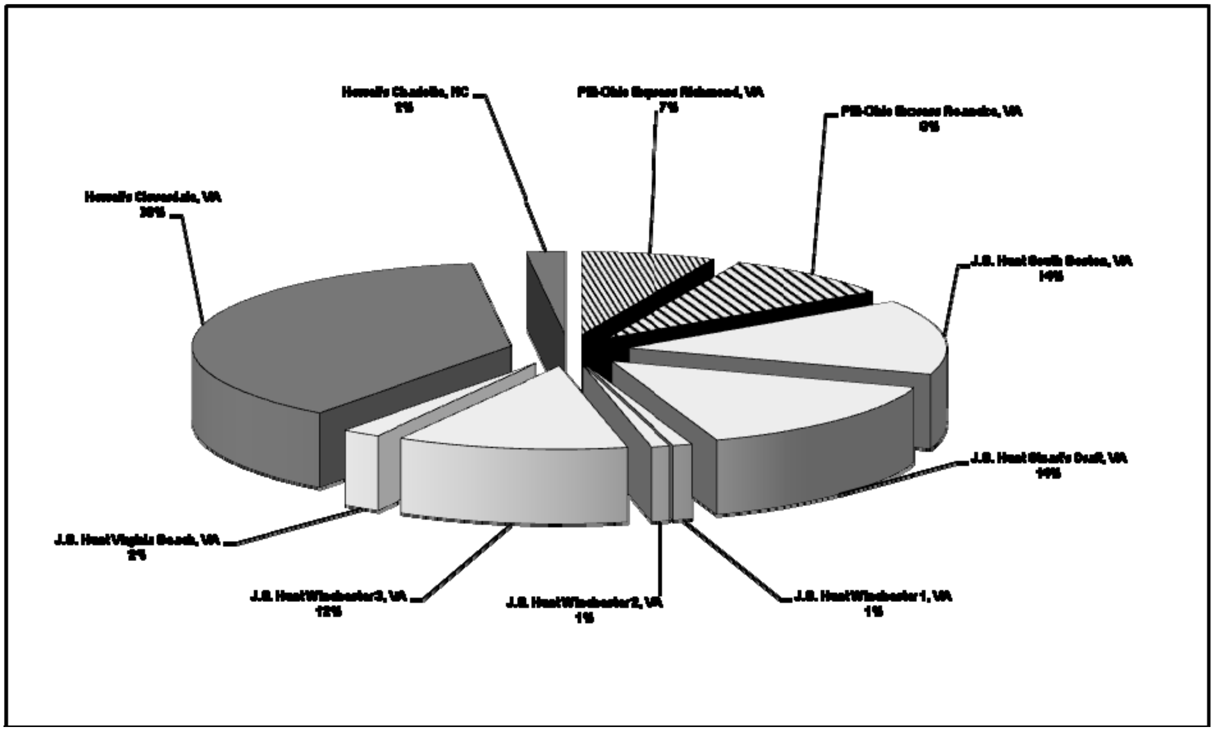

Figure 32. Proportion of Drivers per Company and Terminal Location

The average age of the drivers was 40.0 years (*SD* = 8.24 years) with ages ranging from 24–60 years. Figure 33 shows the drivers' age distribution. Drivers had an average of 10.6 years of driving experience (self-reported; *SD* = 8.37 years), ranging from 0.5–42 years. The majority of the participants were Caucasian-Americans (65%), followed by 29 percent African-Americans (Figure 34). Four percent were Native-Americans. Asian-Americans and Hispanic-Americans were the least represented with 1 percent each. Ninety-one percent (94 out of 103) of the participants reported education level. Of these 94 participants, 49 percent reported having some type of education after high school, 36 percent had high school as their highest education level, and 15 percent did not finish high school education.

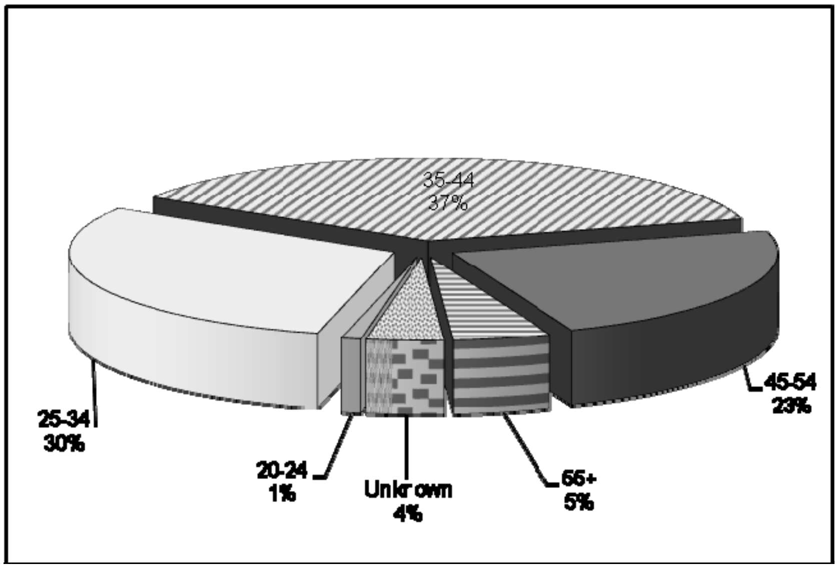

Figure 33. Drivers' Age Distribution

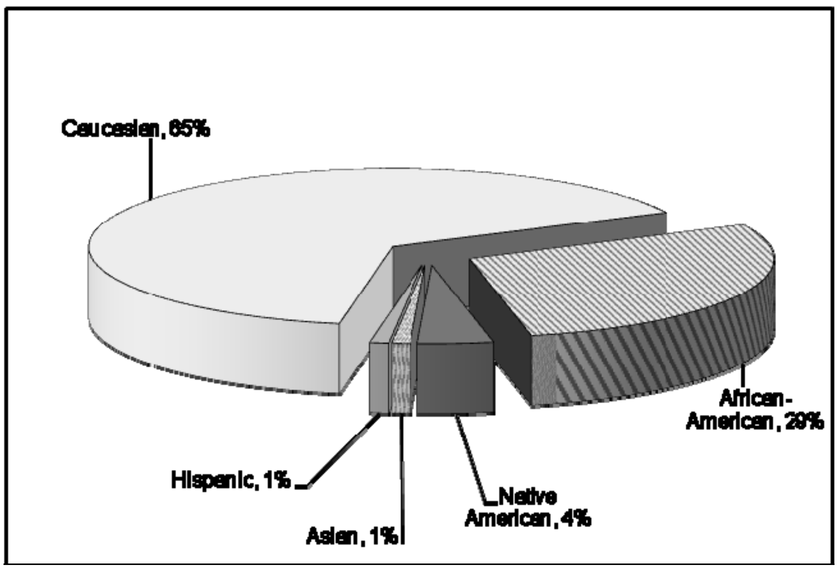

Figure 34. Drivers' Ethnicity Distribution

As mentioned previously, drivers participated in an experimental group or a control group. Drivers were randomly assigned to either an experimental group (exposed to the DFM's active mode) or to a control group (exposed to the DFM's dark mode). Of the 103 drivers, 79 were part of the experimental group and the other 24 drivers were in the control group. A total of 57 participants were line-haul drivers, and 46 were long-haul drivers. Table 5 shows how the participants were divided according to the experimental design modification under which their data were collected. Figure 35 shows the reasons why 22 participants did not complete the study (dropped out). In addition to the 22 participants who did not finish, data from seven participants who did finish their assigned weeks were later classified as incomplete because of missing data that resulted in fewer than the required number of valid weeks of data. For the 29 drivers who either dropped out of the study or did not have a sufficient number of weeks of data, the mean number of collected weeks was 6.81 weeks (*SD* = 4.19 weeks). Overall, the 103 drivers participated in the study for 12.48 weeks on average (*SD* = 4.04 weeks). The median number of weeks for the 103 drivers was 14. These numbers are very similar if the driver who used glasses is not considered (i.e., average = 12.53 weeks, *SD* = 4.02 weeks, median = 14 weeks).

Table 5. Number of Drivers by Experimental Condition Who Participated in the FOT

	Control	Experimental	Total
Modification 1	6	20	26
Modification 2	13	35	48
Dropouts/Incomplete	5	24	29
Total	24	79	103

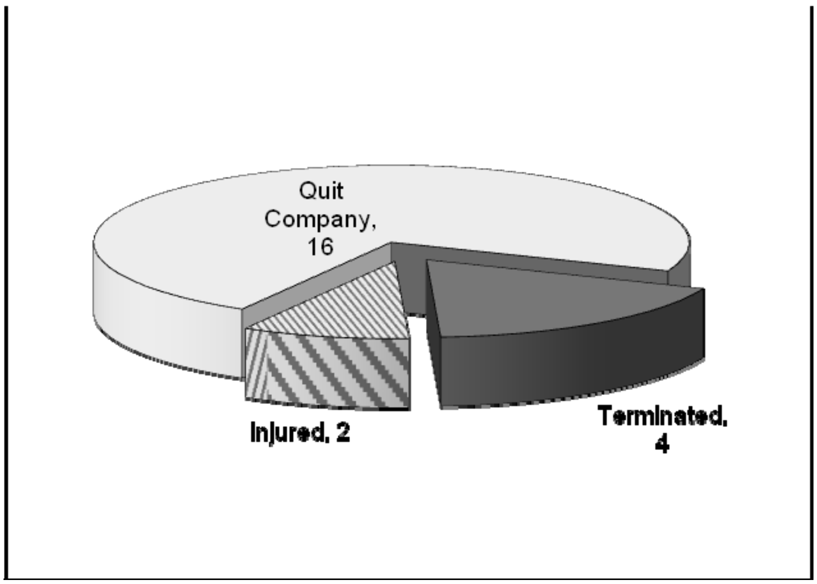

Figure 35. Reasons for Participants Dropping Out of the FOT

Experimental Procedures: Screening, Questionnaires, and Training

Drivers were recruited for the study, screened, and trained at nine terminals belonging to the three companies. First, the drivers were approached by VTTI researchers as well as company management. Recruitment flyers displayed at the different terminals also advertised the study. Participation was voluntary. Interested drivers were contacted and screened to assess their suitability for the study. As mentioned previously, a known limitation of the DFM is that it does not work reliably for drivers with glasses. Therefore, drivers with glasses did not participate in the study. Note that, to field-test the hypothesis that the system would not work reliably for a driver with glasses, one driver with glasses was tested after approval from the Volpe Center.

At the beginning of the screening, an informed consent form was given to the driver to be read and signed if he or she agreed to participate (Appendix I). The informed consent form provided information on the purpose of the research study, the procedure to follow during the study, the risks associated with the participation in the study, benefits, explanation of anonymity and confidentiality, certificate of confidentiality (Appendix J), compensation terms, and freedom to withdraw from the study. In addition, the document stated participants' responsibilities, agreement to participate voluntarily, and authorization to use participants' video data files. A copy of the signed informed consent form was provided to the driver.

The screening process included answering a pre-participation screening survey (Appendix K) and performing a test with the DFM in a static setting. The DFM test consisted of a DFM connected to a laptop computer fitted with special software that allowed VTTI researchers to determine the ability of the DFM to detect eye closure levels of the participant. The participant was seated in front of the DFM in a dark room. The participant was instructed to look toward the DFM with both eyes open and then close one eye at a time. The researcher used the software to read the DFM values for each case and determined if the DFM was properly detecting eye closure for that participant. The DFM was able to successfully capture the eye closure for all participants tested without any individual adjustments to the device. Following the DFM test, drivers were informally tested for normal or corrected-to-normal vision of at least 20/40 with the Snellen acuity test. The drivers' hearing was also informally tested using an Earscan MP Pure Tone Audiometer. Drivers were tested at 8 frequency levels (500 Hz, 1 kHz, 2 kHz, 3 kHz, 4 kHz, 6 kHz, 8 kHz). Criteria for driver eligibility in the study were as follows:

a) The hearing test results of each participant's better ear needed to be at or less than 40 dB at 500 Hz, 1 kHz, and 2 kHz with or without a hearing aid.
    - All participants passed this test with the exception of one. This participant wore a hearing aid in one ear and therefore failed the hearing test for that ear. However, with Volpe's approval, the driver was permitted to participate in the study and assigned to the control group in which no auditory alarm would be presented during data collection.

b) The result of the second test with the 1 kHz tone on the same ear needed to be within ±10 dB of the result of the first test. If the result of the second test exceeded the first by ±10 dB, then the entire test was to be re-administered for a more accurate reading; however, such re-administration was not required for any of the drivers in this study.

Each driver who agreed to participate in the study was assigned to either the experimental group or the control group. Both experimental and control group drivers were exposed to basic fatigue training. This fatigue training was approximately 2 hours in length. Drivers in the experimental group were then given an explanation of the DFM lasting approximately 0.5 hours. Each driver was then given a pre-study survey to complete and return to the experimenter (Appendix L for experimental group and Appendix M for control group). Though most drivers completed this on-site, a few drivers took it home to complete and returned it prior to the start of their data collection. These few exceptions were made to accommodate drivers who had job-related time constraints. Final instruction on the DFM was given at the beginning of the drivers' data collection. The experimental group drivers were provided with a reference sheet outlining the DFM functions.

Basic fatigue training. Each participant received approximately 2 hours of basic fatigue training. All drivers and fleet managers were invited to participate in the fatigue management session. This training was presented in small groups (i.e., 2 to 6 drivers) or one-on-one sessions. The fatigue training was often scheduled at the same time drivers filled out the surveys and took the screening tests (i.e., hearing, vision, DFM). Scheduling the fatigue training was a challenge because the training, as well as driver screening, needed to be conducted at opportune times when drivers were back at the home terminal and available. Because of the 14-hour HOS limit on driver daily tours of duty, the time spent in fatigue training counted against available daily work hours. When possible, the classroom training was conducted within 2 weeks prior to the start of the test period for the participant.

The fatigue training was based primarily on a PowerPoint program entitled "Understanding Fatigue and Alert Driving," which, though modified, was previously developed by the American Transportation Research Institute (ATRI, formerly the American Trucking Associations Foundation) with funding from FMCSA. Appendix N provides the PowerPoint slides used for this training. Major topics addressed in this program include:

- How serious is the problem?
- What is fatigue, and what causes it?
- Effects on driver alertness and performance;
- Sleep, circadian rhythms, and shift work;
- Effects of drugs and alcohol;
- Sleep disorders; and
- Improving sleep and alertness.

Much of the content of the ATRI presentation was retained, although it was reformatted and many new graphics were added. Slides were added or significantly revised on the following topics:

- Fatigue crash statistics;
- Signs of fatigue while driving;
- Fatigue crashes rates by hour-of-day;
- Crash risks: day versus night driving;
- Findings from FMCSA sleep apnea study;
- Individual differences in fatigue susceptibility;
- Alertness and fatigue in solo versus team driving; and
- Accuracy of fatigue self-assessment.

Participants were given hard copies of the slides formatted three-to-a-page with space for note taking. The instruction in the group settings was approximately one-half lecture/presentation and one-half discussion. Providing ample opportunities for discussion seemed to increase driver interest and involvement in the topic. Drivers would often compare the information presented to their own personal experience and behavior. For example, they often talked about the amount of sleep they got and their sleep patterns and practices. The discussion was always friendly and frequently spirited.

This training segment did not include instruction on the DFM, but it did include some background information on physiological signs of drowsiness, including eyelid droop (PERCLOS). Sleep hygiene "do's" and "don'ts" and operational strategies for reducing fatigue in long-haul driving received considerable emphasis.

DFM instructional sessions took place immediately after the fatigue management session (Appendices O and P). The session explained the DFM's purpose, components, and operation.

Drivers were instructed to use an Actigraph watch (Figure 36) on the wrist of their non-dominant hand. An actigraphy unit is a wristwatch-type activity-monitoring device used to assess a participant's sleep quantity and quality. The device was the size of and worn as a wristwatch. The unit provided an indication of whether or not the person was moving and stored the data as a function of time. The device was self-contained and made no electrical contact with the person wearing it.

Figure 36. MicroMini Motionlogger Actigraph

After the driver had strapped on the Actigraph watch, he or she was taken to the instrumented truck. The on-road data collection began once the driver became comfortable with the data collection procedure. Participants drove the instrumented trucks as they normally would for their jobs. The drivers were informed that they would have to meet the researchers approximately once a week to download data from the trucks, download data from the watches, and check the data collection systems.

Drivers' participation typically varied from 10–16 weeks of data collection. Various factors affected the length of drivers' participation. When the data collection was completed, the driver had to complete a post-study survey (Appendix Q for the experimental group and Appendix R for the control group) and a debriefing survey (Appendix S for the experimental group and Appendix T for the control group). Drivers were paid for their participation either at the debriefing or by mail.

Participants' compensation consisted of $50 for the screening, fatigue management, and DFM sessions, $75 per week of data collection, and a $250 bonus. The bonus was paid to the drivers who completed the data collection period, filled out all the paperwork and surveys, and returned the Actigraph watches given to them. Participants who dropped out of the study before the stipulated time were paid for the time they participated.

Participation Confidentiality

The data gathered in this experiment were treated with the strictest confidence. Drivers' names were separated from the data and replaced with numbers as soon as data collection started. The video and other data from this study have been stored in a secured area at VTTI. Access to the digital video files has to be under the supervision of the principal investigator and lead researchers involved in the project. The video files are accessible to the government sponsor and to those researchers and data analysts associated with this project and for follow-up analytical projects at VTTI and the Volpe Center. The video files will not be released to unauthorized individuals without the participant's written consent.

A Certificate of Confidentiality was obtained, which grants confidentiality to research participants (Appendix J). This confidentiality is provided by the Public Health Services Act (§ 301(d), 42 U.S.C. 8241(d)). It ensures protection against compulsory legal process for personally identifiable research information. For this reason, the driver's data cannot be given to the participant or anyone else.

CHAPTER 5. DATA MANAGEMENT

DATA RETRIEVAL

Video and Dynamic Sensor Data

To retrieve data collected from the instrumented vehicles, VTTI researchers met with participants at pre-determined locations, such as freight company terminals and truck stops. Meetings were typically scheduled every 10 to 14 days (as the storage capacity of the smallest hard drives could store approximately 21 days of data). The hard drives used to store video, audio, and dynamic sensor data from the DAS were encased in a metal shell with a computer interface on one end for communication with the DAS (Figure 37).

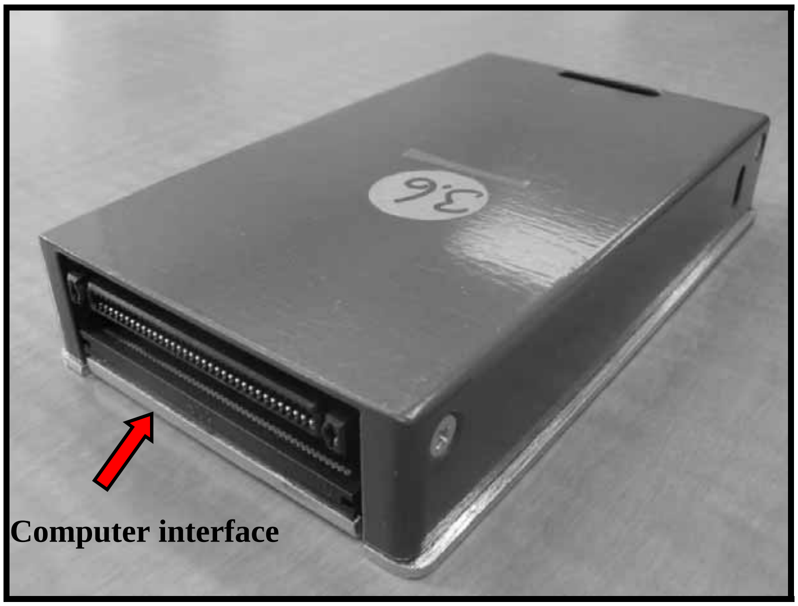

Figure 37. Removable Hard Drive Used for Data Collection

These hard drives were installed in a lockable bay interface on the DAS. During each meeting with the participant, VTTI personnel unlocked and removed the hard drive from the DAS and inserted a blank hard drive into the DAS drive bay. The blank drives were secured in the DAS with a key (circled in red in Figure 38), and the DAS was checked to verify the new hard drive was working correctly (i.e., the DAS booted up with the new hard drive installed).

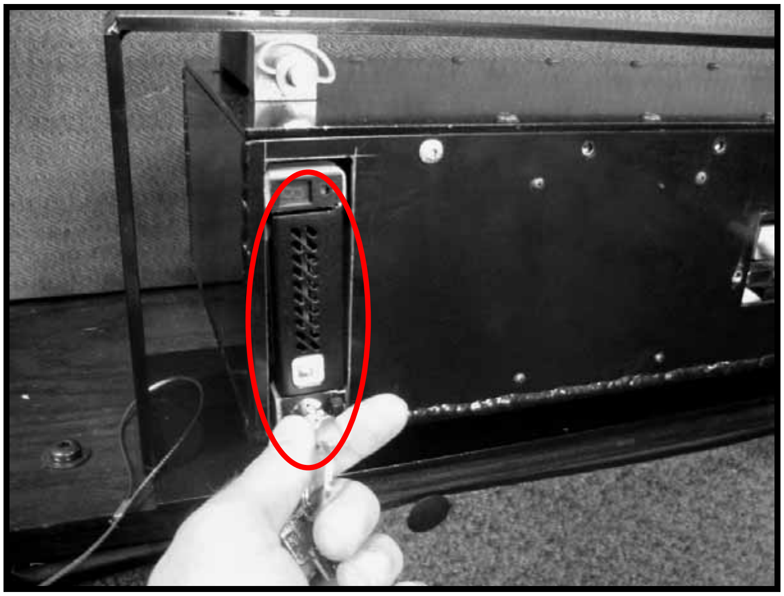

Figure 38. DAS with Installed Hard Drive and Locking Feature

After removing a hard drive from the DAS it was labeled with identifying information, including the company's truck number, truck ID number, participant ID number, date of removal, and hard drive number. The removed drives were returned to VTTI either by VTTI personnel or by an on-site assistant through an express delivery service. On-site assistants shipped the hard drives in a small box that contained no more than four drives packed in protective bubble wrapping. Blank drives were shipped to on-site assistants in the same manner. Once the hard drives arrived at VTTI, the data were downloaded and stored. After the data were securely downloaded from the hard drive, the drive was reformatted and stored for future use.

Actigraph Watch Data

During meetings with drivers, data from the motion logging Actigraph watches were also downloaded (this always occurred on-site). The downloading apparatus for the Actigraph watch consisted of an Actigraph interface connected to a laptop computer with a DB9 serial cable (Figure 39).

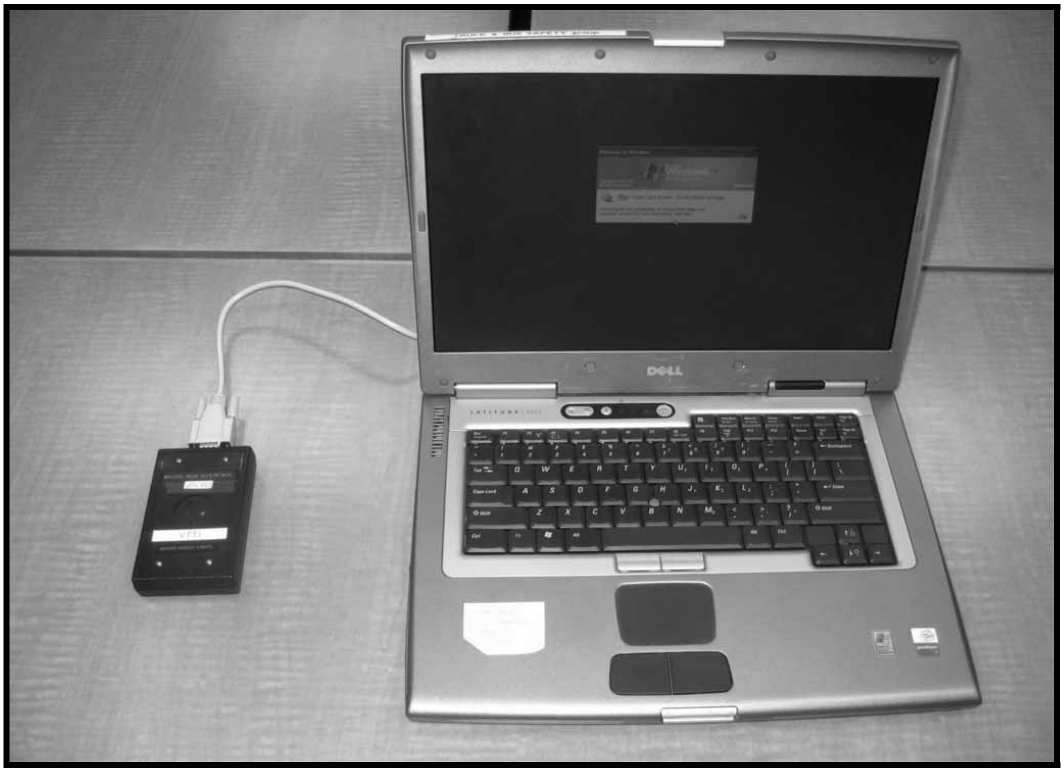

Figure 39. Actigraph Download Apparatus

To download data from the Actigraph watch, the watch was placed on the Actigraph interface (Figure 40). Special software called Act Millennium was used to download the data from the Actigraph unit to the computer. The download time varied with the amount of data stored on the watch but typically was completed in 10 minutes. Once the data were downloaded, it was saved to a laptop computer with a file name that reflected the three-digit participant number followed by the date of download (i.e., ###_mmddyy).

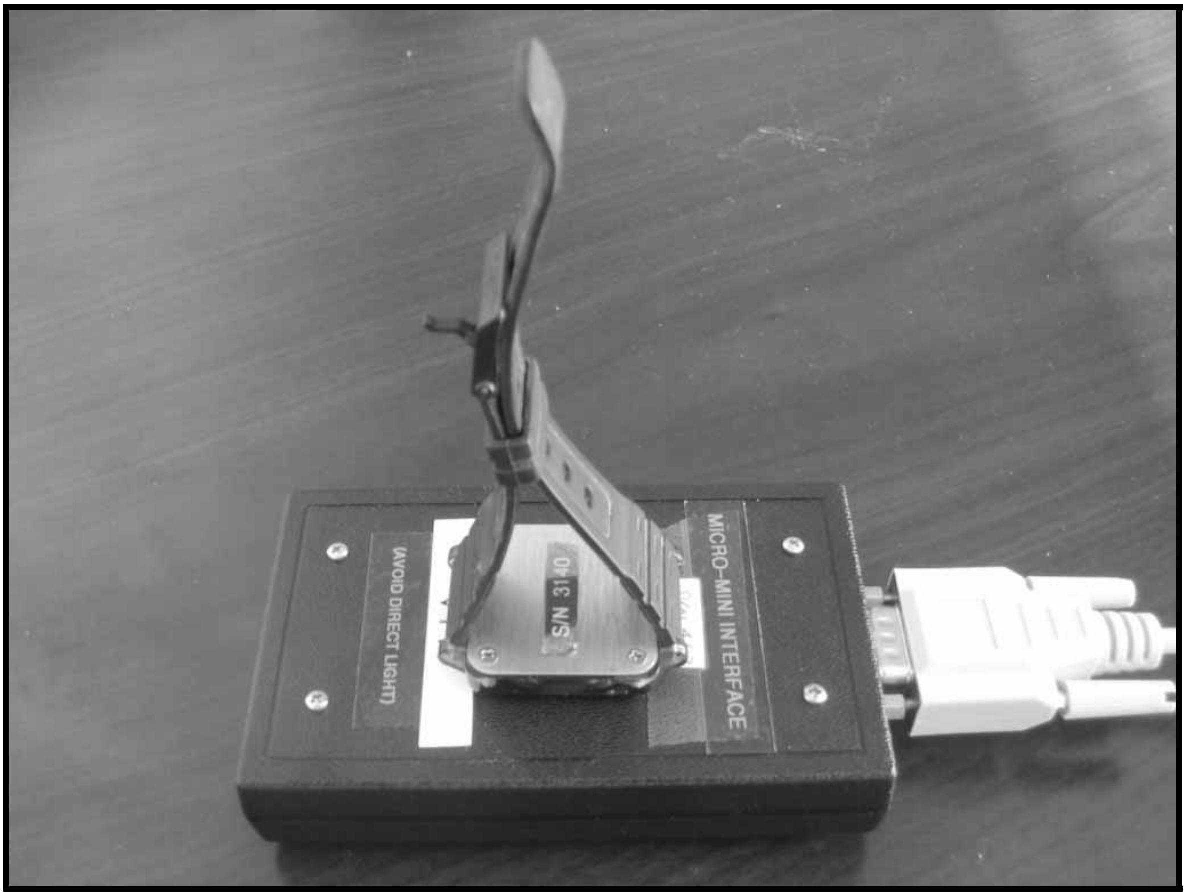

Figure 40. Actigraph Watch Placed on Interface

The downloaded Actigraph file was viewed using Action4 software (provided by Actigraphy distributor) to verify the participant was wearing the Actigraph watch as instructed (Figure 41). The Action4 graph plotted motion (y-axis) versus time (x-axis). Flat lines in the data graph (highlighted in Figure 41) corresponded to time when the participant removed the Actigraph watch. If the data indicated the driver had taken off the Actigraph watch for an extended period of time, research assistants were instructed to reiterate the instructions to the driver to consistently wear the Actigraph. Once the data were downloaded and verified, the Actigraph watch was reinitialized, using the interface and the Act Millennium software, and returned to the driver. Upon return to VTTI, the data downloaded from the Actigraph watch were processed and stored.

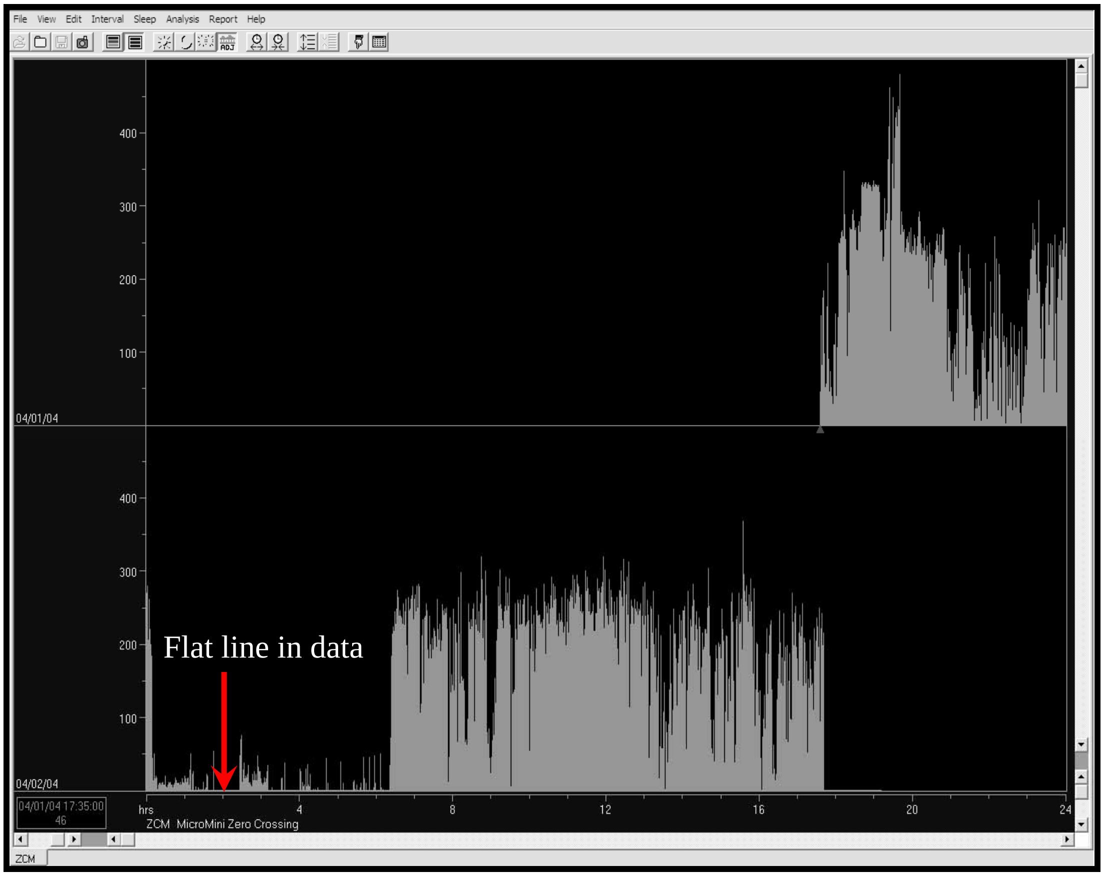

Figure 41. Action4 Software Displaying Collected Motion Logger Data From an Actigraph Watch. Flat Line Indicates That the Watch Was Removed

DATA STORAGE

The data storage system at VTTI was used to perform three main tasks:

1) Collect, configure, and routinely deliver large sets of current driving data to the Volpe Center.
2) Maintain all driving data, including video, on the storage system for immediate availability to data reductionists. The very large capacity and speed of the storage system made it possible to perform data reduction tasks across all accumulated measurements and video data without the need for time-consuming swaps of smaller data subsets between live and archived datasets.
3) Create a backup of the original data and archive all reduced data and results files. Please note that both the backup and archival data sets were stored at an off-site location.

Storage system requirements for quick file access and very large storage capacity resulted in the use of a storage area network design. The SAN hardware consisted of 10 arrays with 15 hard drives each, all managed through a proprietary SAN controller addressed via the networked server. One of the arrays was made up entirely of very fast fiber channel drives and served as the front end through which new data was loaded, checked, configured, and stored onto the back end arrays (larger but slightly slower hard drives). Each of the drive arrays had a standby hotswappable hard disk that automatically replaced a failed drive. All drive arrays were configured with RAID5 protection that enabled rebuilding of a failed drive, thereby allowing recovery of all data files from the lost drive. In fact, of the 150 hard drives within all of the SAN array enclosures, about 20 hard drives failed or indicated error conditions during the project that required hot-swap drives to automatically replace the defective drives. In all cases, no data were lost and the system remained continuously operational.

Figure 42 shows a diagram of the path taken by the driving data as they were downloaded from the instrumented trucks' removable hard drives to the SAN. Then, these data were configured for various tasks and output for data deliveries and data backup and archiving. Three primary datasets were configured within the storage system, including:

1) Volpe shipments: binary data files, ASCII text files, video files, unique binary file translator, data verification listing, file directory listings for the current dataset, truck and driver documentation files, and associated notes and/or updates regarding current and/or past data shipments.
2) Backup/archive datasets.
3) Binary and video files, ordered by driver and truck number, for VTTI data reduction and analyses.

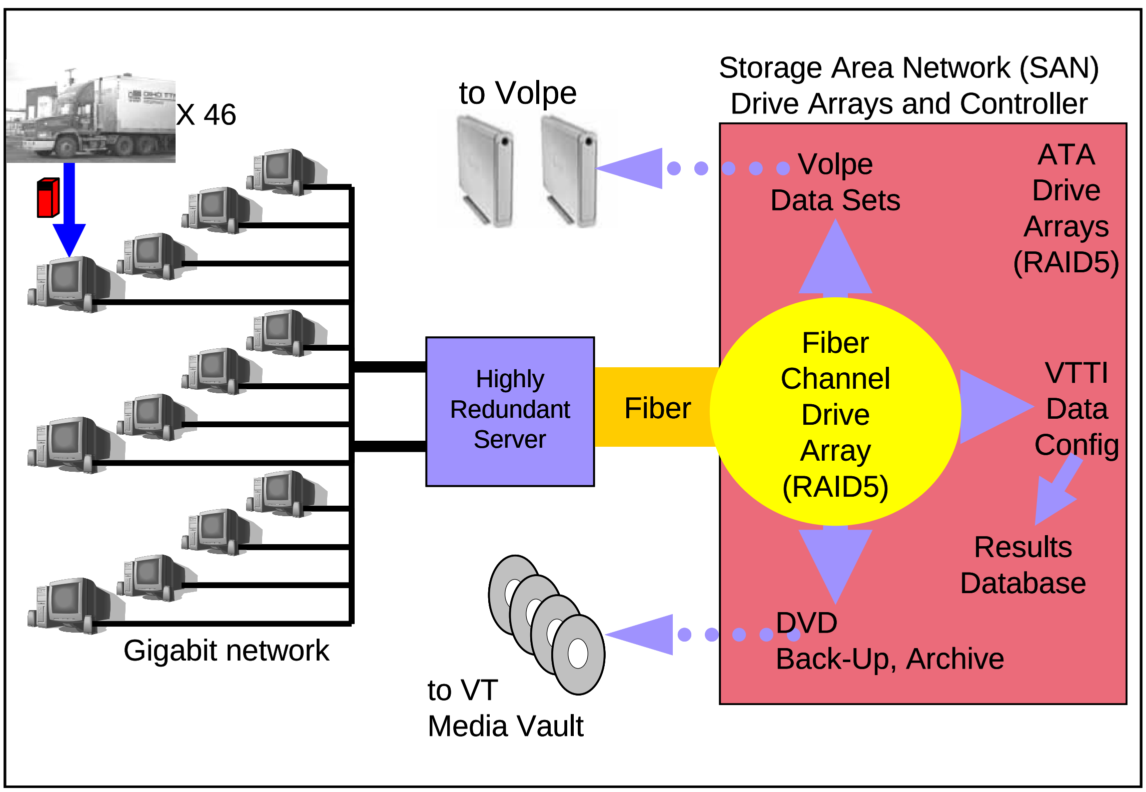

Figure 42. Data Storage System Diagram

Figure 42 also identifies several of the data protection features and productivity optimization decisions embodied within the SAN design, specifically:

- Twelve PC workstations and a SAN-dedicated server on a gigabit network.
- Highly redundant server design. Dual central processing units, power supplies, fans, disk controllers, and mirrored (RAID 0) hard drives (+3rd hot-spare drive) enabled continued operation in the event of single component failures.
- Extremely fast fiber-optics communications between server and SAN.
- Fast front-end fiber channel drives for current data storage and configured datasets across the SAN by task.
- Back-end storage of large ATA drive arrays for long-term storage, data reduction, and mid-term dataset backups.
- Hot-swap hard drives for front- and back-end hard disk arrays allowed immediate replacement of a failed drive.
- RAID 5 data protection was used across the SAN (enabled fast drive re-builds onto a hot-swap drive if an arrayed hard disk failed).
- DVD backup/archive datasets were maintained in an off-site storage location at the Virginia Tech Media Vault. At the vault the disks were indexed into a locked metal cabinet within a limited-access, temperature- and humidity-controlled vault (these services were offered free-of-charge by Virginia Tech).
- High-capacity (500 GB, or 0.5 TB) external hard drives were used to deliver large datasets to the Volpe Center on a biweekly basis.

DATA SUBMITTED TO THE VOLPE CENTER

Data Collected with Instrumented Trucks

Naturalistic driving data was collected from 103 drivers operating 46 instrumented trucks. During the DDWS FOT, VTTI was responsible for regularly delivering video and dynamic sensor data collected from instrumented trucks to the Volpe Center. In all, 37 biweekly data shipments were completed (referred to as Datasets 1–37 in this report). Some top-level results for the amount of data collected and sent to the Volpe Center include:

- Approximately 46,000 driving-data hours covering 2.3 million miles traveled;
- More than 250,000 data, video, and ASCII text files (278,900 files total); and
- Approximately 11.8 TB of data from video and dynamic sensor files.

The files were stored on one or more 500-GB external hard drives equipped with high-speed USB2, Firewire400, and Firewire800 connections that allowed fast and convenient copying of the data.

Each shipment to the Volpe Center contained 10-Hz binary data files, ASCII text translations of most binary variables (Volpe-designated), MPEG-1 hardware compressed video from four cameras operating at 29.97 Hz, MP3 compressed audio files containing short recordings initiated by the drivers with event-button activation, and associated documentation files. VTTI pre-sorted and categorized the data, video, and sound files into folders labeled as the following:

- DataFiles: contained all the normal/good DAT (binary) and MPEG file pairs. Each file (pair) covered no more than 45 min of driving data. Also included in these files were ASCII TXT file translations of all binary data files.
- BadFiles: contained defective DAT files for which the corresponding MPG files were good, or vice-versa. Since each file pair could not be time-synchronized for video and data comparisons, these files were stored in the BadFiles rather than in the DataFiles folder with the normal/good file pairs. Text file translations of all binary data files were included.
- MismatchedFiles: contained the binary files for which no corresponding MPEG video files were recorded or vice-versa. Also included were ASCII text file translations of all binary data files.
- SoundFiles: contained MP3 files generated by a driver depressing an incident button in the truck's cabin. When the button was pushed, a cabin microphone was activated for 30 s. An additional button push within that 30-second period extended the audio file for 30 s beyond the new button press.

Moreover, associated documentation files were also stored on the hard drive(s) shipped to the Volpe Center. These documentation files were labeled "Stuff" and included the following:

- A ReadMe file providing detailed information about the current and/or past datasets.
- The September 6, 2004, version of the VTTI-authored binary data translation executable file, "DataTranslate.exe." This program was used by VTTI to translate all binary DAT files to ASCII TXT files.
- One or two comma-separated value files with data channel verification information for all binary data files collected through the current dataset (e.g., "dataverify thru dataset25.csv" and "dataverify datasets26-32.csv" for the Dataset 32 shipment). Software scans of the data within each variable of each DAT file were performed, and the data quality for each variable was rated as either a 1 if few problems were evident or a 0 if a significant portion of the data values were suspect.
- A "Driver ID pic's" folder providing video frame-grab pictures of all the participant drivers.
- An Excel workbook file specifying, by truck ID and driver ID, the beginning and ending dates for the driving data collected during the dataset period.
- A "FileLists" folder containing detailed directory listings with information about all the files within the dataset (both as provided on the hard drive as well as on the VTTI data storage system).
- A file named "WrongDriverFiles since DataSet#.txt," listing the files in which VTTI determined that a non-subject driver was operating the truck. It was recommended that these files be removed from the Volpe database.
- A file named "First and Last Datasets for FOT-34 Drivers," listing the Dataset/Batch numbers corresponding to the first and last collected data files for each driver.

OTHER DATA COLLECTED

In addition to the on-road driving data, VTTI provided Volpe with non-driving data including load history, actigraphy data, and study surveys.

Load History

Load history data was collected from each driver. Information included departure time, return time, mileage, and destination for each load the drivers delivered. VTTI created load history files by compiling load history reports from the previous month for each driver. These data files were sent to the Volpe Center via e-mail. VTTI delivered a total of 397 load history files from 103 drivers who participated in the FOT. Per the Volpe Center's request, VTTI also made copies of the load history files and mailed the CD to the Volpe Center.

Actigraphy Data and Data Recording Sheets

VTTI also sent Volpe the actigraphy data collected from each driver along with the data recording sheets. The data recording sheets included dates for when the actigraphy data was collected and initialized, success or failure of the initialization, battery and memory status of the Actigraph watch, and the approximate dates and times when drivers removed the watch for more than 3 hours. These data files were sent to the Volpe Center via e-mail approximately twice per month. VTTI delivered a total of 598 actigraphy data files and 356 data recording sheets for approximately 8,000 days' worth of actigraphy data.

Pre-Participation, Pre- and Post-Study, Debriefing, and Fleet Management Surveys

Researchers at VTTI checked the surveys to ensure all questions were completed and each driver's answers appeared valid. If a question was left incomplete or the research assistant questioned the validity of the driver's response, per Volpe Center's request VTTI contacted the driver and asked him or her to complete the questionnaire or to explain the problematic answer. This process continued until all the questions were completed (the verification procedure for the survey is in Appendix U). Then, copies of the completed surveys (pre-participation, pre-study, post-study, debriefing and fleet management surveys) were mailed to the Volpe Center.

PROGRESS UPDATES SUBMITTED TO VOLPE CENTER

As requested by the Volpe Center, several progress updates were submitted by VTTI in addition to the data collected during the DDWS FOT.

Progress of FOT Data Collection

The progress of FOT data collection was sent to Volpe approximately every 2 weeks. The progress report consisted of (1) the number of drivers finished and in-progress according to operation type (i.e., line-haul, long-haul) and truck company, (2) data collection progress by driver, (3) a list of surveys submitted to the Volpe Center, and (4) a timeline of truck DAS installation and data collection for drivers.

Daily Driving Record Sheet

VTTI created a daily driving record sheet to chart the data collection progress for each driver. Those records included the DFM mode (i.e., dark or active) and the data collection status (per day). Appendix V is an example of a daily driving record sheet. VTTI submitted the sheets to the Volpe Center when (1) it was confirmed that 2 weeks of data in the dark mode had been collected (Volpe then decided if the DFM mode should be changed from dark to active), and (2) drivers finished the FOT data collection. The daily driving record sheets of finished drivers were also copied onto a CD and mailed to the Volpe Center.

Crash List

As part of the data reduction process, VTTI identified 14 crashes that occurred during the study. Descriptions of these crashes and the names of files in which they were recorded were sent to Volpe every time a new crash was identified.

First File Name When the DFM Was Switched from Dark to Active Mode

VTTI also created a list of files in which the DFM mode was switched to the active mode for the first time. The list included the fleet name, the driver number, the group (experiment or control), and the first file name when the DFM was set to active mode. The final version of the list was sent to Volpe on September 6, 2005.

DATA ARCHIVES

Data and video files from all truck DASs were backed up in original form as they were loaded onto the SAN storage system at VTTI. The only changes made to the data before being backed up were corrections to obvious errors, such as files named with the incorrect driver ID or truck location code caused by a faulty configuration setup on the truck's DAS.

Once the data were copied from the truck data drive to the SAN, software routines sorted the data and video files into three basic categories: (1) good sensor and corresponding video files, (2) bad sensor or bad corresponding video files, and (3) sensor files missing a corresponding video file or vice-versa. Later, data reductionists performed additional checking and sorting for inoperable video, binary data files that could not be opened or read, or files recorded with an improper driver operating the instrumented vehicle. After the validation, checking, and sorting were completed, the good data and video files were organized by driver ID in weekly data folders on the SAN. At this point, the files were ready for analysis.

Once a driver had completed his or her data collection period (including dropouts) and all files had been loaded onto the VTTI SAN, backed up, checked, and configured, a second backup of each driver's files was performed. This was referred to as the "data archive" as it represented an initial state from which to begin the analysis of driver performance data.

Single-sided DVD+R disks, capable of holding a maximum of 4.7 GB per disk, were used to back up and archive the project binary data files and compressed video files. Disk burns were performed on several PC workstations connected to the SAN gigabit network. A typical burn and verification (checking the copied files for errors) of the 4.7-GB DVD took approximately 8 min. After the burn, several video and data files on the DVD were opened to validate the DVD copy. Disk burns were organized by truck and driver IDs. Each file on the DVD was sequenced by the DAS's recording date and time. All disks were extensively labeled with sufficient detail to enable quick retrieval of the desired files.

Truck and driver files were collected from 103 drivers operating 46 instrumented trucks, resulting in:

- 3,140 DVDs for backing up all original data and video files, and
- 2,960 DVDs for archiving all completed driver files as filtered and stored on the VTTI SAN system.

A total of 6,100 DVDs have been burned and stored in off-site storage. Both DVD backup and archive sets were maintained, separately, at the Virginia Tech Media Vault, where the disks were organized by driver ID in drawers within a locked metal cabinet. The cabinet is housed in a limited-access, temperature- and humidity-controlled vault.

DATA REDUCTION PERFORMED BY VTTI

VTTI developed a data reduction and analysis program to support the DDWS FOT analyses. Data reduction was performed by VTTI for safety-critical incidents, and ORD was recorded for events of interest. The procedure for measuring ORD was developed and first used by Wierwille and Ellsworth (1994). Data reduction used a data directory (Appendix Z). The data directory was adapted from the data directory developed by Knipling, Olson, Hanowski, Hickman, and Holbrook (2004), based on GES and the Large Truck Crash Causation Study directories, and included variables such as road and traffic conditions at the time of the alert as well as potential distractions, drowsiness behaviors, and behaviors after the alert was received. The Volpe Center provided guidance during the development of the data directory and approved the final strategy.

CHAPTER 6. FOCUS GROUP

The goal of the post-FOT focus group was to gather additional subjective information from the drivers, specifically those in the experimental group (i.e., the ones who experienced the active mode of the DFM) about their opinions regarding the DFM and its potential to improve safety. ATI led the focus group meetings. In addition, ATI was responsible for collecting and delivering the focus group data to the Volpe Center. VTTI served as a facilitator to connect ATI and the Volpe Center with the drivers. The tasks accomplished by VTTI for the focus group process included: (1) preparing and submitting the Institutional Review Board (IRB) application for the focus group with ATI, (2) recruiting and scheduling drivers, and (3) helping the ATI representative during the focus group. Two focus group meetings were conducted, one with long-haul drivers from Howell's Motor Freight in Cloverdale, VA, and a second with line-haul drivers from Pitt Ohio in Roanoke, VA.

FOCUS GROUP MATERIALS AND IRB APPROVAL

ATI worked directly with the Volpe Center to prepare the materials for the focus group and submitted drafts to VTTI for review. The discussion covered topics such as (1) what drivers thought were positive and negative features of the DFM, (2) whether the DFM had any effects on the drivers' sleep patterns, and (3) how drivers think the current DFM can be improved. After the materials that were used for the discussion were finalized, VTTI worked with ATI on the protocol of the focus group discussion. The protocol was included in the application submitted to the Virginia Tech IRB. The IRB approved the protocol, which included the informed consent form (Appendix W).

DRIVER RECRUITMENT

The participants for the focus group were recruited from the group of drivers who participated in the DDWS FOT and met the following criteria: (1) were part of the experimental group, (2) completed data collection, (3) worked for Howell's Motor Freight in Cloverdale, VA or Pitt Ohio in Roanoke, VA, and (iv) were currently working for their respective company at the time of the focus group. VTTI initially contacted drivers by telephone and explained the purpose of the focus group. The drivers who were interested in participating were then scheduled for one of the focus group meetings. Each focus group was intended to have between 7–10 drivers. To help ensure participants would attend the focus group, VTTI contacted all drivers who agreed to participate in the focus group a second time by phone a few days before the meeting to remind them about the focus group schedule.

FOCUS GROUP MEETING

As noted, the focus group was conducted by a representative of ATI. The Volpe Center and VTTI served as support during the focus group. ATI served as the discussion facilitator by posting questions to the drivers using a slide presentation (Appendix X) and discussion guide (Appendix Y). VTTI gave support to the discussion facilitator by soliciting comments from participants and ensuring that all participants were given an opportunity to participate in the discussion. The facilitator also ensured that the discussion was completed within the allotted time. The Volpe Center representative participated via a conference call to take notes.

The meetings were held in a conference room at the fleet terminals. A total of 14 drivers participated in the two focus group sessions (8 line-haul drivers at one company and 6 long-haul drivers at the other company). As drivers arrived to the meetings, they were informed of the objective and of their role in the focus groups. Drivers were then asked to read the informed consent form (Appendix W) and sign it if they felt comfortable participating. Drivers were instructed that their participation was strictly voluntary and that they were allowed to withdraw from the meeting at any time. The meetings lasted approximately 2 h.

A video camera and microphone were used to videotape the discussion, which allowed the Volpe Center to review it at a later time. The camera and microphone were placed so that all drivers were within the camera's field of view and the discussion was clearly recorded.

At the end of the focus group, drivers were thanked for their participation and paid $100 for their time. After the meetings, ATI submitted the data (audio tapes) to the Volpe Center for analysis.

PRELIMINARY RESULTS FROM THE FOCUS GROUP

Various topics about DFM usage, safety, and privacy issues were discussed during the focus group. Some highlights from the drivers' comments are listed below.

Things drivers liked about the DFM:

- "The DFM worked if it worked." The drivers commented that the DFM sometimes presented the warnings when they were actually tired, but the DFM also presented the warnings when they were not tired (i.e., false alarms).
- Drivers could rely on the DFM warning at night, but not at dusk and dawn.
- There were varieties (six types) of auditory alarms from which drivers could choose.
- The control knobs and buttons were easy to use.

Things drivers did not like about the DFM:

- Too many false alarms were presented, sometimes "every few minutes," when:
  - The truck was in traffic and drivers had to check mirrors or nearby vehicles by moving their head/eyes to look at the area surrounding the truck;
  - The light level changed quickly in the cab due to the different light levels on the road;
  - It was dusk or dawn;
  - The truck went by a work zone in the highway where the amber hazard lights were flashing;
  - The truck went alongside Jersey barriers (concrete barriers separating opposing lanes of traffic), which have strips to reflect headlights. The jersey barriers reflected the headlights from either the truck or the vehicle behind the truck, and the lights reflected toward the cab seemed to affect the DFM on the dashboard; and
  - The side mirrors of the truck reflected xenon headlights from the vehicles behind the truck, which makes the driver squint.

- Dealing with the false alarms while in heavy traffic was stressful. Drivers had to stretch out to the DFM to stop the alarm while managing higher-priority tasks (i.e., checking their trucks and nearby vehicles).
- The range of the DFM camera was too small to capture the drivers' face and eyes all the time. Drivers had to sit in the same position all the time in order to reduce the alarms. However, sitting in the same position would make them sleepy, and stretching (moving eyes out of the current camera range) would trigger and alert but was necessary to keep the drivers awake;
- It annoyed drivers when the DFM alarm went off less than one-half hour after the shift had started given that drivers knew they were awake;
- The blinking IR sensor in the DFM camera could be hypnotic, which sometimes made drivers sleepy; and
- The DFM blocked the view of the spot mirror (a small mirror located near the front of the tractor for the blind spot from the hood to the back on the right side of the truck) in some types of trucks.

Effects of the DFM on the sleeping patterns:

- One of the 8 line-haul drivers increased his nap frequency.
- A few long-haul drivers increased their break frequencies.

Concerns for the third party accessing drivers' fatigue level:

- A couple of line-haul drivers said they would have no problem if their managers or any third party would have access to the information about the drivers' fatigue level, whereas the remaining line-haul drivers objected to their managers having access to the information.
- All the long-haul drivers said they would accept doctors having access to the information about fatigue levels because doctors may resolve fatigue problems. However, most drivers objected to the idea of their managers or DOT having access to the information about the drivers' fatigue level, believing there may be negative consequences.

How to improve the DFM:

- Reduce the false alarm rate (i.e., the DFM alarm goes off when the drivers don't think they are fatigued).
- Separate the DFM camera from the DFM controls (i.e., the DVI of the DFM). Place the camera at the upper center area of the windshield, and put the DFM controls in the same area where vehicle controls are located on the dashboard as if the DFM controls are built in. That way, the driver does not have to lean toward the dashboard to change the DFM controls. Do not put either the DFM camera or controls on the dashboard, blocking the driver's view.
- Expand the range of the DFM camera that captures the driver's eyes.
- Use a smaller camera to minimize the visual area blocked by the system.

- Use two or three DFM cameras in the cab or around the windshield to expand the viewing area.
- Use a few additional light sensors to moderate sensitivity to ambient light level (e.g., street lights, work-zone lights, reflected headlights) and reduce the warning's false alarm rate.
- Apply a zoom-in function to the DFM camera for drivers with smaller eyes.
- Make the DFM work for drivers with glasses.
- Make the DFM work during daytime. Several long-haul drivers mentioned that they become drowsy around 2 p.m. to 4 p.m.
- Increase the minimum volume of the warning sound; the current minimum volume is easily covered by the radio or CB radio.
- Increase the volume of the warning sound gradually when (1) the warning has been presented several times and (2) the warning has been presented for a while without driver response.
- Make the volume and display brightness knobs visible in the dark.
- Make the visual warning (i.e., rate, total, and bar graph) brighter than other regular visual displays (e.g., sensitivity level).
- Have an override or on-off switch to activate and deactivate the DFM for conditions when many false alarms are expected (e.g., in heavy traffic, dusk and dawn).

Other comments:

- If the false alarm issue were resolved, 3 of the 8 line-haul drivers and all 6 long-haul drivers said they would not mind putting the DFM in their truck.
- All 8 line-haul drivers agreed that they could accept the DFM if the false alarm went off once per hour, whereas all 6 long-haul drivers agreed to accept the false alarm once every 15 minutes.
- Several drivers mentioned that other heavy vehicles (buses, RVs, etc.) should have a similar sort of safety device.

CHAPTER 7. LESSONS LEARNED AND TECHNICAL PROBLEMS

LESSONS LEARNED

The following section discusses the lessons learned from the DDWS FOT as well as suggestions for future studies. In a study of this magnitude, it was expected that there would be technical difficulties that would require swift action on the part of the researchers. The lessons learned, study limitations, and suggestions for future research are described below.

Fleet Logistics

It is important to stress that all three truck companies that participated in this study were very supportive and each have safety as a core company value. In conducting a study of this magnitude and complexity, logistical issues are to be expected. This section highlights issues regarding (1) driver turnover, (2) study liaisons, (3) large driver sample needed, and (4) real-world operations.

Driver Turnover

One issue was the well-publicized high driver turnover rate that plagues the industry. Though the companies that participated in this research are at the top end of the industry, some fleets did have high turnover rates. This presented a problem in conducting the study because some drivers left the company before completing their required number of weeks (even though drivers were recruited based on their stability within the company, i.e., a low risk for leaving during the study period). At multiple sites, drivers left their company before their full, assigned time in the study. In addition to driver turnover, there was also turnover with fleet support staff (i.e., managers, dispatchers, etc.), which meant bringing new company staff up to speed on the nature of the study. Upper-level management at the three companies was very stable, however, and they were very supportive of informing new support staff about the study.

Study Liaisons

An approach used by VTTI to facilitate data collection at the sites was to hire on-site personnel to serve as liaisons between the drivers participating in the study and the researchers. The purpose of these liaisons was to coordinate the time and place for data downloads and other meetings needed during the data collection process. This approach presented some challenges due to the liaison turnover; however, it worked well in most cases and is recommended for future studies.

Large Driver Sample Needed

One of the more challenging aspects to this FOT was recruiting a sufficient number of drivers that met the study criteria (given the envelope of operation of the DFM). Finding 102 volunteer drivers who did not wear glasses and drove at night was difficult. On a number of occasions, the study exhausted all interested, qualified drivers at a particular site and had to move operations to a new site. These moves were made to locations as close to Blacksburg, VA, as possible. However, to obtain the required number of participants, it was necessary to move VTTI's instrumented trucks to locations that were much farther away than originally planned. This required greater traveling distances for VTTI personnel and accentuated the necessity for on-site liaisons.

Real-World Operations

Perhaps the most important benefit of naturalistic data collection is that it occurs in a real-world environment. The trade-off, however, is limited control over trucks and drivers in the study. That is, daily fleet operations and the logistic complexities of running a business are the primary consideration of the trucking company (as it should be). This was expected given that the goals of the study did not supersede the goals of the trucking operation. In all cases, the fleets that participated in this study and their personnel were accommodating given the real-world constraints they had to deal with (e.g., truck breakdowns). VTTI and the Volpe Center recognized the challenge of conducting a study within trucking fleets and developed an experimental design to accommodate the inevitable real-world challenges and delays. The experimental design developed by the Volpe Center included "additional weeks" for each driver. It is strongly recommended that future research efforts follow this model.

Driver Recruitment

The drivers who participated in this study were very professional and accommodating to the requirements of the research. Three issues regarding driver recruitment are noted that may benefit the conduct of future studies of this nature: (1) system constraints, (2) truck assignment, and (3) peer pressure.

System Constraints

As indicated, the available pool of drivers was limited due to the constraints of the DFM. Recall that the DFM does not reliably operate during the daytime or with drivers who wear glasses. Not surprisingly, this limited the number of possible participants. The fleets were very understanding of these constraints and were very willing to accommodate the transfer of vehicles to other sites after all qualified volunteer drivers at one site had participated. Without supportive fleets, the constraints of the DFM could have been a serious problem for this study. VTTI is grateful to all the participating companies for assisting in the transfer of instrumented vehicles to other locations and maintaining those trucks as needed to accommodate driver recruitment.

Truck Assignment

Many of the drivers had a strong attachment to their trucks, even if they were company assigned. Recruiting participants willing to temporarily transfer to a different truck proved challenging. Some drivers declined to participate in the FOT because (1) they wanted to continue driving their own trucks, (2) they were reluctant to drive an instrumented truck, and (3) the companies, due to logistics, were not always able to guarantee that drivers would be assigned back to their original truck after the data collection period ended. These issues led VTTI to install DASs in several of the drivers' own trucks to reach the required number of drivers (i.e., 46 trucks were instrumented rather than 34 trucks in the original plan). To avoid installing DASs into a new truck for each participant, future research should consider the following options: (1) inquire about a common truck that is not assigned to a particular driver and (2) request to instrument trucks that most drivers prefer. However, this might still represent a challenge given that fleets try to optimize all the trucks available.

Peer Pressure

At most locations, peer pressure among drivers was prevalent. Sometimes this was beneficial, as when drivers assisted in recruiting other drivers. However, this was also detrimental in some locations, as some drivers discouraged other drivers from participating in the study. To increase driver participation, VTTI posted flyers in the truck terminals and also conducted one-on-one conversations between VTTI personnel and drivers. To aid in recruiting drivers, VTTI personnel also attended company cookouts and employee meetings, where they presented information about the study and answered drivers' questions and concerns. Also, the on-site liaison helped ensure that prospective participants had the correct information about the study and its purpose.

Instrumented Trucks

As indicated, 46 trucks were instrumented during the course of the FOT. Several issues that may benefit future research efforts are discussed below, including (1) truck preferences, (2) consistent make/model, (3) logistics with slip-seat operations, and (4) driver assignment.

Truck Preferences

Drivers had strong preferences for which trucks they drove. Future studies should consider these preferences early in the planning stages of the project. Preferred truck characteristics included having a large gas tank (80 to 100 gallons), low mileage (approximately 25,000 miles), plenty of interior space for storage (clothing, food, etc.), and a light exterior color as those with a dark exterior color become extremely hot during the summer. Further, the mechanical reliability of each truck should be assessed before installing data collection equipment. Typically, mechanics at each terminal garage knew which trucks in the fleet were reliable. Researchers also had access to a database that indicated the frequency and types of problems associated with each truck. This information was important for planning purposes and in deciding which trucks to instrument.

Consistent Make/Model

When instrumenting multiple trucks, installing data collection equipment on the same type of truck will save time because (1) identical brackets for the sensors can be used and (2) installation personnel become familiar with the trucks, thereby reducing installation time. Researchers must expect equipment and mechanical failures. In the FOT, most of the instrumented trucks, at some point during the study, experienced some type of equipment or mechanical failure that required the truck to be pulled from the road.

Logistics with Slip-Seat Operations

Problems with the truck assignments were enhanced for slip-seat operations, in which one day-shift and one night-shift driver were paired to one truck. If one of these drivers (the night-shift driver in this case) participated in the FOT, he or she typically drove an instrumented truck that was different from his or her original truck. It was not always possible for the paired day-shift driver to transfer to the instrumented vehicle. In some cases, this resulted in logistical challenges.

Driver Assignment

Assigning drivers to instrumented trucks was challenging at times because (1) some drivers returned to the terminal only once a week (the instrumented truck was not always available when the next set of screened drivers returned), (2) non-study drivers drove the instrumented trucks when other trucks were unavailable, and (3) some drivers returned to the terminals late at night or early in morning when VTTI staff were unable to meet with them. These issues are difficult to manage in a real-world operation, and researchers working on future naturalistic studies should be mindful of them.

In summary, it is essential to elicit cooperation from the drivers and have strong support from terminal managers, dispatchers, and mechanics when collecting naturalistic driving data. Establishing and maintaining a partnership with these individuals is critical for successful data collection.

TECHNICAL PROBLEMS ENCOUNTERED

Technical Problems with the DFM

A total of 41 DFM units were used in the DDWS FOT. There were a total of 86 cases of technical problems encountered during data collection. These technical problems were classified into one of two categories: (1) program/software-related problems, and (2) hardware-related problems. Of the 86 technical problems, 28 (33%) were program/software-related. DFM units with program/software-related problems were sent back to ATI for repair. Table 6 shows the frequency and type of the 28 program/software-related cases. Additionally, Appendix AA gives specific details about each program/software-related case (sorted by the DFM serial number).

Table 6. Frequency and Type of the DFM Program/Software-Related Technical Problems

Program/Software-Related Problem	Frequency
Old software was installed	5
DFM cannot be activated	4
DFM does not produce any output/signal to the DAS	4
PERCLOS values were not changing correctly	4
Program in the microchip was damaged by sunlight	3
“Eyes found” was not working correctly	3
“Standby” was lit even when the truck was driving over 35 mph at night	2
DFM in dark mode worked as if it was in active mode (“Standby” was lit even if DFM was in dark mode; DFM in dark mode presented warnings)	2
Sensitivity was set to high instead of low in dark mode; sensitivity outputs included fourth level even if three levels (low, medium, high) were available	1
Total	**28**

Among the 86 technical problems, 58 (67%) were hardware-related problems. VTTI was able to fix 34 of these hardware-related problems, while the other 24 were addressed by ATI. Table 7 shows the frequency and type of the 58 hardware-related problems. Additionally, Appendix BB gives specific details about each hardware-related case (sorted by the DFM serial number).

Table 7. Type and Frequency of the DFM Hardware Problems

Hardware-Related Problem	Frequency
Speaker fell off inside of the DFM	24
DFM had rattle or loose screws	8

IR sensor in the DFM camera did not flash	7
Ambient light sensor attached to the DFM was damaged or fell off	4
DFM camera did not send the signals for view	3
Cable was broken and no signal could be sent from DFM (e.g., no auditory warning)	3
The size of hole for the buttons was inadequate and the buttons were stuck	3
The warning response button (to stop the auditory warning) became loose	3
DFM drew too much power and shut down the DAS	2
"Standby" was not lit in active mode	1
Total	**58**

The majority of program/software- and hardware-related problems were most likely due to normal wear and tear; however, some of the hardware-related problems were likely caused by drivers. There were three cases of the warning response button becoming loose, an example of which is shown in Figure 43. Drivers used the warning response button to respond to the DFM alarm. By depressing the warning response button the DFM alarm would cease. The warning response button was located on the top of the DFM box where it was easy to press. However, it is likely that drivers hit the warning response button very hard to stop the DFM's auditory alarm.

Figure 43. DFM With Loose Warning Response Button

Software Problems Caused by Hardware Problems

Most of the program/software-related problems affected the DFM's performance; thus, no valid data were collected. However, not all the hardware-related problems affected the DFM's performance (e.g., rattle inside of DFM). Some hardware-related problems eventually caused software problems, which took longer to be repaired because the DFM units with software-related problems had to be sent back to ATI.

A failed speaker is a good example of a hardware-related problem that caused a program/software-related malfunction. In the DFM, the speaker was hot glued to the inside of the top cover. This glue was not strong enough to hold the speaker in a truck environment.

Repairing the speaker was difficult because of all the electric boards and cables near it. The speaker was located above the DFM's microchip (where the DFM's software was stored). When the speaker fell off, the microchip was exposed to sunlight (as the DFM was placed on the dashboard in the truck). The sunlight would damage the microchip and erase its DFM software. There were three cases in which a falling speaker appeared to account for the DFM's program/software-related malfunction. Figure 44 displays an example of a DFM's speaker falling off, and Figure 45 shows the DFM's microchip located below the speaker.

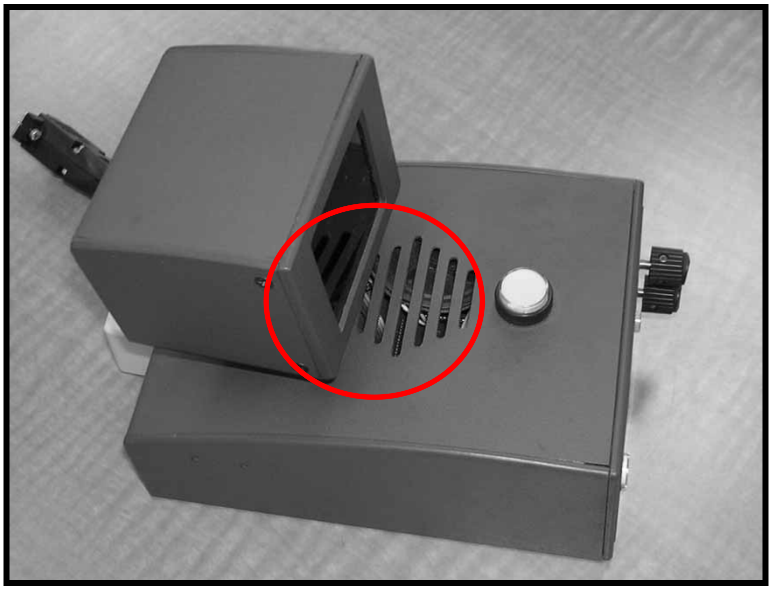

Figure 44. The Speaker (in Circle) Became Loose and Only Half of the Speaker Can Be Seen From the Holes

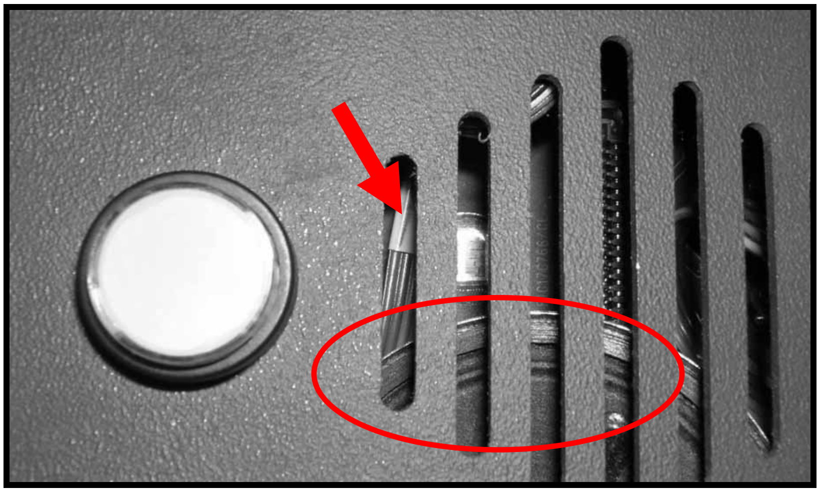

Figure 45. The Microchip (arrow) Located Under the Speaker (circled)

Another example of a hardware-related failure that caused a program/software-related malfunction was a faulty ambient light sensor. One of two problems were encountered if the ambient light sensor unfastened from the DFM or was physically damaged: (1) no data were produced because the DFM was in standby mode or (2) the DFM activated alarms during the daytime because the DFM did not detect daylight and operated as if at night.

Problems With Individual DFM units

Among the 41 DFM units used in the DDWS FOT, 12 units (29%) did not have any technical problems while the remaining 29 units (71%) had at least one hardware- and/or program/software-related problem. Among the 29 units with at least one technical problem, three units were responsible for 21 (24.4%) of the program/software- or hardware-related malfunctions.

Issues Beyond Technical Problems

The high frequency of technical problems with the DFM resulted in a shortage of working units to install in trucks, especially during the beginning of the DDWS FOT. On August 12, 2004, the TOM directed ATI to send VTTI five additional DFM units. However, the shortage of working DFM units continued over the entire data collection period. One of the primary reasons for DFM shortages during the DDWS FOT was the relatively high failure rate of the DFM units.

Another reason for the DFM shortage was the number of the DFM units that needed to be sent to ATI for repair. More than half of the DFM problems (52 cases) required the DFM unit to be sent to ATI for repair; thus, VTTI would be without those DFMs for a considerable period of time. Table 8 shows the frequency and percentage of the program/software- and hardware-related repairs conducted by VTTI and ATI.

Table 8. Frequency and Percentage of Program/Software- and Hardware-Related Repairs Conducted by VTTI and ATI

	VTTI Frequency	VTTI Percentage	ATI Frequency	ATI Percentage
Hardware-related problems	34	40%	24	27%
Program/software-related problems	0	0%	28	33%
Total	34	40%	52	60%

As can be seen in Table 8, ATI repaired 52 of the 86 DFM malfunctions (60%), while VTTI repaired the remaining 34 malfunctions (40%). All 34 repairs made by VTTI were for hardware-related problems, whereas the remaining 24 hardware problems and all 28 program/software problems were repaired by ATI. It took an average of 17 days for ATI to return a repaired DFM (between VTTI shipping the DFM units and ATI returning the repaired DFM units). A DFM returned to VTTI with a new kind of problem required additional weeks to resolve.

Recommendations for Improving DFM Reliability

The following is a list of recommendations to improve DFM hardware and/or program/software reliability:

- Build the DFM strong enough to tolerate a rough environment (e.g., a moving tractor with a trailer).
- Use stronger materials for attaching the speaker (e.g., two-part epoxy instead of hot glue).
- Change the location of the microchip to avoid damage by sunlight.
- Install the ambient light sensor inside the main DFM box to avoid physical damage.
- Install software with higher reliability.

Technical Problems with Actigraph Watch

The MicroMini Motionlogger Actigraph watches (Figure 46) used to collect actigraphy data in this study were replaced with the MicroMini Motionlogger Actigraph with User Exchange Feature watch (Figure 47) in October 2004 due to high rate of technical problems identified with the MicroMini Motionlogger Actigraph watches. To distinguish between these two types of watches, this report refers to the formerly used watch as the “old watch” and the replacement watch as the “new watch.” Both watches were manufactured by Ambulatory Monitoring, Inc. (AMI).

Figure 46. MicroMini Motionlogger Actigraph (old watch)

Figure 47. MicroMini Motionlogger Actigraph ith User Battery Exchange Feature (new watch)

A minimum of 36 watches were needed for actigraphy data collection in the DDWS FOT. As seen in Table 9, the new watches had a lower return rate (31%) than the older watches (56%). This lower return rate indicated the new watches had fewer technical problems.

Table 9. Actigraph Watch Units Sent to VTTI and Returned to AMI for Repair

	Old Watch	New Watch	Total
Watches sent to VTTI	64	58	122
Watches returned to AMI for repair	36 (56% of old watches delivered to VTTI)	18 (31% of new watches delivered to VTTI)	54 (44% of all watches delivered to VTTI)
Watches returned to AMI for reasons other than repair (e.g., new battery)	27	2	29
Watches that drivers lost	1	2	3
Watches available for study	**0**	**36**	**36**

All Actigraph watches with technical problems were returned to AMI for repair. Table 10 lists the frequency of technical problems identified in the 54 watches returned to AMI for repair. Additionally, Appendix CC describes specific details about each case. Note that 10 of the 54 watches had multiple problems, thus, the total number of technical problems was greater than the number of malfunctioning old and new watches.

Table 10. Number of Watches Affected by Each Technical Problem

Problems	Old Watch	New Watch	Total
No data or partial data were collected after	16	12	28

successful initialization			
Watch could not be initialized for data collection	21	3	24
Battery runtime hours became 0 or decreased	2	5	7
Watch was physically damaged (e.g., had a crack or rattle)	6	4	10
Total number of problems	**45**	**24**	**69**

One of the most significant problems encountered in the DDWS FOT was the lack of data collection (or partial data collection) from an Actigraph watch after being successfully initialized. This problem was detrimental because the actigraphy data on these watches were not recoverable. Approximately 7.75 percent of actigraphy data was not collected during the DDWS FOT due to watch malfunctions. It should be stressed that approximately 8,000 days of actigraphy data was collected in this FOT. Among the 28 units with lost data, 7 units (5 old and 2 new watches) demonstrated multiple technical problems, including (1) battery runtime hours were zero, and (2) watch was physically damaged.

To help prevent losses of actigraphy data, VTTI implemented a variety of verification procedures to ensure the Actigraph watch initialization was successful. The verification process checked (1) watch status (i.e., the watch was taking data), (2) battery runtime hours (i.e., should have increased since the last initialization), and (3) the memory status (i.e., the status was "OK"). If any one of these verification criteria was not met, the watch was considered incapable of collecting data and returned to AMI. When it became apparent the old watches were demonstrating a high rate of technical problems, researchers from VTTI and the Volpe Center visited AMI to verify VTTI's procedures for initializing and downloading data from the Actigraph watch. Representatives from AMI confirmed the procedures implemented by VTTI were correct; thus, it was determined that the problem lay with the old watches themselves. Overall, the new watch had fewer technical problems than the old watch. Moreover, drivers preferred the new watches because they looked more like a normal wrist watch.

CHAPTER 8. SUMMARY

As the data collector for this study, VTTI has successfully conducted the FOT by providing the independent evaluator with a very large, comprehensive dataset in which to investigate the safety benefits and operational capabilities, limitations, and characteristics of a DDWS that monitors drivers' drowsiness. To meet this goal, VTTI adhered to three general requirements:

1. The evaluation occurred in a naturalistic driving environment and data were collected from actual truck drivers driving a commercial truck;
2. The participant population was representative of the commercial vehicle truck driver population; and
3. The drivers used the DFM in normal operating conditions (i.e., actual delivery runs).

VTTI has provided the Volpe Center with a dataset that surpasses initial expectations in terms of the number of drivers, trucks, operations, completed drivers, etc. In terms of the amount of data collected, this study is the largest ever conducted by the U.S. DOT. The following list provides an overview of the data collected:

- Almost 46,000 driving-data hours covering 2.3 million VMT (equivalent to almost 96 trips around the world or 770 coast-to-coast trips across the United States).
- More than 250,000 data, video, and ASCII text files (278,900 files total).
- Approximately 11.8 TB of data from video and dynamic sensor files.
- A total of 397 load history files from 103 drivers who participated in the FOT.
- A total of 598 actigraphy data files and 356 data recording sheets from over 8,000 days' worth of actigraphy data (or approximately 195,000 hours of activity/sleep data).
- Pre-participation, pre-study, post-study, and debriefing questionnaires from drivers.
- Fleet management surveys from each company.
- Focus group results from 14 drivers during two post-study focus group sessions.

All of the itemized datasets have been delivered to the Volpe Center for detailed analyses. The Volpe Center and VTTI will analyze this very large dataset to develop the following:

1. A detailed understanding of the DDWS's safety benefits.
2. A characterization of the DDWS's performance and capability.
3. An assessment of driver acceptance of a DDWS.
4. An assessment of fleet management acceptance of a DDWS.
5. An assessment of the deployment prospects of a DDWS.
6. Recommendations for DDWS design changes directed at optimizing safety benefits and increasing driver and fleet management acceptance.
7. An assessment of how a DDWS fits within a comprehensive fatigue-management program.

The results of this data collection effort provide the necessary data to carry out these analyses.

FUTURE RESEARCH IDEAS

Though the primary focus of this study was to assess the safety benefits of a DDWS, the resulting dataset provides a unique opportunity to re-analyze the data for additional purposes. A preliminary list of follow-on research ideas is presented below and highlights a benefit of the naturalistic data collection methodology: that is, the ability to use the dataset in ways beyond the initial purpose of the FOT.

Some of the suggested data mining topics are:

- A meta-analysis comparing light-vehicle and CMV driving behavior using data from the 100-Car Naturalistic Driving Study (Dingus et al., 2006) and DDWS FOT data;
- The relationship between seat vibration, sleep quantity, and fatigue;
- Activity/rest patterns as a function of the type of operation;
- Activity/rest differences between work days and off days;
- Activity/rest patterns in periods (e.g., 24 hours prior, week prior) before critical incidents;
- Distractions due to cell phones, CB radios, and other secondary in-vehicle tasks;
- Models of CMV actions in work zones;
- Characteristics of safety-critical areas by mapping GIS data and GPS data collected in the FOT;
- Evaluations of crashes, near-crashes, and safety-critical incidents across all the DDWS FOT data;
- Improvements to the current observer rating of drowsiness (ORD) method (subjective drowsiness assessment) and an exploration of new methods;
- Criteria for characterizing high-risk drivers versus low-risk drivers and use of these criteria to improve driver training and selection;
- Patterns of seat belt use in CMV drivers;
- Models of CMV lane-change and back-up behavior;
- Driver parking habits relating to space available for parking on the roadways and rest stops;
- Crash countermeasure modeling using FOT data as system/algorithm input; and
- Driver behavior in deer strikes.

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APPENDIX A: LIST OF DAS MEASUREMENTS

Variables are collected through the main sensors/boxes installed in the trucks. Table 11 lists those main sensors and the major data variables they collect. Table 12 gives details about each variable.

Table 11. Main Sensors and Variables in DAS

Sensor name	Example of variables	Column # in Table 12
Data Acquisition System (DAS)	System Box	1 – 4
	Lane Tracker, Yaw Rate	6 – 22
	GPS	23 – 33
	X/Y Acceleration	34 - 36
	Front VORAD	57 – 93
Incident Box	Light Level	41 - 42
Sound Box	Sound Level Meter	95 – 98
	In-Cab Temperature	97
Seat Acceleration	Raw Seat Acceleration	105
DDWS (PERCLOS monitor)	PERCLOS 1, 3, and 5	99 – 101
	Ambient Brightness	102
	Status Vector (e.g., Eyes Found, Operating Mode, Sensitivity)	104
In-Vehicle Network Communication System	Distance	107
	Speed	108
	Vehicle Information	113

Note: The following sensors and variables are not included in Table 12.

- Microphone (in incident box) for recording verbal comments up to 15 seconds.
- Four cameras (face, forward, rear-left, rear-right) for video recording.
- Actigraph watch that drivers wear for sleep log.

Table 12. DAS Raw Data Variable List

DAS Raw Data Variable List. System (in 100-Car DAS)

Column#	Name	Type	Description	Bytes
1	Frame Number	Unsigned long	Current data collection frame/sync number	0-3
2	MPEG Frame Number	Unsigned long	MPEG frame number used as video sync number	4-7
3	Time Elapsed Since Time	Unsigned long	Time in milliseconds since frame 0 (when the data acquisition program starts)	8-11
4	Error Code	Unsigned long	Error code as written into software	12-15

Lane Tracker (in 100-Car DAS)

Column#	Name	Type	Description	Bytes
6	Lane Tracker Status	Bit vector	Lane tracker status: 0=status lost, 1=in the lane between painted lines, 2=crossing a line on the right, 4= crossing a line on the left, 8=aborted crossing line, 16=completed lane change, 32=crossed solid line, 64=calibrating position of camera, 128=low sun angle or glare, 256=nighttime, 512=exit on the right side of road, 1024=exit on the left side of road, 2048= calibrating tilt range of camera, 4096=camera tilt angle off of horizontal, 8192=no video input for frame grabber	20,21
7	Delta Frame	Unsigned integer	Time between frames (ms)	22,23
8	Lane Offset	Unsigned integer	Distance to the center of the lane (1/100th inch)	24,25
9	Lane Width	Unsigned integer	Width of lane (1/100th inch): 11.81 ft on Smart Road	26,27
10	Angle of Vehicle (Gamma)	Unsigned integer	Angle of vehicle with respect to the lane (1/100000 rad)	28,29
11	Radius of Road Curvature (RhoInverse)	Unsigned integer	Inverse of radius of road curvature (1/100000 ft)	30,31
12	Road incline	Unsigned integer	Incline of the road with respect to baseline (1/100000 rad)	32,33

13	Immediate Left Lane information	Packed bit array	Type of Line: 0=None, 1=Double, 2=Single, 3=Gutter, 4=Edge of road, 5=Reflector Color of Line: 0=Light lines, 1=Dark lines Leftmost line: 0=Solid, 1=Dash, 2=Unsure Rightmost line: 0=Solid, 1=Dash, 2=Unsure Line contrast: 0 – 7 0=there was a sharp contrast between lines and backgrounds, 7=there was little contrast between lines and backgrounds	34,35
14	Immediate Left Lane: Probability Value	Unsigned integer	Confidence measure of the immediate left lane information results. Range of values: 0-1024, where 0 is lowest confidence.	36,37
15	Immediate Left Lane: Left Distance	Unsigned integer	Distance from lane's center to left side of marker ($1/100^{th}$ inch)	38,39
16	Immediate Left Lane: Right Distance	Unsigned integer	Distance from lane's center to right side of marker ($1/100^{th}$ inch)	40,41
17	Immediate Right Lane information	Packed bit array	Type of Line: 0=None, 1=Double, 2=Single, 3=Gutter, 4=Edge of road, 5=Reflector Color of Line: 0=Light lines, 1=Dark lines Leftmost line: 0=Solid, 1=Dash, 2=Unsure Rightmost line: 0=Solid, 1=Dash, 2=Unsure Line contrast: 0 – 7 0=there was a sharp contrast between lines and backgrounds, 7=there was little contrast between lines and backgrounds	42,43
18	Immediate Right Lane: Probability Value	Unsigned integer	Confidence measure of the immediate right lane information results. Range of values: 0-1024, where 0 is lowest confidence.	44,45
19	Immediate Right Lane: Left Distance	Unsigned integer	Distance from lane's center to left side of marker ($1/100^{th}$ inch)	46,47
20	Immediate Left Lane: Right Distance	Unsigned integer	Distance from lane's center to right side of marker ($1/100^{th}$ inch)	48,49
21	Yaw Rate of Forward-View Camera	Unsigned integer	Horizontal position of forward-view camera to the center of vehicle (1/100000 rad); positive value indicates the camera is facing toward right	50,51
22	Tilt of Forward-View Camera	Unsigned integer	Vertical position of forward-view camera to the center of vehicle (1/100000 rad); positive value indicates the camera is facing up	52,53

Global Positioning System (GPS) (in 100-Car DAS)

Column#	Name	Type	Description	Bytes
23	Latitude	Float	GPS latitude (degrees)	54-58
24	Longitude	Float	GPS longitude (degrees)	59-61
25	Altitude	Float	GPS altitude (1/100 ft)	62-64
26	Horizontal Velocity	Integer	Velocity horizontal to earth (1/10 MPH)	65,66
27	Vertical Velocity	Integer	Velocity perpendicular to earth (1/10 MPH)	67,68
28	Heading	Integer	Vehicle heading (1/10 degree)	69,70
29	Satellite Acquisition Status	Packed bit array	GPS status/source information GPS status: 0=2D GPS, 1=3D GPS, 2=2D DGPS, 3=3D DGPS, 6=DR, 8=Degraded DR, 9=unknown. Current Data Status: 0=Unknown age, 1=less than 10sec old, 2=more than10 sec old. Usable Satellite Status: 0=Doing Pos Fix, 1=Don't have GPS Time, 3=PDOP too high, 8=no usable satellite, 9= 1 usable satellite, 10= 2 usable satellites, 11= 3 usable satellites, 12=Chosen satellite unusable. Battery/Antenna Status: 0=OK, 1=Battery Backup failed, 2=Antenna Feedline. Almanac Status: 0=OK, 2=RTC not available at power up, 8=Stored almanac not complete and current	71,72
30	GPS Month	unsigned integer	The month of the year (1-12). (this variable was collected since 9/30/2004)	73
31	GPS Day	unsigned integer	The day of the month (this variable was collected since 9/30/2004)	74
32	GPS Hour	unsigned integer	The hour of the day (0-24). (this variable was collected since 9/30/2004)	75
33	GPS Minute	unsigned integer	The minute of the hour (0-59). (this variable was collected since 9/30/2004)	76

Accelerometer (in 100-Car DAS)

Column #	Name	Type	Description	Bytes
34	Y Acceleration	Integer	Data from accelerometer to get Y acceleration as (1/100 g's); positive velocity is a velocity towards the right of the driver	77,78
35	X Acceleration	Integer	Data from accelerometer to get X acceleration as (1/100 g's); positive velocity is a velocity towards the front of the car	79,80
36	Gyro	Integer	Data from Gyro to get rotation in (deg/sec); positive rate is clockwise	81,82

Light Meter (Glare Sensor) (in Incident Box)

Column#	Name	Type	Description	Bytes
41	RawLuxValue	Unsigned integer	Raw lux value from meter	88,89
42	Light Meter Status	Bit vector	Incident Button: 1=pressed, 0=unpressed LEDs: 1=on, 0=off	90

Forward Vorad (in 100-Car DAS)

Column	Name	Type	Description	Bytes
57	Forward Vorad Frame Number	Unsigned character	Vorad timing frame number (rolls over after 255)	144
58	Forward Vorad Target Count	Unsigned character	The number of tracked targets	145
59	Forward Vorad Target1 ID	Unsigned character	Tracking number for target1	146
60	Forward Vorad Target1 Range	Unsigned integer	Range to target1 (1/10 ft)	147,148
61	Forward Vorad Target1 Range Rate	Unsigned integer	Range rate to target1 (1/10 ft/s)	149,150
62	Forward Vorad Target1 Azimuth	Unsigned character	Azimuth to target1 (1/500 radians)	151
63	Forward Vorad Target1 Magnitude	Unsigned character	Magnitude of signal return (dB)	152
64	Forward Vorad Target2 ID	Unsigned character	Tracking number for target2	153
65	Forward Vorad Target2 Range	Unsigned integer	Range to target2 (1/10 ft)	154,155
66	Forward Vorad Target2 Range Rate	Integer	Range rate to target2 (1/10 ft/s)	156,157
67	Forward Vorad Target2 Azimuth	Character	Azimuth to target2 (1/500 radians)	158

68	Forward Vorad Target2 Magnitude	Unsigned character	Magnitude of signal return (dB)	159
69	Forward Vorad Target3 ID	Unsigned character	Tracking number for target3	160
70	Forward Vorad Target3 Range	Unsigned integer	Range to target3 (1/10 ft)	161,162
71	Forward Vorad Target3 Range Rate	Integer	Range rate to target3 (1/10 ft/s)	163,164
72	Forward Vorad Target3 Azimuth	Character	Azimuth to target3 (1/500 radians)	165
73	Forward Vorad Target3 Magnitude	Unsigned character	Magnitude of signal return (dB)	166
74	Forward Vorad Target4 ID	Unsigned character	Tracking number for target4	167
75	Forward Vorad Target4 Range	Unsigned integer	Range to target4 (1/10 ft)	168,169
76	Forward Vorad Target4 Range Rate	Integer	Range rate to target4 (1/10 ft/s)	170
77	Forward Vorad Target4 Azimuth	Character	Azimuth to target4 (1/500 radians)	171
78	Forward Vorad Target4 Magnitude	Unsigned character	Magnitude of signal return (dB)	172
79	Forward Vorad Target5 ID	Unsigned character	Tracking number for target5	173
80	Forward Vorad Target5 Range	Unsigned integer	Range to target5 (1/10 ft)	174,175
81	Forward Vorad Target5 Range Rate	Integer	Range rate to target5 (1/10 ft/s)	176,177
82	Forward Vorad Target5 Azimuth	Character	Azimuth to target5 (1/500 radians)	178
83	Forward Vorad Target5 Magnitude	Unsigned character	Magnitude of signal return (dB)	179
84	Forward Vorad Target6 ID	Unsigned character	Tracking number for target6	180
85	Forward Vorad Target6 Range	Unsigned integer	Range to target6 (1/10 ft)	181,182
86	Forward Vorad Target6 Range Rate	Integer	Range rate to target6 (1/10 ft/s)	183,184
87	Forward Vorad Target6 Azimuth	Character	Azimuth to target6 (1/500 radianss)	185

88	Forward Vorad Target6 Magnitude	Unsigned character	Magnitude of signal return (dB)	186
89	Forward Vorad Target7 ID	Unsigned character	Tracking number for Target7	187
90	Forward Vorad Target7 Range	Unsigned integer	Range to Target7 (1/10 ft)	188,189
91	Forward Vorad Target7 Range Rate	Integer	Range rate to Target7 (1/10 ft/s)	190,191
92	Forward Vorad Target7 Azimuth	Character	Azimuth to Target7 (1/500 radians)	192
93	Forward Vorad Target7 Magnitude	Unsigned character	Magnitude of signal return (dB)	193

Sound Box (in FOT Additional Sensors

Column	Name	Type	Description	Bytes
95	Sound Level	Float	Sound level in dB	195-198
96	Sound Polarity	Unsigned character	Relative pressure to the reference frequency as 1kHz = 0dB: 0 = positive, 1 = negative	199
97	In-cab Temperature	Unsigned integer	Inside-cab temperature (in C^o)	200,201
98	Status	Unsigned character	Confidence measure of the data collected by the Sound box.	202

PERCLOS (in DDWS)

Column #	Name	Type	Description	Bytes
99	PERCLOS 1 min.	Unsigned character	PERCLOS measure for 1 minute	203
100	PERCLOS 3 min.	Unsigned character	PERCLOS measure for 3 minute	204
101	PERCLOS 5 min.	Unsigned character	PERCLOS measure for 5 minute	205
102	Ambient Brightness	Unsigned character	Ambient brightness (Range: 0-254)	206
103	Display Brightness	Unsigned character	PERCLOS monitor display brightness (Range: 0-255)	207
104	Status Vector	Unsigned integer	Eyes found: 0=no eye, 1=one eye, 2=both eyes Sensitivity: 0=High, 1=Medium, 2=Low Operating mode: 0 = DFM unplugged, 1= active mode, 2= dark mode Display status: 1=on, 0=off Longest eye closure on bar graph (in second): 0-4 Warn flag: 0=not triggered, 1=full triggered, 2= Initial triggered Warning sound: 0,1,2,3,4,5	208,209
105	Display Mode	Unsigned character	Mode: 0=Standby, 1=Active (controls lit and are active in active mode), 2=Warn 1 (Full-warning is presented), 3=Warn 2 (OK button is pressed)	210

Seat Acceleration (in FOT Additional Sensors)

Column #	Name	Type	Description	Bytes
106	Raw Seat Acceleration	Integer	Data from accelerometer to get Z-acceleration of driver's seat (1/100 g's)	211, 212

In-Vehicle Network Communication System (J1587)

Note: Not all measures available on all trucks

Column #	Name	Type	Description	Bytes
107	Distance	Unsigned integer	Distance in 1/10th of Mile	213-216
108	Speed	Unsigned character	Speed in Km/H	217
109	Throttle Position	Unsigned character	Throttle pedal position (Normalized range: 0-1): 0 =pedal up, 1=pedal pressed down completely	218
110	Brake Line Pressure	Unsigned character	Degree of pressing break	219
111	Ambient Air Temperature	Integer	Temperature of air surrounding vehicle (in C^o)	220,221
112	Cruise Control Status	Bit vector	State of vehicle velocity control system (active, not active) and system switch (on/off)	222
113	Vehicle Information	Bit vector	Right Turn: 1=present, 0=absent Left Turn: 1=present, 0=absent RF: 1=present, 0=absent Brake: 1=break was pressed, 0=break not pressed Headlights: 1=Headlights on, 0=Headlights off Ignition Signal: 1=on, 0=off	223

Data Validation Check

Column #	Name	Type	Description	Bytes
114	Data Integrity Validation	Unsigned character	Sum of all bytes collected bitwise inversed	224

APPENDIX B: J1587 MEASURES EXTRACTED FROM A 1994 PETERBILT 379 CLASS-8 TRACTOR.

Pid	Parameter	Definition	Character Data Length	Data Type	(Bit) Resolution	Maximum Range	Transmission Update Period	Message Priority	Pid Data Format
71	Idle Shutdown Timer Status	State of the idle shutdown timer system (active, not active) for the various modes of operation	1	Binary Bit-Mapped	Binary	0 to 255	1.0 s	5	Pid Data 71 a (“a” represents a single character) *Data will be calculated based on the following information:* Bit 8: Idle shutdown timer status; 1=active/0=inactive Bits 7-5: Undefined Bit 4: Idle shutdown timer function; 1=enabled in calibration 0=disabled in calibration Bit 3: Idle shutdown timer override; 1=active/0=inactive Bit 2: Engine has shutdown by idle timer 1=yes/0=no Bit 1: Driver alert mode 1=active/0=inactive
74	Maximum Road Speed Limit	Maximum vehicle velocity allowed	1	Unsigned Short Integer	0.5 mph (0.805 km/h)	0.0 to 127.5 mph	On request	8	Pid Data 74 a (“a” represents a single character)
84	Road Speed	Indicated vehicle velocity	1	Unsigned Short Integer	0.805 km/h (0.5 mph)	0.0 to 127.5 mph	0.1 s	1	Pid Data 84 a (“a” represents a single character)
85	Cruise Control Status	State of the vehicle velocity control system (active, not active), and system switch (on, off) for various system operating modes	1	Binary Bit-Mapped	Binary+	0 to 255	0.2 s	3	Pid Data 85 a (“a” represents a single character) *Data will be calculated based on the following information:* Bit 8: cruise mode; 1=active/0=not active Bit 7: clutch switch; 1=on/0=off Bit 6: brake switch; 1=on/0=off Bit 5: accel switch; 1=on/0=off Bit 4: resume switch; 1=on/0=off Bit 3: coast switch; 1=on/0=off Bit 2: set switch; 1=on/0=off Bit 1: cruise control switch; 1=on/0=off
86	Cruise Control Set Speed	Value of set (chosen) velocity of velocity control system	1	Unsigned Short Integer	0.805 km/h (0.5 mph)	0.0 to 127.5 mph	10.0 s	6	Pid Data 86 a (“a” represents a single character)

Pid	Parameter	Definition	Character Data Length	Data Type	(Bit) Resolution	Maximum Range	Transmission Update Period	Message Priority	Pid Data Format
87	Cruise Control High-Set Limit Speed	Maximum vehicle velocity allowed at any cruise control set speed	1	Unsigned Short Integer	0.805 km/h (0.5 mph)	0.0 to 127.5 mph	On request	8	Pid Data 87 a ("a" represents a single character)
88	Crusie Control Low-Set Limit Speed	Minimum vehicle velocity allowed by cruise control before a speed adjustment is called for	1	Unsigned Short Integer	0.805 km/h (0.5 mph)	0.0 to 127.5 mph	On request	8	Pid Data 88 a ("a" represents a single character)
89	Power Takeoff Status	State of the system used to transmit engine power to auxiliary equipment. Status indication is for system (active, not active), and system switch (on, off), for various operating modes	1	Binary Bit-Mapped	Binary	0 to 255	1.0 s	5	Pid Data 89 a ("a" represents a single character) *Data will be calculated based on the following information:* Bit 8: PTO mode; 1=active/0=not active Bit 7: clutch switch; 1=on/0=off Bit 6: brake switch; 1=on/0=off Bit 5: accel switch; 1=on/0=off Bit 4: resume switch; 1=on/0=off Bit 3: coast switch; 1=on/0=off Bit 2: set switch; 1=on/0=off Bit 1: PTO control switch; 1=on/0=off
91	Percent Accelorator Pedal Position	Ratio of actual accelerator pedal position to maximum pedal position	1	Unsigned Short Integer	0.40%	0.0 to 102.0%	0.1 S	3	Pid Data 91 a ("a" represents a single character)
92	Percent Engine Load	Ratio of current output torque to maximum torque available at the current engine speed	1	Unsigned Short Integer	0.50%	0.0 to 127.5%	0.1 s	3	Pid Data 92 a ("a" represents a single character)
100	Engine Oil Pressure	Gage pressure of oil in engine lubrication system as provided by oil pump	1	Unsigned Short Integer	3.45 kPa (0.5 lbf/in2)	0.0 to 127.5 lbf/in2	1.0 s	2	Pid Data 100 a ("a" represents a single character)
102	Boost Pressure	Gage pressure of air measured downstream on the compressor discharge side of the turbocharger	1	Unsigned Short Integer	0.862 kPa (0.125 lbf/in2)	0.0 to 31.875 lbf/in2	1.0 s	4	Pid Data 102 a ("a" represents a single character)
105	Intake Manifold Temperature	Temperature of precombustion air found in intake manifold of engine air supply system	1	Unsigned Short Integer	1.0 °F	0.0 to 255.0 °F	1.0 s	5	Pid Data 105 a ("a" represents a single character)
110	Engine Coolant Temperature	The temperature of liquid found in engine cooling system	1	Unsigned Short Integer	1.0 °F	0.0 to 255.0 °F	1.0 s	4	Pid Data 110 a ("a" represents a single character)

Pid	Parameter	Definition	Character Data Length	Data Type	(Bit) Resolution	Maximum Range	Transmission Update Period	Message Priority	Pid Data Format
175	Engine Oil Temperature	Temperature of engine lubricant	2	Signed Integer	0.25 °F	-8192.00 to +8191.75 °F	1.0 s	4	Pid Data 175 a a (“a a” represents two character)
182	Trip Fuel	Fuel consumed during all or part of a journey	2	Unsigned Integer	0.473 L (0.125 gal)	0.0 to 8191.875 gal	10.0 s	7	Pid Data 182 a a (“a a” represents two character)
183	Fuel Rate (Instantaneous)	Amount of fuel consumed by engine per unit of time	2	Unsigned Integer	16.428 x 10-6 L/s (4.34 x 10-6 gal/s or 1/64 gal/h)	0.0 to 0.284 421 90 gal/s or 0.0 to 1023.98 gal/h	0.2 s	3	Pid Data 183 a a (“a a” represents two character)
184	Instantaneous Fuel Economy	Current fuel economy at current vehicle velocity	2	Unsigned Integer	1.660 72 x 10-3 km/L (1/256 mpg)	0.0 to 255.996 mpg	0.2 s	3	Pid Data 184 a a (“a a” represents two character)
185	Average Fuel Economy	Average of instantaneous fuel economy for that segment of vehicle operation of interest	2	Unsigned Integer	1.660 72 x 10-3 km/L (1/256 mpg)	0.0 to 255.996 mpg	10.0 s	7	Pid Data 185 a a (“a a” represents two character)
187	Power Takeoff Set Speed	Rotational velocity selected by operator for device used to transmit engine power to auxiliary equipment	2	Unsigned Integer	0.25 rpm	0.0 to 16383.75 rpm	10.0 s	6	Pid Data 187 a a (“a a” represents two character)
188	Idle Engine Speed	Minimum nontransient rotational velocity of crankshaft while engine is supplying power to itself and its attendant support systems	2	Unsigned Integer	0.25 rpm	0.0 to 16383.75 rpm	On request	8	Pid Data 188 a a (“a a” represents two character)
189	Rated Engine Speed	The maximum governed rotational velocity of the engine crankshaft under full load conditions	2	Unsigned Integer	0.25 rpm	0.0 to 16383.75 rpm	On request	8	Pid Data 189 a a (“a a” represents two character)
190	Engine Speed	Rotational velocity of crankshaft	2	Unsigned Integer	0.25 rpm	0.0 to 16383.75 rpm	0.1 s	1	Pid Data 190 a a (“a a” represents two character)

Table 13. Definitions of Selected Headings in J1587

Heading	Definition
Pid	Parameter Identification
Data Type	Parameter data type should use one or more of the following data types shown in the following table. All the data types will be transmitted and will display the least significant character first. The parameter data types with corresponding number of characters are as follows: • Binary Bit-Mapped (B/BM) – 1 • Unsigned Short Integer (Uns/SI) – 1 • Unsigned Integer (Uns/I) – 2 • Signed Integer (S/I) - 2
Transmission Update Period and Message Priority	The update period and message priority at which a parameter is transmitted on the data link is primarily the responsibility of the transmitting electronic device. Because overloading the data link and providing compatible update rates are major concerns, a recommended transmission update period and message priority for each parameter is included in the J1587 Measures Table presented above. Variations from the listed update periods should be included in the application document (reference SAE J1587). If multiple parameters are grouped into one message, the message assignment would be based on the highest message priority associated with the group parameters. All requested parameters were assigned the lowest message priority, priority 8, so that the messages would not disrupt the regularly broadcast data.

APPENDIX C: INSTRUCTIONS FOR OPERATING THE ORIGINAL DFM IN TASK 8

POWERING THE DFM:

The DFM is designed to run directly from the vehicle power; a minimum voltage input of 13.5 V is required for proper operation.

CHANGES TO THE DFM INTERFACE:

1. The OK button and Sound button have been switched. The OK button is now on the top of the unit. The drivers found it easier to quickly respond with the button on top in a less crowded area.

2. In its current configuration, the DFM will allow the experimenter to modify the interface. This will offer the ability for experiencing the DFM in several operating modes for test purposes. The final DFM will be set to your specifications for each option. The current default interface:
   a. Does not put the unit in standby for slow speed or high brightness;
   b. Provides an initial advisory tone that does not need to be responded to by the driver; and
   c. Presents the bar graph and audible tone at the same time for the full warning.

Each of these three defaults can be modified by holding a specified button for 3 s. A beep is provided to acknowledge the change. The modifications are as follows:

   d. Holding the standby button for 3 s will enable (disable) the feature requiring a speed and brightness thresholds that will place the DFM in automatic standby mode;
   e. Holding the sensitivity button for 3 s will disable (enable) the initial advisory tone; and
   f. Holding the OK button for 3 s will disable (enable) the bar graph as part of the warning-1 mode.

STANDBY MODE

The unit can be in three different standby modes:

1. Manual Standby Mode: the red standby display is on and steady.
   - The user selects manual standby by pressing the standby button

2. Automated Standby Mode: the red standby light blinks at a 1-second period.
   - Automated standby is entered when the vehicle is traveling at a low speed or excessive ambient light is detected. In this mode when the vehicle is above the target speed and the brightness level is low, the DFM will go to active mode.

3. Manual-Automated Standby Mode: the standby display is dark.
   - The user has selected standby and the vehicle is traveling at a low speed or excessive brightness is detected. In this mode when the vehicle is above the targeted speed and the brightness level is low, the DFM goes to Manual Standby mode.

SPEED AND BRIGHTNESS THRESHOLDS

Dual thresholds are used for both speed and brightness. This is done to assure that the DFM does not rapidly oscillate between active mode and standby mode.

The DFM is activated above 35 mph and deactivated below 30 mph.

The DFM is activated below a brightness value of 120 and is deactivated above a brightness value of 150. (Note: Brightness is determined using the DFM camera. The units are arbitrary and have a full range from 0 to 254)

SENSITIVITY SETTINGS AND PERCLOS THRESHOLDS

<u>High Sensitivity</u>

PERCLOS calculation period:	1 min
Initial advisory tone	PERCLOS = 8 percent (4.8 s)
Full warning	PERCLOS = 12 percent (7.2 s)

<u>Medium Sensitivity</u>

PERCLOS calculation period:	3 min
Initial advisory tone	PERCLOS = 9 percent (16.2 s)
Full warning	PERCLOS = 12 percent (21.6 s)

<u>Low Sensitivity</u>

PERCLOS calculation period:	5 min
Initial advisory tone	PERCLOS = 10 percent (30 s)
Full warning	PERCLOS = 12 percent (36 s)

MOUNTING INSTRUCTIONS

It is recommended that the DFM be mounted to the right of the driver, as close to the centerline as the steering wheel will allow without blocking the driver's view. An angle of about 15(- 20) degrees from the centerline is desirable. A larger angle will result in more false alarms from mirror checking.

The DFM can be attached to the top of the dashboard with a high quality adhesive transfer tape. 3M 467 or 468 tape is recommended. A unit can also be tethered from the camera support to a mounting screw on the dashboard to assure it will not strike the driver during a crash.

DFM Serial Port Input

The DFM accepts speed input through the serial port as an unsigned byte with a range of 0–254 mph. Sending a value of 255 will override the seed and brightness thresholds. The receipt of 255 is acknowledged by a beep.

DFM Serial Port Output Record

(12 comma-delimited fields followed by a carriage return <CR> and a line feed <LF>)
AAA, E, OOO, TTT, FFF, S, BBB, M, C, W, s, I<CR><LF>

FIELD DESCRIPTIONS

AAA	Ambient Brightness	0-254 (0=dark; 254=bright)
E	Number of Eyes Found	0, 1, 2
OOO	PERCLOS1 (high sensitivity)	0-100
TTT	PERCLOS3 (medium sensitivity)	0-100
FFF	PERCLOS5 (low sensitivity)	0-100
S	Sensitivity	0 = H; 1 = M; 2 = L
BBB	Display Brightness (set by driver)	0-255
M	Operating Mode	0 = Automatic Standby 1 = Manual Standby 2 = Automatic-Manual Standby 3 = Active 4 = Warning 1 (Full warning) 5 = Warning 2 (After 'ok' button is pressed)
C	Longest Eye Closure	1, 2, 3, 4
W	Warning Flag	0 = Warning not Triggered 1 = Full Warning 2 = Initial Advisory Tone
s	Warning Sound (set by driver)	0, 1, 2, 3, 4, 5
I	Seven Segment Display	0 = Display Off 1 = Display On

APPENDIX D: ORIGINAL PRE-STUDY SURVEY

DROWSY DRIVER WARNING SYSTEM (DDWS): PRE-EXPOSURE SURVEY

Thank you for taking the time to complete this survey! It should take you about 30 minutes to fill out. The information that you provide will not be shared with any of your managers or other operators, and your responses will be kept strictly confidential. This survey asks you questions about you, your health and well being, use of the DDWS device, and your current work schedule and environment. You are not required to provide answers to any survey items that make you uncomfortable. However, the more data you provide, the better we will be able to understand the potential benefits of the device for drivers like yourself.

Operator Information:

The DDWS may affect different people in different ways. The following questions ask about you and your background, to help us determine who benefits most from the device.

1. Some people feel older or younger than their actual age. How old do you feel? ______ years

2. Please indicate about how many years of each of the following you have completed and if you have graduated.

	Number of Years	*Did You Graduate?*	
High School	_________	☐ Yes	☐ No
Technical School	_________	☐ Yes	☐ No
Subject: __________________			
College	_________	☐ Yes	☐ No

3. What is your present marital status? (Please check one)

   ☐ Single ☐ Divorced
   ☐ Married ☐ Separated
   ☐ Living with Partner ☐ Widowed

4. How many people are dependent upon your income, including yourself? _________

5. How many other people in your household are dependent upon you for a substantial part of their personal care? ______________

Health and Well Being:

The following questions will allow us to better understand the effect of this device on your health. Please pay careful attention to any additional instructions.

1. Draw a line through the bar to indicate how healthy you feel, in general.

Very healthy |————————————————| Not healthy at all

2. *Instructions:* The questions in this scale ask you about your feelings and thoughts during the last month. In each case, please indicate with a check how often you felt or thought a certain way.

   a. In the last month, how often have you felt that you were unable to control the important things in your life?
   ☐ Never ☐ Almost never ☐ Sometimes ☐ Fairly often ☐ Very often

   b. In the last month, how often have you felt confident about your ability to handle your personal problems?
   ☐ Never ☐ Almost never ☐ Sometimes ☐ Fairly often ☐ Very often

   c. In the last month, how often have you felt that things were going your way?
   ☐ Never ☐ Almost never ☐ Sometimes ☐ Fairly often ☐ Very often

   d. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?
   ☐ Never ☐ Almost never ☐ Sometimes ☐ Fairly often ☐ Very often

3. The following questions concern some of your body functions. Please try to answer each question by checking the appropriate box that indicates how often you have experienced each of the items *within the past year.* Check one space for each item below.

Items:	*Never*	*Less than once a month*	*Once or twice a month*	*Once a week*	*2 or 3 times a week*	*About every day*
Back pain						
Acid indigestion, heartburn, or acid stomach						
Gastrointestinal problems						
Constipation						
Tight feeling in stomach						
Blurred vision						
Trouble falling asleep						
Feeling tired upon awaking						
Trouble staying asleep						
Other:						
Other:						

4. What health problems or chronic conditions have you been diagnosed as having, and are they currently being treated? For example, diabetes, sleep apnea, heart condition, cancer, restless legs, etc.

Health Issue	Being Treated? (check one)	
____________________	☐ Yes	☐ No
____________________	☐ Yes	☐ No
____________________	☐ Yes	☐ No

5. How often do you usually have a drink of …? (Check only <u>one space</u> for <u>each item</u> listed below.) *<u>Place a ✓</u> next to the beverage if you use it as a way to stay alert while driving.*

Items:	*Used to stay alert while driving?*	More than 5 times a day	3 to 5 times a day	1 to 2 times a day	Less than once a day	Never or almost never
Beer						
Wine						
Other Liquor						
Coffee						
Tea						
Cola/ Soft Drink						

6. Do you smoke? ☐ yes ☐ no

If <u>yes</u>, how much do you smoke per day on average? *(enter a number)*
How many packs of cigarettes per day ___________
How many cigars per day ___________
How many pipes of tobacco per day ___________

Do you use smoking as a way to remain alert? ☐ yes ☐ no

7. What medications do you take regularly, for what reason, and do they make you feel sleepy? For example, medications including those for high blood pressure, cholesterol, allergies, etc.

Medication:	*What reason?*	*Makes me sleepy:*
____________	____________________	☐
____________	____________________	☐
____________	____________________	☐
____________	____________________	☐
____________	____________________	☐

8. *Instructions:* Read each question carefully. Check the box (✓) underneath the most appropriate time frame.

   a. If you were entirely free to plan your evening and had no commitments the next day, at what time would you choose to go to bed?

8 – 9 PM	9 – 10:15 PM	10:15 PM – 12:30 AM	12:30 – 1:45 AM	1:45 – 3 AM

   b. You have to do 2 hours physically hard work. If you were entirely free to plan your day, in which of the following periods would you choose to do the work?

8 – 10 AM	11 AM – 1 PM	3 – 5 PM	7 – 9 PM

   c. For some reason you have gone to bed several hours later than normal, but there is *no need* to get up at a particular time the next morning. Which of the following is most likely to occur?

      ☐ Will wake up at the usual time and not fall asleep again
      ☐ Will wake up at the usual time and doze thereafter
      ☐ Will wake up at the usual time but will fall asleep again
      ☐ Will not wake up until later than usual

   d. You have a 2-hour test to take, which you know will be mentally exhausting. If you were entirely free to choose, in which of the following periods would you choose to take the test?

8 – 10 AM	11 AM – 1 PM	3 – 5 PM	7 – 9 PM

   e. If you had no commitments the next day and were entirely free to plan your own day, what time would you get up?

5 – 6:30 AM	6:30 – 7:45 AM	7:45 – 9:45 AM	9:45 – 11:00 AM	11:00 AM – 12:00 PM	12pm or later

   f. A friend has asked you to join him twice a week for a work-out in the gym. The best time for him is between 10 p.m. – 11 p.m. Bearing nothing else in mind other than how you normally feel in the evening, how do you think you would perform?

      ☐ Very well
      ☐ Reasonably well
      ☐ Poorly
      ☐ Very poorly

g. One hears about "morning" and "evening" types of people. Which of these types do you consider yourself to be?

☐ Definitely morning type
☐ More a morning than an evening type
☐ More an evening than a morning type
☐ Definitely an evening type

9. *Instructions:* Below are 18 statements that people sometimes make about themselves. Please indicate whether or not you believe each statement applies to you by marking whether you:

1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

_____1. Are you inclined to keep in the background on social occasions?
_____2. Do you like to mix socially with people?
_____3. Do you sometimes feel happy, sometimes depressed, without any apparent reason?
_____4. Are you inclined to limit your acquaintances to a select few?
_____5. Do you like to have many social engagements?
_____6. Do you have frequent ups and downs in mood, either with or without apparent cause?
_____7. Would you rate yourself as a happy-go-lucky individual?
_____8. Can you usually let yourself go and have a good time at a party?
_____9. Are you inclined to be moody?
_____10. Would you be very unhappy if you were prevented from making numerous social contacts?
_____11. Do you usually take the initiative in making new friends?
_____12. Does your mind often wander while you are trying to concentrate?
_____13. Do you like to play pranks upon others?
_____14. Are you usually a "good mixer?"
_____15. Are you sometimes bubbling over with energy and sometimes very sluggish?
_____16. Do you often "have the time of your life" at social affairs?
_____17. Are you frequently "lost in thought" even when you should be taking part in a conversation?
_____18. Do you derive more satisfaction from social activities than from anything else?

10. Have any major stressful life events taken place in your life within the last year?
☐ yes ☐ no If yes, what was the event(s)? ______________________________

DDWS Device:
The following questions will help us to better understand your views of the DDWS device before you use it.

1. Please describe in your own words how the DDWS may help you manage your fatigue while driving:____
____
____

2. How will you know if the device is <u>not working properly</u>? *(Check any that apply)*

☐ Device provides no warnings
☐ Device provides constant warnings
☐ No visual display present
☐ Other: ____

3. How do you plan on using DDWS feedback *immediately* while you are driving? *(Check any that apply)*

☐ I will stop driving and pull over to sleep
☐ I will drink a beverage that contains caffeine
☐ Other: ____

4. How useful do you think the DDWS will be *in combination with a fatigue management program* in helping you manage your fatigue while at work?

☐ Not at all useful ☐ A little useful ☐ Quite useful ☐ Extremely useful

5. How useful do you think the DDWS will be in helping you manage your fatigue at work if used *without the addition* of a fatigue management program?

☐ Not at all useful ☐ A little useful ☐ Quite useful ☐ Extremely useful

6. The DDWS is designed for use by a wide range of drivers and may not always correctly assess the alertness level of a particular person. How will you determine if this device is providing you with accurate information about your level of alertness?

☐ It will only sound warnings when I am fatigued
☐ It will never sound warnings when I am alert
☐ Other: ____

7. Do you feel that using this device will harm your health? ☐ yes ☐ no
   If <u>yes</u>, how? ____

8. To what extent do you believe the DDWS will improve the safety of your driving?

☐ Not at all ☐ A little ☐ Quite a bit ☐ Extremely
Why? ____

9. Draw a line through the bar to indicate the likelihood of you causing a fatigue-related accident or incident…

   a. …when <u>**not using**</u> the DDWS device

Not at all |————————————————| Extremely

   b. …when <u>**using**</u> the DDWS device

Not at all |————————————————| Extremely

10. Under each range of times, enter a value from the following scale to indicate how ***alert*** you anticipate feeling when driving at that time through *rural interstates* using the DDWS.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

11. Under each range of times, enter a value from the following scale to indicate how ***alert*** you anticipate feeling when driving at that time through *city streets and highways* using the DDWS.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

12. *Currently*, how often do you glace at the instrument panel in the cab?

☐ Once or more a minute
☐ Once every 5 to 10 minutes
☐ Once every 15 to 30 minutes
☐ Once every 30 to 60 minutes

13. *Before* you get a warning, how often do you *expect* to glance at the DDWS (in general)?

☐ Once or more a minute
☐ Once every 5 to 10 minutes
☐ Once every 15 to 30 minutes
☐ Once every 30 to 60 minutes
☐ Only when an alarm is sounded

14. *Once* it has given a warning, how often do you expect to glance at the DDWS (in general)?

☐ Once or more a minute
☐ Once every 5 to 10 minutes
☐ Once every 15 to 30 minutes
☐ Once every 30 to 60 minutes
☐ Only when an alarm is sounded

15. How often would the DDWS have to give you a false warning for you to stop using it?

☐ More than once an hour
☐ Every couple of hours
☐ Several times a night
☐ Once a week
☐ Less than once a week

Current Work Schedule and Environment:
The following questions will help us to better understand the impact of your work schedule and work environment before DDWS usage begins.

Instructions: Please answer questions 1 – 4 below about your **stress** level.

1. Draw a line through the bar to indicate how stressed you feel, in general, when driving in the early morning hours through *rural interstates*.

Not at all |————————————————| Extremely

2. Under each clock time, enter a value from the scale below to indicate how stressed you feel, in general, when driving at that time through *rural interstates*.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

3. Draw a line through the bar to indicate how stressed you feel, in general, when driving in the early morning hours through *city streets and highways*.

Not at all |————————————————| Extremely

4. Under each clock time enter a value from the following scale to indicate how stressed you feel, in general, when driving at that time through *city streets and highways*.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

Instructions: Please answer questions 5 – 13 below about your **fatigue** level.

5. While operating a commercial motor vehicle, have you ever, even for a moment, fallen asleep behind the wheel? ☐ yes ☐ no

6. While operating a commercial motor vehicle, have you ever been driving and found yourself somewhere, not remembering how you got there? ☐ yes ☐ no

7. How likely are you to *doze off* or *fall asleep* in the following situations, in contrast to feeling just tired? This refers to your usual way of life in recent times. Even if you have not done some of these things recently, try to work out how they would have affected you. Use the following scale to choose the most appropriate number for each situation:

   0 = no chance of dozing
   1 = slight chance of dozing
   2 = moderate chance of dozing
   3 = high chance of dozing

SITUATION CHANCE OF DOZING :

Sitting and reading ____________
Watching TV ____________
Sitting inactive in a public place (e.g., a theater or a meeting) ____________
As a passenger in a car for an hour without a break ____________
Lying down to rest in the afternoon when circumstances permit ____________
Sitting and talking to someone ____________
Sitting quietly after a lunch without alcohol ____________
In a car, while stopped for a few minutes in traffic ____________

8. Draw a line through the bar to indicate how <u>fatigued</u> you feel, in general, when driving in the <u>early morning</u> hours through *rural interstates*:

Not at all |————————————————| Extremely

9. Draw a line through the bar to indicate how <u>fatigued</u> you feel, in general, when driving in the <u>early morning</u> hours through *city streets and highways*:

Not at all |————————————————| Extremely

10. Under each clock time, enter a value from the following scale to indicate how <u>fatigued</u> you feel, in general, when driving at that time through *rural interstates*.
1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

11. Under each clock time, enter a value from the following scale to indicate how <u>fatigued</u> you feel, in general, when driving at that time through *city streets and highways*.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

12. How well are you *currently* able to comply with your company's fatigue management program?
☐ Not at all ☐ A little ☐ Quite a bit ☐ Very much

13. How well do you think you *will be able to* comply with your company's fatigue management program, using DDWS feedback?

☐ Not at all ☐ A little ☐ Quite a bit ☐ Very much

<u>*Instructions*: Please answer questions 14 & 15 below about your **alertness** level.</u>

14. Under each clock time, enter a value from the following scale to indicate how <u>alert</u> you feel, in general, when driving at that time through *rural interstate areas*.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

15. Under each clock time enter a value from the following scale to indicate how <u>alert</u> you feel, in general, when driving at that time through *city streets and highways*.

1 = Not at all   2 = A little   3 = Quite a bit   4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

16. How do you plan on using DDWS feedback (if at all) you received while driving during your non-driving time?
 - ☐ Planning a sleep/wake schedule
 - ☐ Planning meal times
 - ☐ I do not plan on using the DDWS feedback I received during non-driving time
 - ☐ Other: ____

17. What time(s) do you typically take a meal break while on duty? ________________________

 ____

18. Have you ever been involved in an accident or incident while working that you feel was related to your sleepiness or fatigue level? ☐ yes ☐ no
 If yes, how many? _______________

19. Have you been involved in other fatigue management programs within the past *year*?
 ☐ yes ☐ no
 If *yes*, please briefly explain what they contained: ____________________________________

20. Please indicate your familiarity with fatigue management:

☐ Very Familiar/expert ☐ Familiar ☐ Somewhat familiar ☐ Novice ☐ Completely new concept

21. How many total *hours* do you work in a typical week? __________.
 How many of these hours do you spend driving? __________.

22. Please record your *typical* work start and end times for each day in the grid below.
 - Write *"off"* for those days you are <u>not</u> usually scheduled to work.
 - If the days you work change from week to week, fill in the *typical* time you might work for each day and check the '<u>variable work schedule</u>' box below the grid.

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday

☐ *variable work schedule*

23. What percent of your <u>work time</u> do you drive on:
 city streets and highways: ___________%
 rural interstates: ___________%
 Other: ______________________________%

24. How often during a typical work shift do you load and or unload your own cargo?

- ☐ Never
- ☐ Occasionally
- ☐ Sometimes (about half the time)
- ☐ Frequently
- ☐ Always

25. On typical loads, how long does it usually take you to load/unload the truck during deliveries:

- ☐ Half-hour or less
- ☐ About one hour
- ☐ 1 to 2 hours
- ☐ More than 2 hours
- ☐ This question does not apply; I do not generally load/unload my truck

Do you find this activity to be more alerting or fatiguing?

☐ Alerting ☐ Fatiguing ☐ Neither

Why: ____

26. What other work-related duties do you typically perform, if any, besides driving and loading/ unloading? ____

27. What type of tractor do you most frequently drive? __________________________________

THANK YOU FOR COMPLETING THIS SURVEY!

APPENDIX E: ORIGINAL POST-STUDY SURVEY

DROWSY DRIVER WARNING SYSTEM (DDWS): POST-EXPOSURE QUESTIONNAIRE

Thank you for taking the time to complete this survey. It should take you about 30 minutes to fill out. The information that you provide will <u>not</u> be shared with any of your managers or other operators, and your responses will be kept strictly <u>confidential</u>. This survey asks you questions about your health and well being, use of the DDWS device, and your current work schedule and environment. You are not required to provide answers to any survey items that make you uncomfortable. However, the more data you provide, the better we will be able to understand the potential benefits of the device for drivers like yourself.

Health and Well Being:
The following questions will allow us to better understand the effect of this device on your health. Please pay careful attention to any additional instructions.

1. Draw a line through the bar to indicate how healthy you feel, in general.

   Very healthy |————————————————| Not healthy at all

2. The following questions concern some of your body functions. Please try to answer each question by checking the appropriate box that indicates how often you experienced each of the items *during the course of the study*. Check <u>one space</u> for <u>each item</u> below.

Items:	*Never*	*Less than once a month*	*Once or twice a month*	*Once a week*	*2 or 3 times a week*	*About every day*
Back pain						
Acid indigestion, heartburn, or acid stomach						
Gastrointestinal problems						
Constipation						
Tight feeling in stomach						
Blurred vision						
Trouble falling asleep						
Feeling tired upon awaking						
Trouble staying asleep						
Other:						
Other:						

3. Did any major stressful life events take place in your life during the study?
☐ yes ☐ no
If yes, what was the event(s)? ____

4. *Instructions:* The questions in this scale ask you about your feelings and thoughts during the last month. In each case, please indicate with a check how often you felt or thought a certain way.

a. In the last month, how often have you felt that you were unable to control the important things in your life?
☐ Never ☐ Almost Never ☐ Sometimes ☐ Fairly Often ☐ Very Often

b. In the last month, how often have you felt confident about your ability to handle your personal problems?
☐ Never ☐ Almost Never ☐ Sometimes ☐ Fairly Often ☐ Very Often

c. In the last month, how often have you felt that things were going your way?
☐ Never ☐ Almost Never ☐ Sometimes ☐ Fairly Often ☐ Very Often

d. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?
☐ Never ☐ Almost Never ☐ Sometimes ☐ Fairly Often ☐ Very Often

DDWS Device:
The following questions will help us to better understand your view of the DDWS device now that you have used it.

1. Please describe…
   a. how you believe that the DDWS *works*: ________________________________
   ____
   b. how the DDWS may have *helped you manage* your fatigue while driving: ______
   ____

2. Were you aware of any situations where the DDWS device did not operate properly during the study? ☐ yes ☐ no

If yes, how did you know that the device was not operating properly? *(Check any that apply)*

☐ Device provided no warnings
☐ Device provided constant warnings
☐ No visual display present
☐ Other: ____

3. How did you use DDWS feedback *immediately* while you were driving? *(Check any that apply)*

   ☐ I stopped driving and pulled over to sleep
   ☐ I drank a beverage that contained caffeine
   ☐ Other: ____

4. How useful do you think the DDWS was *in combination with a fatigue management program* in helping you manage your fatigue while at work?

   ☐ Not at all useful ☐ A little useful ☐ Quite useful ☐ Extremely useful

5. How useful do you think the DDWS was in helping you manage your fatigue at work if used *without the addition* of a fatigue management program?

   ☐ Not at all useful ☐ A little useful ☐ Quite useful ☐ Extremely useful

6. The DDWS was designed for use by a wide range of drivers and may not always have correctly assessed the alertness level of a particular person. How did you determine whether this device was providing you with accurate information about your level of alertness?

   ☐ It only sounded warnings when I was fatigued
   ☐ It never sounded warnings when I was alert
   ☐ Other: ____

7. To what extent do you believe the DDWS improved the safety of your driving?

   ☐ Not at all ☐ A little ☐ Quite a bit ☐ Extremely
   Why? ____

8. *Before* getting a warning, how often did you usually glance at the DDWS device?

   ☐ Once or more a minute
   ☐ Once every 5 to 10 minutes
   ☐ Once every 15 to 30 minutes
   ☐ Once every 30 to 60 minutes
   ☐ Only when an alarm is sounded

9. *Once* the DDWS gave a warning, how often did you usually glance at the device?

   ☐ Once or more a minute
   ☐ Once every 5 to 10 minutes
   ☐ Once every 15 to 30 minutes
   ☐ Once every 30 to 60 minutes
   ☐ Only when an alarm is sounded

10. Draw a line through the bar to indicate how much effort you gave in <u>monitoring</u> the DDWS.

    None |————————————————————| Extreme

11. Draw a line through the bar to indicate how much effort you gave in <u>reacting</u> to the DDWS warnings.

    None |————————————————————| Extreme

12. How often did you feel that the DDWS *accurately* determined your level of alertness by providing you with *appropriate* warnings?

☐ Almost never ☐ Occasionally ☐ Frequently ☐ Almost always

13. Draw a line through the bar to indicate your overall *annoyance* with false DDWS warnings.

None |————————————————| Extreme

14. How did you decide whether or not the DDWS was providing you with *correct* warnings? (Check all that apply)

☐ I almost always received warnings when I was tired
☐ I knew that I was alert while driving and did not expect to receive any warnings
☐ Other: ____

15. What did you do when the device gave you *false* warnings? (Check all that apply)

☐ Ignored the device ☐ Reset the device ☐ Covered the device
☐ Other: ____

16. How often did you feel that the device gave you a false warning regarding your level of fatigue?

☐ Almost never ☐ Occasionally ☐ Frequently ☐ Almost always

17. Using the following scale, indicate how *difficult* it was, in general, to <u>quickly understand and react</u> to DDWS warnings for <u>each</u> of the below time periods.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

18. Draw a line through the bar to indicate how easy it was to *read* the DDWS display *while driving*.

Not at all |————————————————| Extremely

19. Draw a line through the bar to indicate how easy it was to *hear* the DDWS warnings.

Not at all |————————————————| Extremely

20. List the steps you usually took when the DDWS provided you with a warning:____________

____

____

21. Using the following scale, indicate how *often*, in general, the DDWS gave you an incorrect warning for each of the time periods below.

    1 = Almost never   2 = Occasionally   3 = Frequently   4 = Almost always

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

22. Did the DDWS provide you with all of the *information* that you needed to make good decisions?
    ☐ Yes   ☐ No
    If "no", what additional information would you have liked? ______________________________

23. Was the *location* of the DDWS acceptable? (Check one)   ☐Yes   ☐No
    If "no", what was the problem? ____

24. Under what conditions were you most likely to *use the DDWS warning information*? (Check all that apply)
    ☐ When I felt very tired
    ☐ During poor driving conditions
    ☐ When there was very little traffic
    ☐ Other: ________________________________

25. Draw a line through the bar to indicate the extent that you found yourself *relying too much* on the DDWS to *warn* you about your level of fatigue.

    Not at all |——————————————————————————| Extremely

26. How often did you find yourself *unable* to take actions to improve your alertness once the DDWS produced a warning?

    ☐ Almost never   ☐ Occasionally   ☐ Frequently   ☐ Almost always

27. How often did you find yourself *unwilling* to take actions to improve your alertness once the DDWS produced a warning?

    ☐ Almost never   ☐ Occasionally   ☐ Frequently   ☐ Almost always

28. In what situations did you *most frequently* not take corrective action after the DDWS warning was sounded? ____

29. What was your *biggest problem* when operating the DDWS? (Check one)

    ☐ Reading the display
    ☐ Turning off the alarm
    ☐ Changing device sensitivity
    ☐ Hearing the warning
    ☐ No problem
    ☐ Other: ________________________________

30. How did you use the DDWS feedback that you received while driving (if at all) during your non-driving time? *(check all that apply).*

☐ Planned my sleep/wake schedule
☐ Planned meal times
☐ I did not use the DDWS feedback I received during non-driving time
☐ Other: ____

31. Did you use DDWS output to guide your other fatigue management activities?
☐ No ☐ Yes
If "yes," how did you use the DDWS information? ______________________

32. Draw a line through the bar to indicate your comfort level in *using DDWS output* to guide your other fatigue management activities (for example, changing the time you sleep, etc.).

Not at all |————————————————| Extremely

33. How <u>long</u> did it take you to <u>understand</u> the ways in which you could use DDWS output in your other fatigue management activities? (Check one)

☐ One day ☐ Less than 1 week ☐ Less than 1 month ☐ Still learning

34. Were you able to understand the <u>written</u> materials that you received about the DDWS?
☐ No ☐Yes

35. Would it have helped you if DDWS <u>training</u> materials were written in a language *other* than English? ☐ No ☐Yes If "yes," which language? __________________

36. Draw a line through the bar to indicate the <u>usefulness</u> of the DDWS compared to other fatigue management interventions that you use.

Not at all |————————————————| Extremely

37. Draw a line through the bar to indicate the <u>completeness</u> of the <u>*DDWS training*</u> that was provided to you by your company.

Not at all |————————————————| Extremely

38. Draw a line through the bar to indicate the <u>completeness</u> of the <u>*fatigue management training*</u> provided to you by your company.

Not at all |————————————————| Extremely

39. Do you believe that the DDWS information was kept *confidential* as discussed at the beginning of the study? Yes ☐ No ☐
If "no," why not? ____

40. How many warnings did the DDWS need to provide you before you *tried to take actions to improve your alertness*? ☐ 1 ☐ 2 ☐ 3 ☐ 4 or more

41. Do you find the information given to you by the DDWS *useful for managing your fatigue*?
☐ Yes ☐ No Why or why not? ____

42. Have you found uses for the DDWS <u>other than</u> as a fatigue management tool?
☐ No ☐ Yes
If "yes," what are the uses? ____

43. How do you feel that the DDWS has affected your health? (check one)

☐ Improved my health ☐ No effect on my health
☐ Impaired my health Why? ______________________________

44. Draw a line through the bar to indicate the <u>likelihood</u> of you being involved in a fatigue-related *accident* or *incident* when <u>not using</u> the DDWS.

Not at all |————————————————————| Extremely

45. Draw a line through the bar to indicate the <u>likelihood</u> of you being involved in a fatigue-related *accident* or *incident* when <u>using</u> the DDWS.

Not at all |————————————————————| Extremely

46. Do you feel that, for whatever reason, using the DDWS made you feel <u>more fatigued</u> when you drove your usual hours? ☐No ☐ Yes
If "yes," why? ____

47. Would you be willing to continue using the DDWS device after the study is over if the information it provides you is <u>not recorded or available</u> to your company and others?
☐ No ☐ Yes Why or why *not*? ____

48. I would be willing to: (check all that apply)
- ☐ purchase a DDWS myself, if affordable
- ☐ cost-share the purchase of a DDWS for my truck cab with my employer
- ☐ request that my employer purchase a DDWS device for my truck
- ☐ request that my employer purchase DDWS devices for the fleet

49. Have you recommended the *use and purchase* of this device to your <u>management</u>?
☐ No ☐ Yes

50. Have you recommended the use of the DDWS to other drivers in your company?
☐ No ☐ Yes

51. Have you recommended the use of the DDWS device to professional drivers outside your company? ☐ No ☐ Yes

52. How often did you ignore DDWS warnings?

☐ Almost never ☐ Occasionally ☐ Frequently ☐ Almost always

53. How often did you trick the DDWS device so that it would no longer give you warnings?

☐ Almost never ☐ Occasionally ☐ Frequently ☐ Almost always

54. Draw a line through the bar to indicate *how well* you feel that you were able to include the DDWS into your fatigue management routines.

Not at all |————————————————| Extremely

55. In the boxes below, write down any other *fatigue-fighting actions* or *activities* you do when driving and their frequency of use:
1 = Nightly 2 = Weekly 3 = Monthly 4 = Only rarely

Fatigue-fighting Action or Activity	*Frequency*

56. Please briefly describe what you do *personally* to try to control your on-duty fatigue: ______

____

57. Do you feel that the DDWS helped you to avoid an accident or a close call when it was turned *on* during the study? ☐ No ☐ Yes
If yes, how often? ____

58. Did you take any fatigue or safety management classes, *other than what was provided for the DDWS*, during your participation in this study? ☐ No ☐ Yes
If "yes," what class? ____

59. How annoying were the auditory alerts provided by the DDWS?
☐ Unacceptably annoying
☐ Somewhat annoying
☐ Tolerable
☐ Only slightly annoying
☐ Not at all annoying

60. Overall, I think that DDWS <u>increased</u> my driving safety.

Strongly disagree |————————————————| Strongly agree

61. Overall, how <u>satisfied</u> were with you with the DDWS system?

Very unsatisfied |————————————————| Very satisfied

62. On average, how often per duty period do you feel that the DDWS device gave you a <u>false warning</u> regarding your level of fatigue? _______ times per duty period.

63. How <u>comfortable</u> did you feel using the DDWS device?

Very uncomfortable |————————————————| Very comfortable

64. How <u>easy or difficult</u> did you find it to drive using the DDWS device?

Very difficult |————————————————| Very easy

65. How easily were you able to <u>recognize</u> alerts from the DDWS device?

Not easily |————————————————| Very easily

66. Overall, I think the DDWS device <u>got my attention quickly</u> when it provided an alert.

Strongly disagree |————————————————| Strongly agree

67. Were there ever situations when the DDWS device operated in a manner that you did not understand? ☐ No ☐ Yes If "*yes*", please explain: ___________________________

____

68. On average, how often per duty period do you feel that the DDWS device did <u>not</u> give you a warning regarding your level of fatigue when you felt that one was necessary? _______ times per duty period

69. Draw a line through the bar to indicate how <u>easy</u> it was to *use* the DDWS device *while driving*.

Not at all |————————————————| Extremely

70. Did you stop relying on the DDWS due to false warnings? ☐ No ☐ Yes

71. While operating a commercial motor vehicle during the study, did you ever, even for a moment, fall asleep behind the wheel? ☐ No ☐ Yes

72. While operating a commercial motor vehicle during the study, did you ever find yourself somewhere, not remembering how you got there? ☐ No ☐ Yes

73. Please indicate your overall acceptance rating of the DDWS system?

For each choice you will find 5 possible answers. When a term is completely appropriate, please put a check (•) in the square next to that term. When a term is appropriate to a certain extent, please put a check to the left or right of the middle at the side of the term. When you have no specific opinion, please put a check in the middle.

The DDWS system was:

useful						useless
pleasant						unpleasant
bad						good
nice						annoying
effective						superfluous
irritating						likeable
assisting						worthless
undesirable						desirable
raising alertness						sleep-inducing

Current Work Schedule and Environment:
The following question will help us to better understand the impact of your work schedule and work environment after using the DDWS device.

Instructions: Please answer questions 1 – 4 below about your **stress** level while driving using the DDWS.

1. Draw a line through the bar to indicate how **stressed** you felt, in general, when driving in the early morning hours through *rural interstates* using the DDWS:

   Not at all |————————————————| Extremely

2. Under each clock time, enter a value from the scale below to indicate how **stressed** you felt, in general, when driving at that time through *rural interstates* using the DDWS.

   1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

3. Draw a line through the bar to indicate how **stressed** you felt, in general, when driving in the early morning hours through *city streets and highways* using the DDWS.

   Not at all |————————————————| Extremely

4. Under each clock time enter a value from the following scale to indicate how **stressed** you felt, in general, when driving at that time through *city streets and highways* using the DDWS.

   1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

Instructions: Please answer questions 5 – 10 below about your **fatigue** level while driving using the DDWS.

5. Draw a line through the bar to indicate how **fatigued** you felt, in general, when driving in the early morning hours through *rural interstates* using the DDWS.

   Not at all |————————————————| Extremely

6. Under each clock time, enter a value from the following scale to indicate how **fatigued** you felt, in general, when driving at that time through *rural interstates*.

   1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

7. Draw a line through the bar to indicate how **<u>fatigued</u>** you felt, in general, when driving in the <u>early morning</u> hours through *city streets and highways* <u>using the DDWS</u>.

Not at all |————————————————| Extremely

8. Under each clock time, enter a value from the following scale to indicate how **<u>fatigued</u>** you felt, in general, when driving at that time through *city streets and highways* <u>using the DDWS</u>.

1 = Not at all   2 = A little   3 = Quite a bit   4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

9. How well do you *now* think that you will be able to comply with your company's fatigue management program, by using DDWS feedback?

☐ Not at all   ☐ A little   ☐ Quite a bit   ☐ Very much

10. How likely are you to *doze off* or *fall asleep* in the following situations, in contrast to feeling just tired? This refers to your usual way of life in recent times. Even if you have not done some of these things recently, try to work out how they would have affected you. Use the following scale to choose the most appropriate number for each situation:

0 = no chance of dozing
1 = slight chance of dozing
2 = moderate chance of dozing
3 = high chance of dozing

SITUATION CHANCE OF DOZING :

Sitting and reading ____________
Watching TV ____________
Sitting inactive in a public place (e.g., a theater or a meeting) ____________
As a passenger in a car for an hour without a break ____________
Lying down to rest in the afternoon when circumstances permit ____________
Sitting and talking to someone ____________
Sitting quietly after a lunch without alcohol ____________
In a car, while stopped for a few minutes in traffic ____________

<u>*Instructions*: Please answer questions 11 & 12 below about your **alertness** level.</u>

11. Under each clock time, enter a value from the following scale to indicate how **<u>alert</u>** you felt, in general, when driving at that time through *rural interstate areas* <u>using the DDWS</u>.

1 = Not at all   2 = A little   3 = Quite a bit   4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

12. Under each clock time enter a value from the following scale to indicate how **alert** you felt, in general, when driving at that time through *city streets and highways* using the DDWS.

1 = Not at all   2 = A little   3 = Quite a bit   4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

13. Did you drive any new or unfamiliar runs over the duration of the study?

☐ No   ☐ Yes   If yes, please list the runs below.

Run
Example: Pittsburgh to Boston via Routes 80,84,90

THANK YOU FOR COMPLETING THIS SURVEY!

APPENDIX F: ORIGINAL DEBRIEFING SURVEY

DEBRIEFING SURVEY

The entire study staff would like to thank you for your participation in this experiment! We realize that this was not an easy or a short study, and therefore very much appreciate your willingness to complete all of the requested tasks. The data collected from this experiment will be used to assess and further develop the DDWS for the American trucking industry. You have made a major contribution to our understanding of the safety benefits of this device and how we may improve upon it.

Instructions: Please write your answers under each question. Use the back of the page if you need additional space.

1. What part(s) of the experiment did you find objectionable or were a hardship?

2. What did you enjoy or find interesting about the study?

3. How do you think the *training* on using the DDWS can be improved to be more helpful?

4. Was the amount of money you received for participating in the study a fair compensation for the extra work that you had to do? (Check one) ☐ No ☐ Yes

   If you answered "No," what compensation would have been fair?

5. Do you feel that a *reward incentive* (e.g.,, receiving a reward for reducing the number of warnings you received over the duration of the study) would have changed the way you used the DDWS feedback? (Check one) ☐ No ☐ Yes

   If "Yes", how?

6. Did you find any part of the study (e.g.,, the training, explanation, focus groups, etc.) to be overly rushed or poorly timed? (Check one) ☐ No ☐ Yes

   If "Yes", what part of the study was rushed and how might it be fixed?

7. What problems, if any, did you notice in how the study was conducted?

8. How aware were you of the DDWS and being in a study when the device was *not turned on*?

9. In general, did you feel *more alert* throughout the night during the study than you would have otherwise? ☐ No ☐ Yes

   If "yes", why do you think that you felt this way?

10. Overall, how did you feel that you were treated during the experiment? How could we improve the experience of future participants?

11. General comments and observations:

APPENDIX G: COMPANY PROFILES

PITT OHIO EXPRESS

Pitt Ohio Express is headquartered in Pittsburgh, Pennsylvania. It is involved primarily in less-than-a-truckload (LTL) operations, in which drivers deliver loads and return to the base location in a short period of time (usually less than 24 hours). The company has 20 terminals located mainly within the Mid-Atlantic States and Ohio and West Virginia. All the drivers make day trips and return to the terminal within 24 hours, driving approximately 500 miles per shift. Additionally, Pitt Ohio Express provides 14-ft van trucks for short-haul transportation at selected terminals. These van trucks were not employed for the DDWS FOT.

Pitt Ohio employs a slip-seat operation for assigning trucks to drivers, in which one day driver and one night driver are paired up to drive the same truck. All drivers begin and end their shifts at the same terminal. Usually there is less than an hour between the daytime and the nighttime driver's shift. The daytime drivers usually leave the terminal in the morning between 7 and 9 a.m. and return in the evening between 7 and 8 p.m.; the nighttime drivers are informed about their departure time on that evening, depending on delivery time, destination, and when their truck is expected to return to the terminal. The nighttime drivers return to the terminal the next morning between about 5 and 8 a.m.. At this point the daytime driver gets into the truck again. The operation runs from Monday morning with the daytime drivers to Saturday morning with the return of the nighttime drivers. All drivers participating in the study were nighttime drivers, and the instrumented trucks were day-cab type trucks (i.e., no sleeper in the cab).

Drivers from two Pitt Ohio Express terminals in Roanoke and Richmond, Virginia, participated in the study. As of June 2005, the Roanoke terminal employed 54 drivers and 7 dispatchers. Of the 54 drivers, 37 were daytime drivers and 17 were nighttime drivers. Of the 17 nighttime drivers, 9 participated in the study. The Roanoke terminal had 24 tractors with single trailers and 12 straight (single-unit) trucks. Of the 24 tractors, 4 were instrumented by VTTI to be used in the study. The terminal had both daytime and nighttime mechanics on site.

The Richmond terminal is base for more than 50 drivers; about 48 of them are tractor-trailer drivers. Approximately 30 of those are daytime drivers and 18 are nighttime drivers. The terminal also runs single-unit trucks. Four trucks were instrumented by VTTI to participate in the study. Of the 18 nighttime drivers, 7 qualified and agreed to participate in the study. The primary routes for the participating drivers included driving from Richmond to terminals in Baltimore and Cumberland, Maryland, and Roanoke, Virginia. The drivers typically logged between 5 and 9 hours of driving time per night, five nights per week. None of the drivers drove regularly on Saturday or Sunday nights.

J.B. HUNT

J.B. Hunt Transport Services, Inc., is headquartered in Lowell, Arkansas. J.B. Hunt is a major transport company hauling throughout the entire continental United States as well as Canada and Mexico. Transport components include dry van, inter-modal, and dedicated contract services. J.B. Hunt currently employs approximately 12,800 drivers at 217 terminals. Six Virginia terminals participated in this study.

The first terminal to participate in the study was located in South Boston, Virginia. J.B. Hunt was the dedicated service provider for a general goods store located in South Boston, Virginia. This terminal employed approximately 130 drivers, 15 of whom participated in the study. Out of the total 130 trucks that this terminal maintained, 15 were instrumented to collect data. The majority of all loads were hauled during nighttime, with an approximate average of 500 miles per shift. This contract was canceled, and J.B. Hunt offered further participation in the study by transferring all instrumented trucks to a new location in Stuarts Draft, Virginia. Drivers also transferring to this new location continued their participation in the study.

In Stuarts Draft, J.B. Hunt was the dedicated service provider for a major chain store. This terminal employed approximately 60 drivers, 16 of whom participated in the study. A total of 65 trucks were maintained by this terminal, including the 15 instrumented trucks transferred from South Boston. One extra truck was also instrumented to allow participation for an additional participant. The majority of all loads from this terminal were hauled in the nighttime, with an approximate average of 500 miles per shift running from Sunday mornings to Saturday evenings. After exhausting all the available and interested drivers for participation in the study, 8 of the 15 instrumented trucks were transferred to a new location in Winchester, Virginia for further participation recruitment.

J.B. Hunt was the dedicated service provider for another general goods store in Winchester. This terminal employed approximately 70 drivers, 12 of whom participated in the study. A total of 72 trucks were maintained by this terminal, including 8 of the trucks transferred from Stuarts Draft. The majority of all loads from this terminal were hauled during nighttime, with an approximate average of 600 miles per shift running seven days a week. After exhausting the population of available and interested drivers for participation in the study, J.B. Hunt offered further participation in the study by allowing VTTI to use three other small locations. Two of these locations were in Winchester, Virginia, and third was in Virginia Beach, Virginia.

The first new location made available for driver recruitment was a major home improvement chain store in Winchester, Virginia, for whom J.B. Hunt was the dedicated service provider. This terminal employed approximately 20 drivers, one of whom participated in the study. Approximately 80 percent of the deliveries are performed during the day, leaving 20 percent as overnight deliveries. A total of 22 trucks were maintained by this terminal, including the instrumented truck transferred from Stuarts Draft for specific use in the study. The approximate average miles per shift were 400 mi.

A second new location made available for driver recruitment was in Virginia Beach, Virginia, where J.B. Hunt was a dedicated service provider. This terminal employed approximately 14 drivers, 2 of whom participated in the study. Approximately 40 percent of the deliveries were performed during the day, leaving 60 percent as overnight deliveries. A total of 17 trucks were maintained by this terminal, including 2 of the instrumented trucks transferred specifically for use in the study. The approximate average miles per shift was 1,000 miles. The terminal generally performs deliveries from Sunday evening to Saturday morning.

The last location made available for driver recruitment was in Winchester, Virginia, where J.B. Hunt was again a dedicated service provider. This terminal employed 5 drivers, one of whom participated in the study. The majority of loads were performed on flatbed trailers. This small terminal delivered approximately 75 to 80 deliveries per week. A total of five trucks were maintained by this terminal, including the instrumented truck use in the study. Drivers generally averaged about 400 miles per shift and work typically Sunday evening until Friday evening.

HOWELL'S MOTOR FREIGHT

Howell's Motor Freight, Inc., is a privately owned, Virginia-based freight carrier providing temperature-controlled and dry truckload, LTL, pool, and distribution services primarily to the wholesale/retail food and grocery industry and its suppliers.

Howell's currently owns and operates 200 tractor trucks and 500 refrigerated trailers. The trucks owned by the company include both day cabs and sleepers. The trailer fleet includes both 53-ft and 48-ft trailers. Drivers are usually assigned to particular trucks. Exceptions to this include assignment of new trucks and truck breakdowns. Howell's operates seven terminal locations across five States. Virginia terminals include Roanoke and Portsmouth. North Carolina terminals are located at Charlotte and Raleigh. The other terminals are located in Atlanta, Georgia; Columbia, South Carolina; and Louisville, Kentucky. The two terminals that participated in the study were the Roanoke and Charlotte terminals.

The Roanoke terminal is base to 52 out of the 180 trucks owned by the company. Seventeen of these trucks were instrumented by VTTI to participate in the study. Of the 40 trucks based in Charlotte, 2 were instrumented to participate in the study as well.

Operations at Howell's depend on 170 drivers, 45 of whom are based in Roanoke and 35 in Charlotte. Of the 170 drivers at Howell's, 42 are truckload drivers. Of these 42 drivers, 39 participated in the study at the Roanoke terminal using the 17 instrumented trucks at this location. Two Charlotte LTL drivers participated in the study as well, with the two instrumented trucks at this terminal. The truckload drivers typically leave the terminal on Sunday or Monday and come back Friday or Saturday. Due to the nature of trucking operations, this schedule varies depending on the loads, due dates, etc. Some drivers may drive during weekends as well. Drivers report an approximate of 460 miles driven per day.

Howell's temperature-controlled terminals in Roanoke, Portsmouth, Raleigh, Charlotte, and Atlanta, provide full-service pool and LTL distribution as well as support for the truckload/line-haul division. The truckload/line-haul division operates in a territory that encompasses Delaware, Georgia, Illinois, Indiana, Kentucky, Maryland, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia , West Virginia, Missouri, and Alabama. The company also operates several stand-alone dedicated operations along with a logistics division for customer services.

Operation Site Number: __________ **Confidential**

Date:___________

APPENDIX H: FLEET MANAGEMENT SURVEY

Instructions: Thank you for taking the time to fill in this survey. It should take you about twenty minutes to complete. Please leave blank any information you are not sure of or do not feel comfortable providing. We will use this information in aggregate to determine market factors that may influence the penetration of this new technology into the commercial trucking industry.

---

1. What is the safety record of your company (accidents per vehicle mile): _______________

2. In which safety management programs (for example, 1-800 drive safe, etc.) does your organization participate?____

3. How often do your drivers receive safety training? (Check one):

   ☐ only once ☐ every 6 months ☐ annually ☐ every 2 years ☐ other:___________

4. How often do your drivers receive fatigue management training? (Check one):
   ☐ only once ☐ every 6 months ☐ annually ☐ every 2 years ☐ other:___________

5. Please describe the content and structure of your fatigue management program, or attach a course outline or other relevant materials (if applicable): __________________________
   ____
   ____
   ____
   ____

6. Does your senior management recognize the need for fatigue management? (Check one)
   ☐ No ☐ Yes

7. How does your senior management support fatigue management? (Check one)
   ☐ Appropriates funding ☐ Provides a liaison ☐ Writes policy statements
   ☐ Other____

8. What data and information does your senior management need to justify a business case for investing in fatigue management?____
   ____
   ____

9. What data and information does your senior management need to justify a business case for investing in drowsy driver warning systems for the fleet?______________________
   ____
   ____
   ____
   ____

10. What is the extent of the safety training that you provide for new employees? __________
    ____
    ____
    ____

11. What do you see as the main potential safety-related economic benefits of installing the Drowsy Driver Warning System (DDWS) in your fleet? ____________________________
    ____

12. What federal incentives would make you more likely to recommend the purchase of this device for your fleet?____
    ____

13. What insurance incentives would make you more likely to recommend the purchase of this device for your fleet? ____
    ____

14. What is the maximum price that your company would be willing to pay per installed DDWS unit? $_________________

15. What price might your company be willing to pay per installed DDWS unit if it yielded the following percent reductions in reportable accidents and incidents?

1%	5%	10%	15%	20%
$	$	$	$	$

16. Would your fleet management want to use DDWS alert information if they had access to it? (Check one) ☐ No ☐ Yes

    If yes, how might they use this information? _________________________________
    ____
    ____

17. What kind of policy might your fleet management put in place, given driver behavior regarding DDWS alert information? ____
    ____
    ____

18. If you already have a fatigue management program in place, how might you modify it to incorporate the DDWS? ____
    ____
    ____

19. What concerns, if any, do you have with the performance of the DDWS? ______________
____
____
____

20. What additional features or capabilities would you like the DDWS to have? How much above the DDWS base cost would you be willing to pay for this feature?

Feature				
Additional cost for feature	$	$	$	$

21. What other improvements would you like to see with the DDWS? ____________________
____
____
____

22. From what you know and heard about the DDWS, do you feel your drivers would be willing to use this safety device in an appropriate manner? (Check one) ☐ No ☐ Yes

Why or why not? ____
____
____
____

23. In your opinion, what are the major factors that will lead to driver acceptance of the DDWS?
____
____
____
____

APPENDIX I: INFORMED CONSENT FORM

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Informed Consent for Participants
in Research Projects Involving Human Subjects

Title of Project: Drowsy Driver Warning System (DDWS) Field Operational Test (FOT)
Task 18: Collect On-Road Data
Investigators: Dr. Richard Hanowski, Dr. Ronald Knipling, Akiko Nakata

I. Purpose of this Research/Project

The purpose of this study is to evaluate the safety benefits of a device that monitors driver drowsiness. This device is called a Driver Fatigue Monitor (DFM). As you know, drowsiness is of particular safety concern in the trucking industry. The DFM monitors drivers' eye closures and provides an alert if it detects that the driver is becoming drowsy. This study will investigate how well this system works at improving safety, and determine how drivers feel about the device.

II. Procedures

We would like you to drive your truck and complete your work route as you normally do. A DFM has been mounted on the dash of your truck. In addition, a variety of other data collection equipment has been instrumented on your truck. This data collection equipment is necessary for us to understand the safety benefits of the DFM.

In addition to driving your truck, there are several other tasks that you will need to complete:

1. Read and sign this Informed Consent Form (if you agree to participate).
2. Wear a wrist activity monitor (called Actigraph watch), for the length of your participation.
3. Complete pre- and post-study surveys.
4. Participate in a training session that will include a fatigue management course and information about the study.

The study will last 10, 14 or up to 16 weeks for the research team to conduct a thorough analysis of the DFM. We are collecting data from many truck drivers like yourself (102 drivers total). To understand if the DFM might benefit the trucking industry, it is important that you use the device as it is intended for the entire study period.

The starting day of data collection is determined by the date when you start wearing the wrist activity monitor. Your regular days-off will be counted towards the number of data collection weeks but you will be expected to wear the Actigraph watch on your days-off. We ask that you not take vacation time during the period that you are participating in the study. However, if you do take vacation days during the study, these vacation days will not be counted towards the data collection weeks.

III. Risks and Discomforts
There are some risks and discomforts to which you will be exposed in volunteering for this research. The risks are:

1. The risk of an accident associated with driving a truck as you usually do.
2. The slight additional risk of an accident that might possibly occur while pressing a button to indicate that a critical incident has occurred.
3. The slight additional risk of an accident that might possibly occur while interacting with the DFM.
4. While driving the vehicle, you will be videotaped by a camera. Because of this, we ask that you not wear sunglasses. If this, at any time during the course of your driving, impairs your ability to drive the vehicle safely, you may wear the glasses. Otherwise, we ask you not to do so.

The following precautions will be taken to ensure minimal risk to the subjects:

1. Drivers will be trained on how to operate the critical incident button and the DFM.
2. All data collection equipment is mounted such that, to the greatest extent possible, it does not pose a hazard to you in any foreseeable way.
3. You will be instructed to follow your company's safety protocol.

There is not expected to be any additional risk posed by having the DFM in the vehicle. The DFM involves infrared beams that detect retinal reflectance to determine a percentage of eyelid closure. The beams are emitted from a small mounted camera that will in no way be in contact with any part of your body. When compared to a similar device that has been judged to be safe by an expert, Dr. David H. Sliney (a Physicist in the Laser/Optical Radiation Program with the U.S. Army) concluded that the camera's illumination system has irradiation levels well below the safe value of 10-mW/cm^2.

IV. Benefits
No promise or guarantee of benefits is being made to encourage you to participate. Research, such as that being conducted here, is important because it improves driving safety and helps reduce crashes. Drivers' participation is necessary to assess the efficacy of a drowsiness monitor aimed at reducing fatigue-related crashes. Past experience with previous studies involving heavy-vehicle drivers indicates that you may find the study interesting.

V. Extent of Anonymity and Confidentiality

The data gathered in this experiment will be treated with confidentiality. Shortly after participating, your name will be separated from the data and replaced with a number. That is, your data will not be attached to your name, but rather to a number (e.g., Driver No.1).

While you are driving the vehicle, a camera will videotape your face with some additional space around the head to accommodate any head-movements. Additionally, video cameras will capture views looking in front, and to both sides of the vehicle.

If a critical incident occurs, you will be asked to press a button on the dash. This will place a flag in the data set so researchers can more easily locate the event. Also, pressing the button opens up an audio channel for 1-minute. In this 1-minute, you can describe the critical incident that occurred.

The video and other data from this study will be stored in a secured area at the Virginia Tech Transportation Institute. Access to the digital video files will be under the supervision of the Principal Investigator and lead researcher involved in the project. The video files will be accessible to the government sponsor and to those researchers and data analysts associated with this project and for follow-up analytical projects, at VTTI and the Volpe Center (the independent evaluator for this project). The video files will not be released to unauthorized individuals without your written consent.

We will do everything we can to keep others from learning about your participation in this study. To further help us protect your privacy, the investigators have obtained a Confidentiality Certificate from the Department of Health and Human Services (DHHS). This confidentiality is provided for by the Public Health Services Act (§ 301(d), 42 U.S.C. 8241(d)).

With this Certificate, the investigators cannot be forced (for example by court subpoena) to disclose information that may identify you in any federal, state, or local civil, criminal, administrative, legislative, or other proceedings.

Disclosure will be necessary, however, upon request of DHHS for the purpose of audit or evaluation.

You should understand that a Confidentiality Certificate does not prevent you or a member of your family from voluntarily releasing information about yourself or your involvement in this research. Note however, that if an insurer, employer or other outside party, learns about your participation, and obtains your consent to receive research information, then the investigator may not use the Certificate of Confidentiality to withhold this information. This means that you and your family must also actively protect your own privacy.

Finally, you should understand that the investigator is not prevented from taking steps, including reporting to authorities, to prevent serious harm to yourself or others.

VI. Compensation
You will be paid for participating in this FOT. You will be paid $20 for a DFM screening test, and $30 for the DFM and fatigue management training sessions. During the on-road data collection, you will be paid $75 per week for driving the instrumented DFM truck. You will be paid a bonus of $250 for completing the study, including meeting VTTI regularly for data downloading, submitting all surveys to VTTI, and wearing the actigraph watch during your participation period. The total payment will be $1050 ($20+$30+$75*10weeks ($750) +250) for 10 weeks of data collection; $1350 ($20+$30+$75*14weeks ($1050) +250) for 14 weeks of data collection; and $1500 ($20+$30+$75*16weeks +$250) for 16 weeks of data collection.

You will be paid in cash, immediately after completion, for the DFM screening test ($20). You will be paid for the on-road data collection at the end of the study. Payment for the on-road data collection part of the study will be made by check and mailed to you after your participation in the study is over.

XIII. Freedom to Withdraw
As a participant in this research, you are free to withdraw at any time without penalty. If you choose to withdraw, you will be compensated for the portion of time of the study for which you participated. However, you will not be eligible for the bonus. Furthermore, you are free not to answer any question or respond to experimental situations without penalty.

IX. Approval of Research
This research project has been approved, as required, by the Institutional Review Board for Research Involving Human Subjects at Virginia Polytechnic Institute and State University.

September 11, 2003	September 10, 2005
IRB Approval Date	Approval Expiration Date

X. Subject's Responsibilities
I voluntarily agree to participate in this study. I have the following responsibilities:

1. To be physically free from any illegal substances (i.e., drugs) or alcohol while driving,
2. To conform to the laws and regulations of driving on public roadways,
3. To follow the experimental procedures as well as you can,
4. To perform the driving task without interfering with the operation of the DDWS or other on-board equipment,
5. To inform the experimenters if you incur difficulties of any type,
6. To comply with the testing procedures and to not interfere with the DFM’s operation, and
7. To return all the equipment and actigraph watch to VTTI at the end of my participation in the study. If any equipment and/or watches are not returned, a replacement cost will be deducted from my compensation.

XI. Subject's Permission
I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project.

If I participate, I understand that I may withdraw at any time without penalty. I agree to abide by the rules of this project.

____Date___________________________ *Subject signature*

XII. Voluntary Use of Data for Presentations
You have agreed to participate in the Drowsy Driver Warning System and Data Acquisition System Field Operational Test. The purpose of this research is to test the reliability of the Drowsy Driver Warning System. In support of this research, digital video cameras will be used to record driving behavior that represents the way drivers drive. We realize that this digital video files could be used to clarify the methods used and to demonstrate the findings at technical conferences and for other presentations.

With your permission, we would like to have the opportunity to show and release portions of videotape displaying your image. The purpose of this form is to obtain your consent to do so. If you agree, please read and sign below. If you do not agree, you will still be able to participate in this study, but your data will not be used for demonstration or presentation purposes.

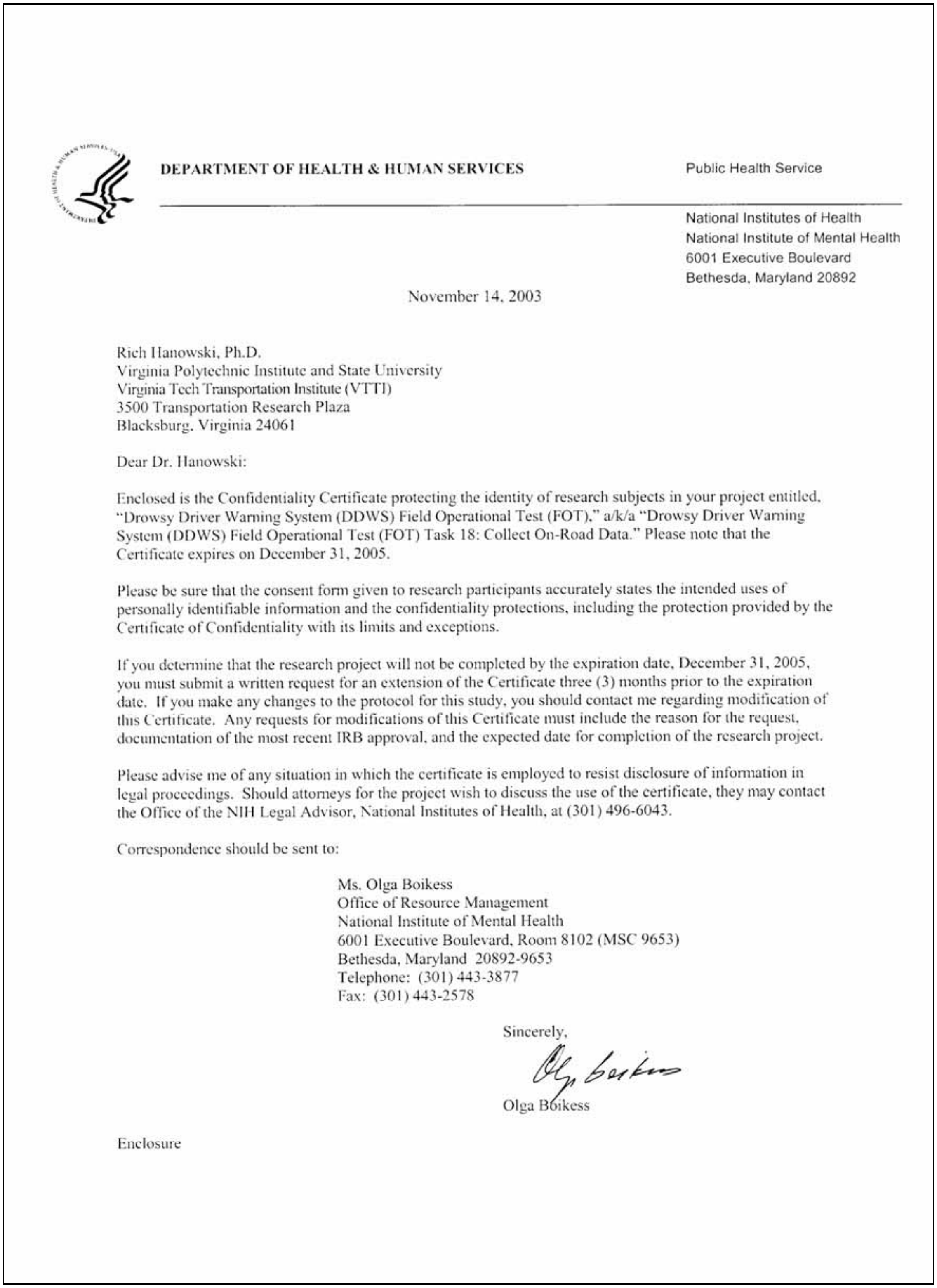
____Date___________________________ *Subject signature*

Should I have any questions about this research or its conduct, I may contact:

_____Richard Hanowski_________ ***Investigator(s)***	__[redacted] ***Telephone/e-mail***
_____Akiko Nakata____________________ ***Senior Research Associate***	__[redacted] ***Telephone/e-mail***
_____David M. Moore____________________ ***Chair, IRB*** ***Office of Research Compliance*** ***Research & Graduate Studies***	__[redacted]____ ***Telephone/e-mail***

Subjects must be given a complete copy (or duplicate original) of the signed Informed Consent.

APPENDIX J: Certificate of Confidentiality



DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

National Institutes of Health
National Institute of Mental Health
6001 Executive Boulevard
Bethesda, Maryland 20892

November 14, 2003

Rich Hanowski, Ph.D.
Virginia Polytechnic Institute and State University
Virginia Tech Transportation Institute (VTTI)
3500 Transportation Research Plaza
Blacksburg, Virginia 24061

Dear Dr. Hanowski:

Enclosed is the Confidentiality Certificate protecting the identity of research subjects in your project entitled, "Drowsy Driver Warning System (DDWS) Field Operational Test (FOT)," a/k/a "Drowsy Driver Warning System (DDWS) Field Operational Test (FOT) Task 18: Collect On-Road Data." Please note that the Certificate expires on December 31, 2005.

Please be sure that the consent form given to research participants accurately states the intended uses of personally identifiable information and the confidentiality protections, including the protection provided by the Certificate of Confidentiality with its limits and exceptions.

If you determine that the research project will not be completed by the expiration date, December 31, 2005, you must submit a written request for an extension of the Certificate three (3) months prior to the expiration date. If you make any changes to the protocol for this study, you should contact me regarding modification of this Certificate. Any requests for modifications of this Certificate must include the reason for the request, documentation of the most recent IRB approval, and the expected date for completion of the research project.

Please advise me of any situation in which the certificate is employed to resist disclosure of information in legal proceedings. Should attorneys for the project wish to discuss the use of the certificate, they may contact the Office of the NIH Legal Advisor, National Institutes of Health, at (301) 496-6043.

Correspondence should be sent to:

Ms. Olga Boikess
Office of Resource Management
National Institute of Mental Health
6001 Executive Boulevard, Room 8102 (MSC 9653)
Bethesda, Maryland 20892-9653
Telephone: (301) 443-3877
Fax: (301) 443-2578

Sincerely,

Olga Boikess

Enclosure

Confidential

APPENDIX K: STUDY PRE-PARTICIPATION SURVEY

Instructions: Thank you for taking the time to fill in this survey. It should take you about one minute to complete. Please leave blank any information you are not sure of or do not feel comfortable giving. We will use this information to help us determine which drivers are best suited to participate in the study. The information you give will be kept confidential and will not be shared with any of your managers or other drivers.

Name:___________________________________ Date:___________

1. What is your age?: ___________ years   2. Gender *(Check one)*: ☐ Male ☐ Female
2. What is your eye color? ______________
3. Height: _______feet _______inches   5. Weight: ___________pounds
4. Build *(check one)*: ☐ Small frame ☐ Medium frame ☐ Large frame
5. Do you wear contact lenses? *(Check one)* ☐ No ☐ Yes (Lens color:________________)
6. Do you wear glasses at *night* when driving? ☐ No ☐ Yes – if *yes*: ☐ Metal frame ☐ Plastic frame
7. Do you use a hearing aid? ☐ No ☐ Yes, – if *yes*: in which ear(s)? _____________
8. Which of the following groups is <u>most</u> representative of your background? *(Check one)*

   ☐ African/American ☐ Asian/American ☐ Caucasian/American
   ☐ Hispanic/American ☐ Native American

9. Is English your language of preference for: reading? *(check one)* ☐ No ☐ Yes

   speaking? *(check one)* ☐ No ☐ Yes

10. How long have you been driving commercial vehicles? _____years _____months
11. How long have you been working for this company? _____years _____months
12. How long did you work for your <u>previous</u> employer (your job before this one)? _____years _____months
13. Are you a member of a union *(Check one)*? ☐ No ☐ Yes, which one?___________
14. Type of license and endorsements held: License:________________ Endorsements: _______________
15. I would like to participate in this experiment *(Check one)*: ☐ No ☐ Yes

    If <u>yes</u>: What is your phone number? __________

    What is the best time to reach you? __________

The following three questions refer to your behavior while sleeping, trying to sleep, or while feeling sleepy. Please check one box for each question.

During the last month have you done or been told that you do any of the following?

	Never	**Rarely (< 1 time per week)**	**1-2 times per week**	**3-4 times per week**	**5-7 times per week**	**Don't know**
Loud Snoring						
Snorting or gasping						
Your breathing stops, or you struggle for breath						

16. Do you carry a cell phone while on the job? *(Check one)* ☐ Yes ☐ No

If Yes: Who is your cell phone carrier? ________________________

What is the brand name of your cell phone? ________________________

About how many minutes do you talk per month? __________________
(Please put approximate minutes you use the cell phone, rather than the allotted minutes for your cell phone plan)

How many times, on average, do you use your cell phone per day? _______________

Participant Number: E________ CONFIDENTIAL

Administration Date: _________ Completion Date: _________ Mailing Date: _________

APPENDIX L: PRE-STUDY SURVEY FOR EXPERIMENTAL GROUP

Thank you for taking the time to complete this survey. It should take you about 30 minutes to fill out. The information that you give will not be shared with any of your managers or other operators, and your responses will be kept strictly confidential. This survey asks you questions about you, your health and well being, use of the drowsy driver warning system (DDWS), and your current work schedule and environment. You are not required to give answers to any survey items that make you uncomfortable. However, the more data you give, the better we will be able to understand the potential benefits of the device for drivers like yourself.

Operator Information:
The questions below about yourself and your background will help us to learn about what types of people are participating in this study.

1. Some people feel older or younger than their actual age. How old do you feel? ______ years

2. Please write down about how many years of each you have finished. Then check the correct box under whether or not you graduated.

	Number of years	*Did You Graduate?*	
High School	__________	☐ Yes	☐ No
Technical School	__________	☐ Yes	☐ No
Subject: __________________			
College	__________	☐ Yes	☐ No

3. What is your present marital status? *(Check one)*

☐ Single ☐ Divorced
☐ Married ☐ Separated
☐ Living with Partner ☐ Widowed

4. How many people depend on your income, including yourself? __________

5. How many other people in your household depend on you for a large part of their personal care? _______________

Health and Well Being:
The questions below will help us to better understand the status of your health. Please carefully follow any additional instructions.

1. Draw a line through the bar to show how healthy you usually feel.

Very healthy |————————————————| Not healthy at all

Please continue on to the next page…

Participant Number: E_________ CONFIDENTIAL

Administration Date: _________ Completion Date: _________ Mailing Date: _________

2. *Instructions:* The questions in this scale ask you about your feelings and thoughts <u>during the last month</u>. In each case, please check how often you felt or thought a certain way.

   a. In the last month, how often have you felt that you were unable to control the important things in your life?
      ☐ Never ☐ Almost never ☐ Sometimes ☐ Fairly often ☐ Very often

   b. In the last month, how often have you felt confident about your ability to handle your personal problems?
      ☐ Never ☐ Almost never ☐ Sometimes ☐ Fairly often ☐ Very often

   c. In the last month, how often have you felt that things were going your way?
      ☐ Never ☐ Almost never ☐ Sometimes ☐ Fairly often ☐ Very often

   d. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?
      ☐ Never ☐ Almost never ☐ Sometimes ☐ Fairly often ☐ Very often

3. The questions below concern some of your body functions. Please try to answer each question by checking the appropriate box that shows how often you experienced each of the items *within the past year*. Check <u>one space</u> for <u>each item</u> below.

Items:	*Never*	*Less than once a month*	*Once or twice a month*	*Once a week*	*2 or 3 times a week*	*About every day*
Back Pain						
Acid indigestion, heartburn, or acid stomach						
Gastrointestinal problems						
Constipation						
Tight feeling in stomach						
Blurred vision						
Trouble falling asleep						
Feeling tired upon awaking						
Trouble staying asleep						
Other:						
Other:						

Please continue on to the next page…

4. What health problems or chronic conditions have you been diagnosed with? Are they currently being treated? For example, diabetes, sleep apnea, heart condition, cancer, restless legs, etc.

Health Issue	Being Treated? (check one)	
______________________	☐ Yes	☐ No
______________________	☐ Yes	☐ No
______________________	☐ Yes	☐ No

5. How often do you usually have a drink of …? *(Check only one space for each drink item listed below). Then, place a ✓ in the shaded column if you use that beverage to stay awake while driving.*

Items:	More than 5 times a day	3 to 5 times a day	1 to 2 times a day	Less than once a day	Never or almost never	*Used to stay alert while driving?*
Beer						
Wine						
Other Liquor						
Coffee						
Tea						
Cola/ Soft Drink						

6. Do you smoke? ☐ Yes ☐ No

If yes, how much do you smoke per day, on average? *(Enter a number)*

How many packs of cigarettes per day __________

How many cigars per day __________

How many pipes of tobacco per day __________

Do you use smoking as a way to remain alert? ☐ Yes ☐ No

7. Please list the medications you take regularly and for what reason you take them. Also, please check the box for those that make you feel sleepy. For example, medications including those for high blood pressure, cholesterol, allergies, etc.

Medication:	*What reason?*	*Makes me sleepy:*
______________	______________________	☐
______________	______________________	☐
______________	______________________	☐
______________	______________________	☐
______________	______________________	☐

Please continue on to the next page…

Participant Number: E________ CONFIDENTIAL

Administration Date: _________ Completion Date: __________ Mailing Date: __________

8. *Instructions:* Read each question carefully. Check the box (✓) underneath the most appropriate time frame.

a. If you were entirely free to plan your evening and had no commitments the next day, at what time would you choose to go to bed?

8 – 9 PM	9 – 10:15 PM	10:15 PM – 12:30 AM	12:30 – 1:45 AM	1:45 – 3 AM

b. You have to do 2 hours physically hard work. If you were entirely free to plan your day, in which of the following periods would you choose to do the work?

8 – 10 AM	11 AM – 1 PM	3 – 5 PM	7 – 9 PM

c. For some reason you have gone to bed several hours later than normal, but there is no need to get up at a particular time the next morning. Which of the following is most likely to occur?

- ☐ Will wake up at the usual time and not fall asleep again
- ☐ Will wake up at the usual time and doze thereafter
- ☐ Will wake up at the usual time but will fall asleep again
- ☐ Will not wake up until later than usual

d. You have a 2-hour test to take, which you know will be mentally exhausting. If you were entirely free to choose, in which of the following periods would you choose to sit the test?

8 – 10 AM	11 AM – 1 PM	3 – 5 PM	7 – 9 PM

e. If you had no commitments the next day and were entirely free to plan your own day, what time would you get up?

5 – 6:30 AM	6:30 – 7:45 AM	7:45 – 9:45 AM	9:45 – 11:00 AM	11:00 AM – 12:00 PM	12 PM or later

f. A friend has asked you to join him twice a week for a work-out in the gym. The best time for him is between 10pm - 11pm. Bearing nothing else in mind other than how you normally feel in the evening, how do you think you would perform?

- ☐ Very well
- ☐ Reasonably well
- ☐ Poorly
- ☐ Very poorly

g. One hears about 'morning' and 'evening' types of people. Which of these types do you consider yourself to be?

- ☐ Definitely morning type
- ☐ More a morning than an evening type
- ☐ More an evening than a morning type
- ☐ Definitely an evening type

Please continue on to the next page…

Administration Date: _________ Completion Date: __________ Mailing Date: __________

9. *Instructions:* Below are 18 statements that people sometimes make about themselves. Please indicate whether or not you believe each statement applies to you by marking whether you:

1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

_____1. Are you inclined to keep in the background on social occasions?
_____2. Do you like to mix socially with people?
_____3. Do you sometimes feel happy, sometimes depressed, without any apparent reason?
_____4. Are you inclined to limit your acquaintances to a select few?
_____5. Do you like to have many social engagements?
_____6. Do you have frequent ups and downs in mood, either with or without apparent cause?
_____7. Would you rate yourself as a happy-go-lucky individual?
_____8. Can you usually let yourself go and have a good time at a party?
_____9. Are you inclined to be moody?
_____10. Would you be very unhappy if you were prevented from making numerous social contacts?
_____11. Do you usually take the initiative in making new friends?
_____12. Does your mind often wander while you are trying to concentrate?
_____13. Do you like to play pranks upon others?
_____14. Are you usually a "good mixer?"
_____15. Are you sometimes bubbling over with energy and sometimes very sluggish?
_____16. Do you often "have the time of your life" at social affairs?
_____17. Are you frequently "lost in thought" even when you should be taking part in a conversation?
_____18. Do you derive more satisfaction from social activities than from anything else?

10. Have any major stressful events taken place in your life within the last year? ☐ Yes ☐ No
If yes, what was the event(s)?
____

DDWS Device:
The questions below will help us to better understand what you think about the DDWS device before you use it.

1. Please describe in your own words how the DDWS may help you handle your fatigue while driving:____
____
____

2. How will you know if the device is not working right? *(Check any that apply)*

☐ Device gives no warnings
☐ Device gives constant warnings
☐ No visual display present
☐ Other: ____

Please continue on to the next page…

3. How do you plan on using DDWS warnings immediately while you are driving? *(Check any that apply)*

   ☐ I will stop driving and pull over to sleep
   ☐ I will drink a beverage that has caffeine in it
   ☐ Other: ____

4. Along with a fatigue management program, how useful do you think the DDWS will be in helping you manage your fatigue while at work?

   ☐ Not at all useful ☐ A little useful ☐ Quite useful ☐ Extremely useful

5. Without a fatigue management program, how useful do you think the DDWS will be in helping you manage your fatigue at work?

   ☐ Not at all useful ☐ A little useful ☐ Quite useful ☐ Extremely useful

6. The DDWS is designed for use by many different types of drivers. It may not always correctly measure the alertness level of each person. How will you know if this device is giving you correct information about your level of alertness? *(Check any that apply)*

   ☐ It will only sound warnings when I am fatigued
   ☐ It will never sound warnings when I am alert
   ☐ Other:

   ____

7. Do you feel that using this device will harm your health? ☐ Yes ☐ No
   If yes, how?

____

8. How much do you believe the DDWS will improve the safety of your driving?

   ☐ Not at all ☐ A little ☐ Quite a bit ☐ Extremely

   Why?

____

9. Draw a line through the bar to show how likely it is for you to be involved in a fatigue-related accident or incident when not using the DDWS.

   Not at all |————————————————| Extremely

10. Draw a line through the bar to show how likely it is for you to be involved in a fatigue-related accident or incident when using the DDWS.

   Not at all |————————————————| Extremely

Please continue on to the next page…

11. Under each clock time, use the scale below to write down how alert you expect to feel when driving at that time through rural interstates using the DDWS.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

12. Under each clock time, use the scale below to write down how alert you expect to feel when driving at that time through city streets and highways using the DDWS.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

13. Currently, how often do you look at the instrument panel in the cab?

☐ Once or more a minute
☐ Once every 5 to 10 minutes
☐ Once every 15 to 30 minutes
☐ Once every 30 to 60 minutes

14. Before you get a warning, how often do you expect to look at the DDWS?

☐ Once or more a minute
☐ Once every 5 to 10 minutes
☐ Once every 15 to 30 minutes
☐ Once every 30 to 60 minutes
☐ Only when an alarm is sounded

15. Once it has given a warning, how often do you expect to look at the DDWS?

☐ Once or more a minute
☐ Once every 5 to 10 minutes
☐ Once every 15 to 30 minutes
☐ Once every 30 to 60 minutes
☐ Only when an alarm is sounded

16. How often would the DDWS have to give you an incorrect warning for you to stop using it?

☐ More than once an hour
☐ Every couple of hours
☐ Several times a night
☐ Once a week
☐ Less than once a week

Current Work Schedule and Environment:

The questions below will help us to better understand the impact of your work schedule and work environment.

Instructions: The questions below ask about your stress level when driving.

1. Draw a line through the bar to show how stressed you usually feel when driving in the early morning hours through rural interstates:

Not at all |――――――――――――――――| Extremely

Please continue on to the next page…

2. Under each clock time, use the scale below to write down how stressed you usually feel when driving at that time through rural interstates.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

3. Draw a line through the bar to indicate how stressed you usually feel when driving in the early morning hours through city streets and highways:

Not at all |————————————————| Extremely

4. Under each clock time, use the scale below to write down how stressed you usually feel when driving at that time through city streets and highways.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

Instructions: The questions below ask about your fatigue level when driving.

5. While operating a commercial motor vehicle, have you ever, even for a moment, fallen asleep behind the wheel? ☐ Yes ☐ No

6. While operating a commercial motor vehicle, have you ever been driving and found yourself somewhere, not remembering how you got there? ☐ Yes ☐ No

7. How likely are you to doze off or fall asleep in the following situations, in contrast to feeling just tired? This refers to your usual way of life in recent times. Even if you have not done some of these things recently, try to work out how they would have affected you. Use the following scale to choose the most appropriate number for each situation:

   0 = no chance of dozing
   1 = slight chance of dozing
   2 = moderate chance of dozing
   3 = high chance of dozing

SITUATION CHANCE OF DOZING :

Sitting and reading _____________
Watching TV _____________
Sitting inactive in a public place (e.g., a theater or a meeting) _____________
As a passenger in a car for an hour without a break _____________
Lying down to rest in the afternoon when circumstances permit _____________
Sitting and talking to someone _____________
Sitting quietly after a lunch without alcohol _____________
In a car, while stopped for a few minutes in traffic _____________

Please continue on to the next page…

Administration Date: _________ Completion Date: __________ Mailing Date: __________

8. Draw a line through the bar to show how fatigued you usually feel when driving in the early morning hours through rural interstates:

Not at all |————————————————| Extremely

9. Under each clock time, use the scale below to write down how fatigued you usually feel when driving at that time through rural interstates.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

10. Draw a line through the bar to show how fatigued you usually feel when driving in the early morning hours through city streets and highways:

Not at all |————————————————| Extremely

11. Under each clock time, use the scale below to write down how fatigued you usually feel when driving at that time through city streets and highways.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

12. How well are you currently able to follow your company's fatigue management program?

☐ Not at all ☐ A little ☐ Quite a bit ☐ Very much ☐ Non-applicable

13. How well do you think you will be able to follow your company's fatigue management program, using DDWS feedback?

☐ Not at all ☐ A little ☐ Quite a bit ☐ Very much ☐ Non-applicable

Instructions: The questions below ask about your alertness level when driving.

14. Draw a line through the bar to show how alert you usually feel when driving in the early morning hours through rural interstate areas:

Not at all |————————————————| Extremely

Please continue on to the next page…

15. Under each clock time, use the scale below to write down how alert you usually feel when driving at that time through rural interstate areas.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

16. Draw a line through the bar to show how alert you usually feel when driving in the early morning hours through city streets and highways:

Not at all |——————————————| Extremely

17. Under each clock time, use the scale below to write down how alert you usually feel when driving at that time through city streets and highways.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

18. During your non-driving time, how do you plan on using the DDWS feedback you received while driving?
    - ☐ Planning a sleep/wake schedule
    - ☐ Planning meal times
    - ☐ I do not plan on using the DDWS feedback I received during non-driving time
    - ☐ Other: ____

19. What time(s) do you usually take a meal break while on duty? *(Please write down hour(s) and AM/PM)* ____

20. Have you ever had an accident or incident while working that you feel was related to your sleepiness or fatigue level? ☐ yes ☐ no If yes, how many? _______

21. Have you been involved with other fatigue management programs within the past year?
☐ yes ☐ no If yes, please briefly explain what they contained:____________________
____

22. Please indicate how familiar you are with fatigue management:

☐ Very familiar/expert ☐ Familiar ☐ Somewhat familiar ☐ Novice ☐ Not at all familiar

23. How many total hours do you work in a typical week? _________. How many of these hours do you spend driving? _________

Please continue on to the next page…

Participant Number: C________ CONFIDENTIAL

Administration Date: _________ Completion Date: _________ Mailing Date: _________

24. *Please write down your typical work start and end times for each day in the grid below*.
   - Write *"off"* for those days you are not usually scheduled to work.
   - If the days you work change from week to week, fill in the *typical* time you might work for each day and check the 'variable work schedule' box below the grid.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Start time							
End time							

☐ *variable work schedule*

25. What percent of your work time do you drive on:
   city streets and highways: __________%
   rural interstates: __________%
   Other: ___________________________%

26. How often during a typical work shift do you load and or unload your own cargo?

- ☐ Never
- ☐ Occasional shifts
- ☐ Sometimes (about half of the time)
- ☐ Most shifts
- ☐ Every shift

27. For typical loads, how long does it take you to load/unload the truck during deliveries? ____ minutes

   Do you find loading/unloading the truck to be more alerting or fatiguing?
   ☐ Alerting ☐ Fatiguing ☐ Neither Why: ____________________________________

   ☐ This question does not apply; I do not usually load/unload my truck.

28. What other work-related duties do you usually do, if any, besides driving and loading/unloading?
   ____

29. What type of tractor do you usually drive? ____

THANK YOU for completing this survey!

Do you have any vacations, holiday or other planned time off scheduled over the 16 weeks of this study?

If yes, please give the dates that you will be out of work:

Participant Number: C________ CONFIDENTIAL

Administration Date: _________ Completion Date: _________ Mailing Date: _________

APPENDIX M: PRE-STUDY SURVEY FOR CONTROL GROUP

Thank you for taking the time to complete this survey. It should take you about 15 minutes to fill out. The information that you give will not be shared with any of your managers or other operators, and your responses will be kept strictly confidential. This survey asks you questions about you, your health and well being, fatigue management, and your current work schedule and environment. You are not required to give answers to any survey items that make you uncomfortable. However, the more data you give, the better we will be able to understand the potential benefits of the device for drivers like yourself.

Operator Information:

The questions below about yourself and your background will help us to learn about what types of people are participating in this study.

1. Some people feel older or younger than their actual age. How old do you feel? ______ years

2. Please write down about how many years of each you have finished. Then check the correct box under whether or not you graduated.

	Number of years	*Did You Graduate?*	
High School	_________	☐ Yes	☐ No
Technical School	_________	☐ Yes	☐ No
Subject: _________________			
College	_________	☐ Yes	☐ No

3. What is your present marital status? *(Check one)*

☐ Single ☐ Divorced
☐ Married ☐ Separated
☐ Living with Partner ☐ Widowed

4. How many people depend on your income, including yourself? _________

5. How many other people in your household depend on you for a large part of their personal care? ______________

Health and Well Being:

The questions below will help us to better understand the status of your health. Please carefully follow any additional instructions.

1. Draw a line through the bar to show how healthy you usually feel.

Very healthy |————————————————| Not healthy at all

Please continue on to the next page…

Participant Number: C_________ CONFIDENTIAL

Administration Date: __________ Completion Date: __________ Mailing Date: __________

2. *Instructions:* The questions in this scale ask you about your feelings and thoughts during the last month. In each case, please check how often you felt or thought a certain way.

   a. In the last month, how often have you felt that you were unable to control the important things in your life?
      ☐ Never ☐ Almost never ☐ Sometimes ☐ Fairly often ☐ Very often

   b. In the last month, how often have you felt confident about your ability to handle your personal problems?
      ☐ Never ☐ Almost never ☐ Sometimes ☐ Fairly often ☐ Very often

   c. In the last month, how often have you felt that things were going your way?
      ☐ Never ☐ Almost never ☐ Sometimes ☐ Fairly often ☐ Very often

   d. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?
      ☐ Never ☐ Almost never ☐ Sometimes ☐ Fairly often ☐ Very often

3. The questions below concern some of your body functions. Please try to answer each question by checking the appropriate box that shows how often you experienced each of the items *within the past year*. Check one space for each item below.

Items:	*Never*	*Less than once a month*	*Once or twice a month*	*Once a week*	*2 or 3 times a week*	*About every day*
Back Pain						
Acid indigestion, heartburn, or acid stomach						
Gastrointestinal problems						
Constipation						
Tight feeling in stomach						
Blurred vision						
Trouble falling asleep						
Feeling tired upon awaking						
Trouble staying asleep						
Other:						
Other:						

Please continue on to the next page…

Participant Number: C________ CONFIDENTIAL

Administration Date: _________ Completion Date: _________ Mailing Date: _________

4. What health problems or chronic conditions have you been diagnosed with? Are they currently being treated? For example, diabetes, sleep apnea, heart condition, cancer, restless legs, etc.

Health Issue | Being Treated? (check one)

_______________________________ ☐ Yes ☐ No
_______________________________ ☐ Yes ☐ No
_______________________________ ☐ Yes ☐ No

5. How often do you usually have a drink of …? *(Check only one space for each drink item listed below). Then, place a ✓ in the shaded column if you use that beverage to stay awake while driving.*

Items:	More than 5 times a day	3 to 5 times a day	1 to 2 times a day	Less than once a day	Never or almost never	*Used to stay alert while driving?*
Beer						
Wine						
Other Liquor						
Coffee						
Tea						
Cola/ Soft Drink						

6. Do you smoke? ☐ Yes ☐ No

If yes, how much do you smoke per day, on average? *(Enter a number)*

How many packs of cigarettes per day __________

How many cigars per day __________

How many pipes of tobacco per day __________

Do you use smoking as a way to remain alert? ☐ Yes ☐ No

7. Please list the medications you take regularly and for what reason you take them. Also, please check the box for those that make you feel sleepy. For example, medications including those for high blood pressure, cholesterol, allergies, etc.

Medication: | *What reason?* | *Makes me sleepy:*

_______________ _______________________________ ☐
_______________ _______________________________ ☐
_______________ _______________________________ ☐
_______________ _______________________________ ☐
_______________ _______________________________ ☐

Please continue on to the next page…

8. *Instructions:* Read each question carefully. Check the box (✓) underneath the most appropriate time frame.

a. If you were entirely free to plan your evening and had no commitments the next day, at what time would you choose to go to bed?

8 – 9 PM	9 – 10:15 PM	10:15 PM – 12:30 AM	12:30 – 1:45 AM	1:45 – 3 AM

b. You have to do 2 hours physically hard work. If you were entirely free to plan your day, in which of the following periods would you choose to do the work?

8 – 10 AM	11 AM – 1 PM	3 – 5 PM	7 – 9 PM

c. For some reason you have gone to bed several hours later than normal, but there is no need to get up at a particular time the next morning. Which of the following is most likely to occur?

- ☐ Will wake up at the usual time and not fall asleep again
- ☐ Will wake up at the usual time and doze thereafter
- ☐ Will wake up at the usual time but will fall asleep again
- ☐ Will not wake up until later than usual

d. You have a 2-hour test to take, which you know will be mentally exhausting. If you were entirely free to choose, in which of the following periods would you choose to sit the test?

8 – 10 AM	11 AM – 1 PM	3 – 5 PM	7 – 9 PM

e. If you had no commitments the next day and were entirely free to plan your own day, what time would you get up?

5 – 6:30 AM	6:30 – 7:45 AM	7:45 – 9:45 AM	9:45 – 11:00 AM	11:00 AM – 12:00 PM	12 PM or later

f. A friend has asked you to join him twice a week for a work-out in the gym. The best time for him is between 10pm - 11pm. Bearing nothing else in mind other than how you normally feel in the evening, how do you think you would perform?

- ☐ Very well
- ☐ Reasonably well
- ☐ Poorly
- ☐ Very poorly

g. One hears about 'morning' and 'evening' types of people. Which of these types do you consider yourself to be?

- ☐ Definitely morning type
- ☐ More a morning than an evening type
- ☐ More an evening than a morning type
- ☐ Definitely an evening type

Please continue on to the next page…

9. *Instructions:* Below are 18 statements that people sometimes make about themselves. Please indicate whether or not you believe each statement applies to you by marking whether you:

1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

_____1. Are you inclined to keep in the background on social occasions?
_____2. Do you like to mix socially with people?
_____3. Do you sometimes feel happy, sometimes depressed, without any apparent reason?
_____4. Are you inclined to limit your acquaintances to a select few?
_____5. Do you like to have many social engagements?
_____6. Do you have frequent ups and downs in mood, either with or without apparent cause?
_____7. Would you rate yourself as a happy-go-lucky individual?
_____8. Can you usually let yourself go and have a good time at a party?
_____9. Are you inclined to be moody?
_____10. Would you be very unhappy if you were prevented from making numerous social contacts?
_____11. Do you usually take the initiative in making new friends?
_____12. Does your mind often wander while you are trying to concentrate?
_____13. Do you like to play pranks upon others?
_____14. Are you usually a "good mixer?"
_____15. Are you sometimes bubbling over with energy and sometimes very sluggish?
_____16. Do you often "have the time of your life" at social affairs?
_____17. Are you frequently "lost in thought" even when you should be taking part in a conversation?
_____18. Do you derive more satisfaction from social activities than from anything else?

10. Have any major stressful events taken place in your life within the last year? ☐ Yes ☐ No
If yes, what was the event(s)?

____

Current Work Schedule and Environment:
The questions below will help us to better understand the impact of your work schedule and work environment.

Instructions: The questions below ask about your stress *level when driving.*

1. Draw a line through the bar to show how stressed you usually feel when driving in the early morning hours through rural interstates:

Not at all |———————————————| Extremely

Please continue on to the next page…

2. Under each clock time, use the scale below to write down how <u>stressed</u> you usually feel when driving at that time through <u>rural interstates</u>.

   1 = Not at all   2 = A little   3 = Quite a bit   4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

3. Draw a line through the bar to indicate how <u>stressed</u> you usually feel when driving in the <u>early morning</u> hours through <u>city streets and highways</u>:

   Not at all |————————————————| Extremely

4. Under each clock time, use the scale below to write down how <u>stressed</u> you usually feel when driving at that time through <u>city streets and highways</u>.

   1 = Not at all   2 = A little   3 = Quite a bit   4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

Instructions: The questions below ask about your <u>fatigue</u> level when driving.

5. While operating a commercial motor vehicle, have you ever, even for a moment, fallen asleep behind the wheel? ☐ Yes ☐ No

6. While operating a commercial motor vehicle, have you ever been driving and found yourself somewhere, not remembering how you got there? ☐ Yes ☐ No

7. How likely are you to <u>doze off</u> or <u>fall asleep</u> in the following situations, in contrast to feeling just tired? This refers to your usual way of life in recent times. Even if you have not done some of these things recently, try to work out how they would have affected you. Use the following scale to choose the most appropriate number for each situation:

   0 = no chance of dozing
   1 = slight chance of dozing
   2 = moderate chance of dozing
   3 = high chance of dozing

SITUATION CHANCE OF DOZING :

Sitting and reading _____________
Watching TV _____________
Sitting inactive in a public place (e.g., a theater or a meeting) _____________
As a passenger in a car for an hour without a break _____________
Lying down to rest in the afternoon when circumstances permit _____________
Sitting and talking to someone _____________
Sitting quietly after a lunch without alcohol _____________
In a car, while stopped for a few minutes in traffic _____________

Please continue on to the next page…

8. Draw a line through the bar to show how <u>likely</u> it is for you to be involved in a fatigue-related accident or incident.

Not at all |————————————————| Extremely

9. Draw a line through the bar to show how <u>fatigued</u> you usually feel when driving in the <u>early morning</u> hours through <u>rural interstates</u>:

Not at all |————————————————| Extremely

10. Under each clock time, use the scale below to write down how <u>fatigued</u> you usually feel when driving at that time through <u>rural interstates</u>.

1 = Not at all   2 = A little   3 = Quite a bit   4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

11. Draw a line through the bar to show how <u>fatigued</u> you usually feel when driving in the <u>early morning</u> hours through <u>city streets and highways</u>:

Not at all |————————————————| Extremely

12. Under each clock time, use the scale below to write down how <u>fatigued</u> you usually feel when driving at that time through <u>city streets and highways</u>.

1 = Not at all   2 = A little   3 = Quite a bit   4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

13. How well are you <u>currently</u> able to follow your company's fatigue management program?

☐ Not at all   ☐ A little   ☐ Quite a bit   ☐ Very much   ☐ Non-applicable

Instructions: The questions below ask about your <u>alertness</u> level when driving.

14. Draw a line through the bar to show how <u>alert</u> you usually feel when driving in the <u>early morning</u> hours through <u>rural interstate areas</u>:

Not at all |————————————————| Extremely

Please continue on to the next page…

15. Under each clock time, use the scale below to write down how <u>alert</u> you usually feel when driving at that time through <u>rural interstate areas</u>.

1 = Not at all　　2 = A little　　3 = Quite a bit　　4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

16. Draw a line through the bar to show how <u>alert</u> you usually feel when driving in the <u>early morning</u> hours through <u>city streets and highways</u>:

Not at all |————————————————| Extremely

17. Under each clock time, use the scale below to write down how <u>alert</u> you usually feel when driving at that time through <u>city streets and highways</u>.

1 = Not at all　　2 = A little　　3 = Quite a bit　　4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

18. What time(s) do you usually take a meal break while on duty? *(Please write down hour(s) and AM/PM)*

____

19. Have you ever had an accident or incident while <u>working</u> that you feel was related to your sleepiness or fatigue level? ☐ yes ☐ no If yes, how many? ________

20. Have you been involved with other fatigue management programs within the <u>past year</u>?
☐ yes ☐ no If <u>yes</u>, please briefly explain what they contained:____
____

21. Please indicate how familiar you are with fatigue management:
☐ Very familiar/expert ☐ Familiar ☐ Somewhat familiar ☐ Novice ☐ Not at all familiar

22. How many total <u>hours</u> do you work in a <u>typical</u> week? __________. How many of these hours do you spend driving? __________

Please continue on to the next page…

23. *Please write down your <u>typical</u> work start and end times for each day in the grid below*.
- Write *"off"* for those days you are <u>not</u> usually scheduled to work.
- If the days you work change from week to week, fill in the *typical* time you might work for each day and check the '<u>variable work schedule</u>' box below the grid.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Start time							
End time							

☐ *variable work schedule*

24. What percent of your <u>work time</u> do you drive on:
city streets and highways: __________%
rural interstates: __________%
Other: ____________________________%

25. How often during a <u>typical</u> work shift do you load and or unload your own cargo?

☐ Never
☐ Occasional shifts
☐ Sometimes (about half of the time)
☐ Most shifts
☐ Every shift

26. For <u>typical</u> loads, how long does it take you to load/unload the truck during deliveries? _____ minutes

Do you find loading/unloading the truck to be more <u>alerting</u> or <u>fatiguing</u>?
☐ Alerting ☐ Fatiguing ☐ Neither Why: ____________________________________

☐ This question does not apply; I do not usually load/unload my truck.

27. What other work-related duties do you usually do, if any, <u>besides</u> driving and loading/unloading?
____

28. What type of <u>tractor</u> do you usually drive?
____

29. <u>Currently</u>, how often do you look at the instrument panel in the cab?
☐ Once or more a minute ☐ Once every 15 to 30 minutes
☐ Once every 5 to 10 minutes ☐ Once every 30 to 60 minutes

Please continue on to the next page…

THANK YOU for completing this survey!

Do you have any vacations, holiday or other planned time off scheduled over the 17 weeks of this study?

If yes, please give the dates that you will be out of work:

____

APPENDIX N: FATIGUE MANAGEMENT COURSE

Understanding Fatigue and Alert Driving

Sponsored by:

Federal Motor Carrier Safety Administration

&

American Transportation Research Institute

American Trucking Associations

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Understanding Fatigue and Alert Driving

Customized for the

Drowsy Driver Warning System (DDWS)
Field Operational Test (FOT)

Sponsored by:

National Highway Traffic Safety Administration

Federal Motor Carrier Safety Administration

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Training Overview

- How serious is the problem?
- What is fatigue, and what causes it?
- Effects on driver alertness & performance
- Sleep, circadian rhythms, & shiftwork
- Effects of drugs & alcohol
- Sleep disorders
- Improving sleep & alertness.

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How Serious is the Problem?

- Police Accident Reports: 1-13% of large truck crashes, depending on crash type and category.
- NTSB (1990): Fatigue probable cause of 31% of fatal-to-truck-driver crashes.
- VTTI (2000): Reduced driver alertness apparent in 20% of truck safety incidents.

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Truck Driver Fatigue

- Around-the-clock industry
- Hard work & long hours
- Potential for high crash severity
- Potential for liability lawsuits, loss of revenue, loss of CDL
- Improved alertness → increased safety, productivity, & quality of life.

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What is Fatigue?

- Body & mind's response to lack of sleep and/or continued activity.
- Characterized by:
  - Loss of alertness and attention
  - Poor response; slower reactions
  - Impaired judgment
  - Loss of motivation
  - Feelings of tiredness.

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Causes of Fatigue

- Excessive physical activity
- Excessive mental activity
- Heat or other adverse conditions
- Circadian “troughs”
- Inadequate sleep.

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Factors Affecting Fatigue

- Quantity & quality of prior sleep**
- Time-of-day: circadian rhythms*
- Physical health
- Environment (e.g., heat, cold)
- Time on task
- Type of task (e.g., repetitious)
- Individual differences*

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How Do We Recognize Fatigue?

- Drowsiness
- Desire to sleep
- Wandering thoughts
- Mental lapses ("microsleeps")
- Slowed responses & decision making.

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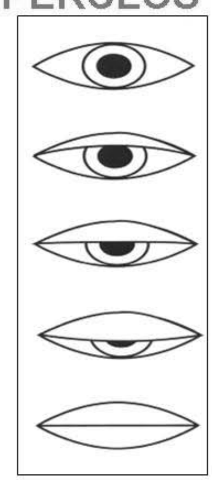
How Do We Recognize Fatigue? (Continued)

- Lane deviations
- Random variations in vehicle speed
- Yawning
- Head nodding
- Eyelid droop* ("PERCLOS")

PERCLOS



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Are you *chronically* sleep deprived?

- Do you fall asleep in 5 minutes or less?
- Can you nap any time, anywhere?
- Feel sleepy after a big meal?
- Feel sleepy when you're bored? (e.g., during this training???)
- Do you fall asleep easily in front of the TV?

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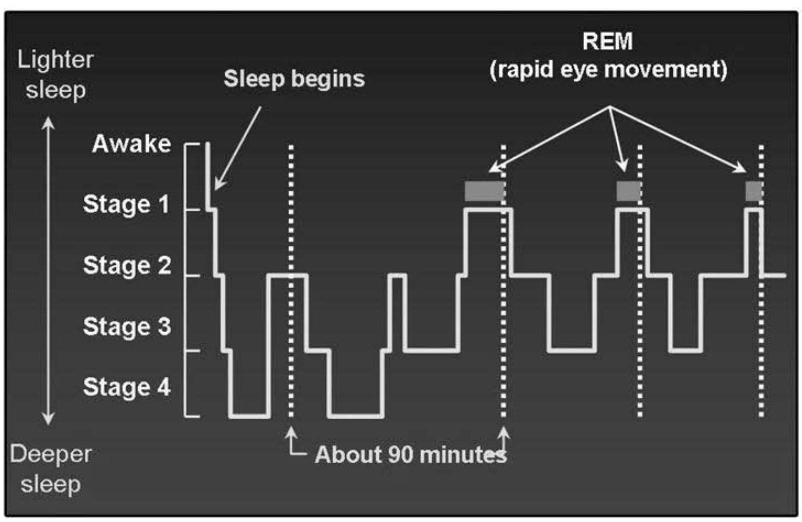
States & Stages of Sleep



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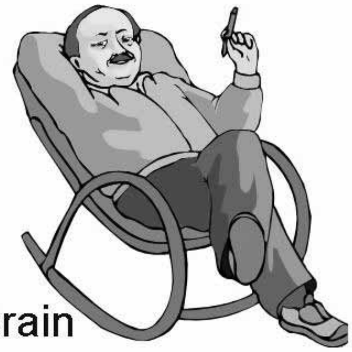
Sleep vs. Rest

- *Not* the same thing!
- Rest is an awake break from a task.
- Rest can restore energy, but cannot substitute for sleep.
- Sleep allows both body and brain to be restored and refreshed.



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How much sleep is enough?

- Most adults need 7-8 hours of uninterrupted sleep
- Some individual differences
- "Sleep debt" accumulates with continued inadequate sleep
- Result: deterioration in alertness & performance.

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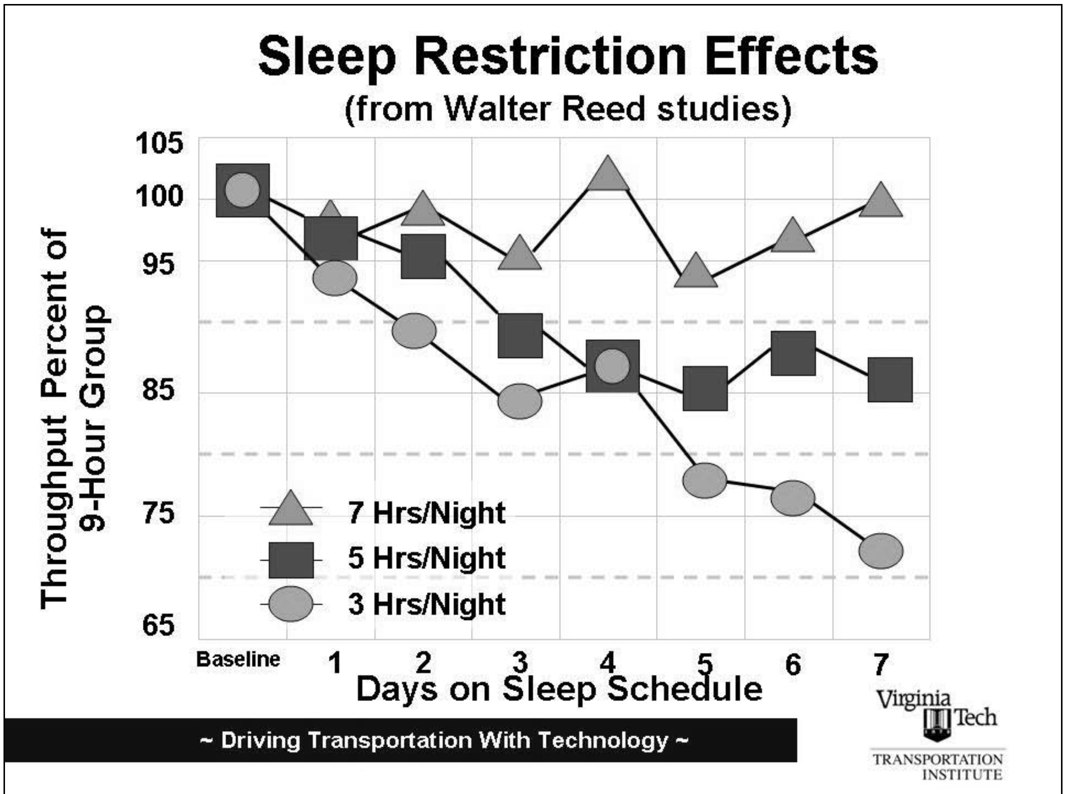
Sleep Restriction Effects
(from Walter Reed studies)
Throughput Percent of 9-Hour Group
105
100
95
85
75
65
7 Hrs/Night
5 Hrs/Night
3 Hrs/Night
Baseline
1
2
3
4
5
6
7
Days on Sleep Schedule
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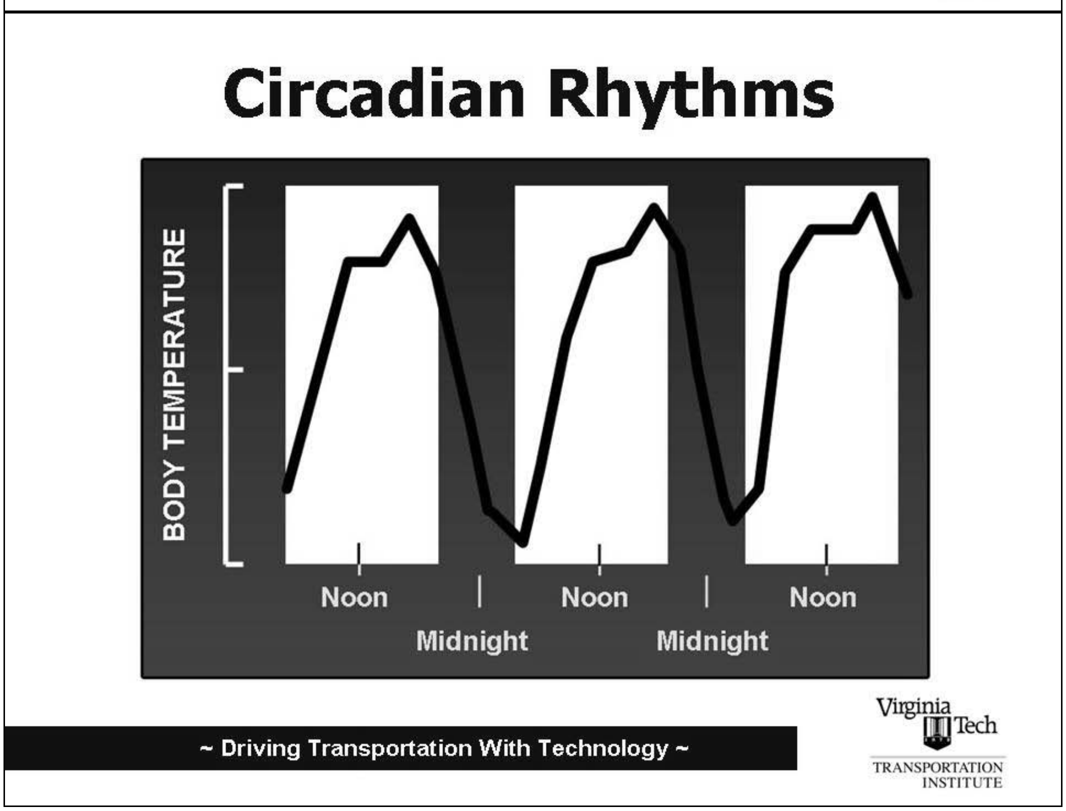
Circadian Rhythms
BODY TEMPERATURE
Noon
Midnight
Noon
Midnight
Noon
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Circadian Rhythm Facts

- Brain's internal circadian "clock" coordinates daily cycles:
  - Sleeping/waking
  - Body temperature
  - Hormonal secretions
  - Alertness
  - Performance.

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Circadian Highs & Lows

- **Highs:**
  - **Morning**
  - **Late afternoon/early evening**
- **Lows:**
  - **Late night/early morning**
  - **Early/mid afternoon**

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Interactions:
Sleep & Circadian Rhythms

- Circadian lulls can occur even without sleep deprivation.
- But sleep deprivation makes the “troughs” deeper.

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Effects of Circadian Disruption

- Disturbed sleep/difficulty falling asleep
- Increased feelings of sleepiness
- Decreased alertness & performance
- Negative mood
- Gastrointestinal problems.

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"Resetting" the Clock

- Circadian clock cannot adjust quickly (e.g., jet lag can last days or weeks)
- Bright light and/or darkness affect circadian rhythms
- Activity, social interaction, stimulants, and sedatives can affect rhythms
- Different people adapt at different rates
- Harder to adapt as you get older.

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Night Operations & Alertness

- Shiftwork is difficult for most people – many *never* adapt.
- **Make sleep a priority!!!**
- When possible, seek bright light to help stay awake.
- Make your bedroom as **dark** and quiet as possible.
- Avoid caffeine, exercise, or large meals before going to bed.

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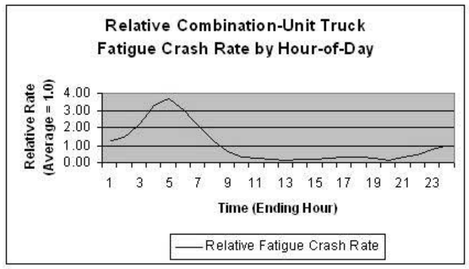
Fatigue Crashes & Night Driving



Crash Risks: Day vs. Night

- Daytime:
  - Traffic
  - Errors of other drivers
- Nighttime:
  - Darkness – seeing and being seen
  - Slippery roads (e.g., black ice)
  - Fatigue (both CMV and non-CMV drivers)
  - Alcohol (mostly drunk non-CMV drivers)
  - Reckless driving (mostly non-CMV drivers)

Chemical Aids to Sleep & Wakefulness

- Truck drivers may use *stimulants* to stay awake and/or *hypnotics* to fall asleep.
- Many such drugs are illegal without a prescription.
- They should be used correctly and only when necessary.
- They are no substitute for sleep!

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Stimulants

- Can extend performance for awhile
- Can cause a range of physiological and behavioral responses
- Often a rebound fatigue effect
- Cause damage with repeated use
- Nicotine: a stimulant but does not improve alertness.

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Caffeine

- The most widely used stimulant; e.g., in coffee, sodas, some medications.
- Can produce a relatively quick increase in alertness.
- Body adapts to caffeine; after repeated or excessive use, increased doses may be required for the same effect.

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Using Caffeine

- Use for a quick, short-term effect.
- Allow 20-30 minutes for the desired boost.
- While driving, take small sips and "nurse" the cup over a longer time. This extends alertness boost.
- Avoid caffeine for several hours before bedtime.
- Don't forget other, more healthy liquids – like water and fruit juice.

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Sleeping Pills

- Both prescription and over-the-counter types.
- Can have serious limitations as sleep aids.
- Can disrupt sleep quality.
- Barbiturates are now illegal.
- Use carefully, if at all.

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Alcohol and Sleep

- Some people use alcohol as a sleep aid.
- Can make you sleepy.
- But it actually *disrupts* sleep:
  - Suppresses REM sleep
  - Causes "rebound" awakening.
- Disruptive effects often increase with age.

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Sleep Disorders

- Insomnia:
  - Can't fall asleep
  - Can't stay asleep
  - Wake up too early
- Apnea: stop breathing during sleep
- Restless leg syndrome
- Narcolepsy: sudden sleep attacks

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Sleep Apnea

- Serious, life-threatening condition
- Blockage of the airway;
  e.g., from walls of throat "sagging."
- May briefly stop breathing up to 60 times an hour
- Sleep is constantly disrupted and thus abnormal
- Results in extreme sleepiness and various medical effects (e.g., high blood pressure)
- Associated with snoring and obesity.
- Treatable, e.g., with CPAP device worn in mouth.

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Some findings from a recent FMCSA/ATA/UPENN Sleep Apnea Study of CMV drivers

- Sleep apnea severity
  - Mild: 17.6%
  - Moderate: 5.8%
  - Severe: 4.7%
- Severity correlated with all ***objective*** measures of performance, but not ***subjective*** measures.
- Sleep <5 hours nightly: 13.5% of sample

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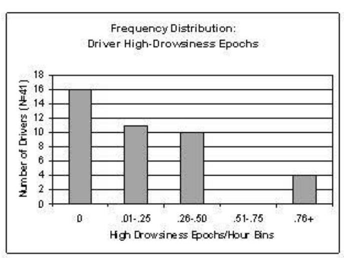
Individual Differences in Fatigue Susceptibility

Local/Short Haul Study Drowsiness Episode Rate



285 Drowsy Episodes

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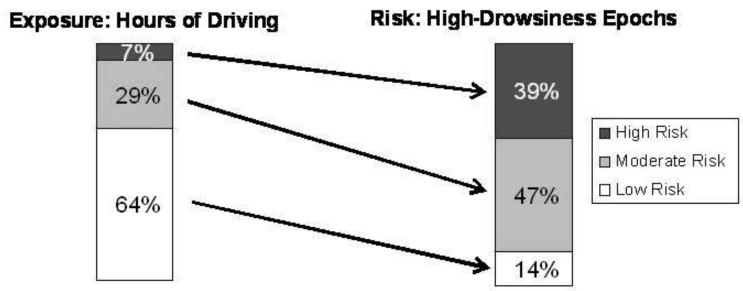
Individual Differences in Fatigue Susceptibility (Continued)

L/SH Study: Exposure vs. Drowsiness



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Individual Differences in Fatigue Susceptibility (Continued)

- High, moderate, and low risk groups
- 25-fold difference in fatigue risk in LSH Study
- Similar findings in many studies
- Cannot be explained solely by sleep disorders
- When people are repeatedly sleep deprived:
  - Large differences between different people
  - Individual responses stable and consistent.
- Level of susceptibility to fatigue appears to be an enduring personal trait.

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Sleep Hygiene Strategies

- At home, get the best sleep possible before starting a trip.
- On a trip, try to get as much sleep as you do at home.
- Get sleep at the right circadian times; e.g., 1-4 AM
- Don't forget nutrition and exercise.
- If you feel sleepy, you ***are*** sleepy!

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Develop Good Sleep Habits

- Minimize disruptions
- Sleep in a dark, quiet place
- Keep room at 65-70°
- Get a comfortable mattress
- Develop pre-sleep "wind down" routine.

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Operational Strategies

- Engage in conversation (e.g., CB)
- Stay active
  (e.g., stretch your muscles)
- Take rest and exercise breaks
- "Nurse" a cup of coffee while driving
- Open window or vents for cool, fresh air
- Don't smoke – smoke makes you drowsy.
- **Get enough sleep!!!**
- **Wear your safety belt!!!**

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Napping Strategies

- A short nap (e.g., 20-40 minutes) can dramatically improve alertness and safety.
- Longer naps can make you "groggy" afterwards and disrupt main sleep.
- Plan ahead for "nap breaks."

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Solo vs. Team Driving: VTTI Sleeper Berth Study

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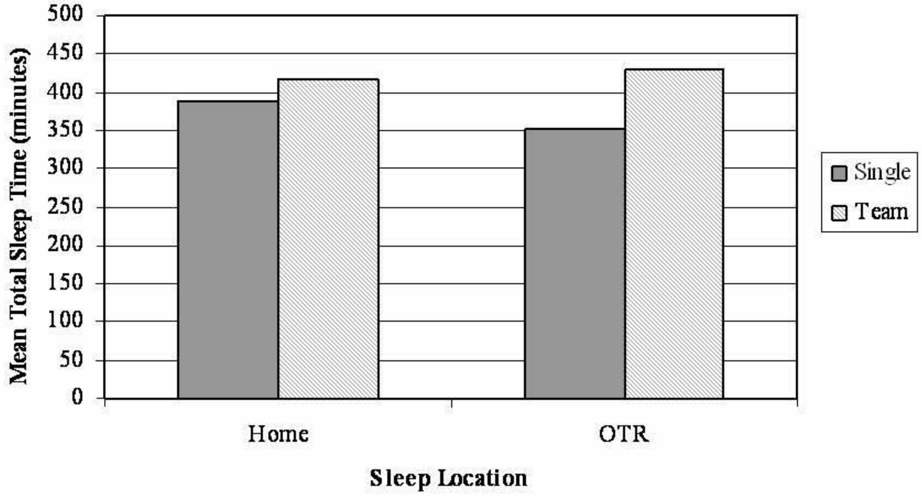

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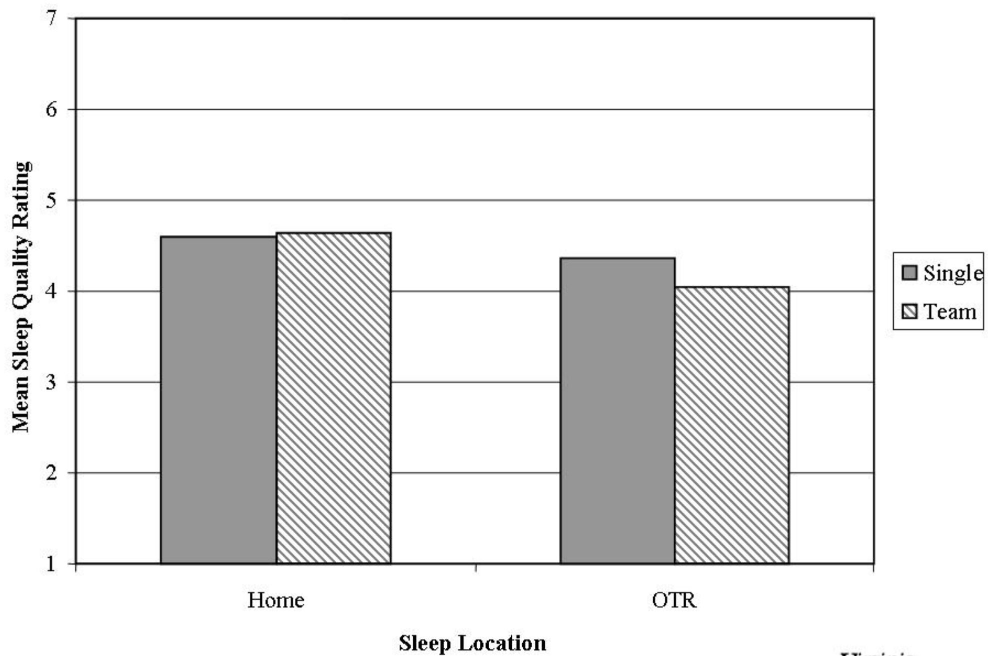

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Conclusions: Solo vs. Team Driving

- **Team** drivers got more sleep.
- **Solo** drivers got better quality sleep.
- **Solo** drivers much more likely to:
  - Push themselves “to the limit”
  - Make safety-related driving errors; e.g.,
    - Evasive maneuvers like hard braking or steering
    - “Near-misses” involving other vehicles
    - Extreme drowsiness.

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Do you know how sleepy you are?

- **FMCSA Driver Fatigue & Alertness Study** of 80 OTR Drivers: self-ratings of drowsiness **did not** correlate significantly with objective measures.
- **Stanford University Study**: sleep-deprived subjects were **generally poor** at predicting whether they would fall asleep in the next two minutes.
- Objective measures (such as PERCLOS) are **more accurate** than self-ratings.

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Common Misconceptions

- "I know how tired I am."
- "I've lost sleep before and did just fine."
- "I'm motivated and tough enough to push through."
- "Dealing with fatigue is easy."

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Thank you for your attention!

We look forward to working with you!

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APPENDIX O: DFM Training

Driver Fatigue Monitor (DFM)

- Location: mounted on the dash of the cab

DFM

Driver Fatigue Monitor (DFM)

- The DFM has 2 Components:

Camera

Driver **V**ehicle **I**nterface (DVI)

Driver Fatigue Monitor (DFM)

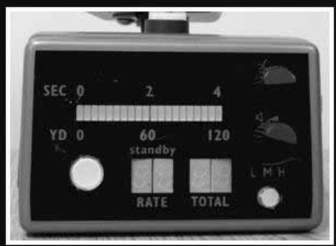
- Camera

  Purpose: To monitor your eyes closed (and open)

Driver Fatigue Monitor (DFM)

- Driver Vehicle Interface (DVI)

  Purpose: To present auditory and visual warnings when you become too drowsy to continue driving safely



Settings

- The DFM has several settings
  - Sound for Auditory Warning
  - Volume of Auditory Warning
  - Display Brightness
  - Sensitivity
  - Operation Mode

Auditory Warning

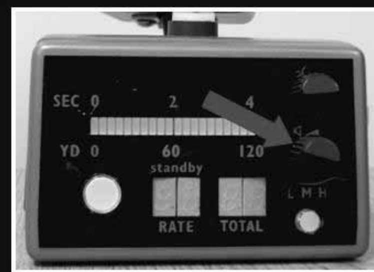
- 6 different sounds for the auditory warnings
- Sounds range from a mellow tone to a loud buzzer
- Choose the sound you like by pressing the **INFO** button one at a time
- Let the sound finish playing before pressing the button again

INFO Button

Auditory Warning

- Adjusting the Volume

- Increase the volume by turning the volume knob clockwise

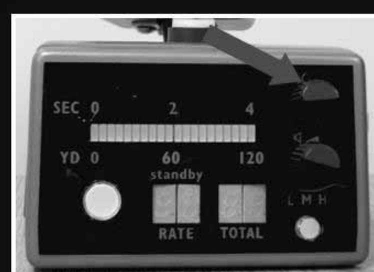


Volume Knob

Display Brightness

- Adjusting the Brightness

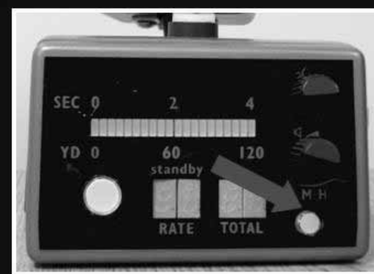
- Increase the brightness of the DVI display by turning the brightness knob clockwise



Brightness Knob

Sensitivity

- Sensitivity is thresholds for activating warnings
- 3 settings
  - High (H): DFM produces warnings with shorter period of eye closure
  - Medium (M)
  - Low (L): DFM produces warnings with longer period of eye closure
- Change the Sensitivity by press the **Sensitivity** button



Sensitivity Button

Operation Mode

Dark mode

Active mode

Using the DFM

1. The DFM is activated when the truck battery is turned on.

   - Sound is played
   - Standby lights up

Standby sign

Using the DFM

2. The DFM display lights up when:
   - Speed is above 35mph
   - Cab is dark

   - Default Sensitivity is M (medium)

Sensitivity as Medium (**M**)

Using the DFM

3. Press Sensitivity button for your preferred setting

4. Change Sensitivity to H (high) when:

   - at the end of shift
   - you are tired

Sensitivity as High (H)

Auditory & Visual Warnings

- Initial Advisory Tone
  - Auditory warning will be played
- Full Warning
  - Both Auditory and Visual warnings will be presented

Auditory & Visual Warnings

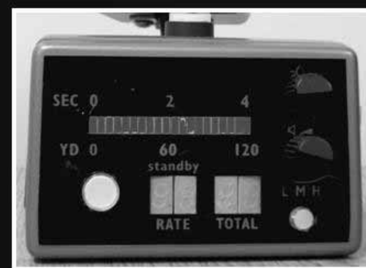
- **Initial Advisory Tone**
  - Auditory warning will be played after a predetermined length of time that your eyes have been closed (depending on the **Sensitivity** setting)
  - The auditory warning will be played once
  - You do ***not*** need to press any button to stop this warning

Auditory & Visual Warnings

- **Full Warning**
  - Auditory warning
    The sound will be played *repeatedly*
  - Visual warning
    Bar graph will light up in red

Auditory & Visual Warnings

- **Bar graph**
  - Represents the longest length of the eye closure (1, 2, 3, or 4 seconds)
  - Lights up red when the full warning goes off
  - Completely lights up if eye closure was longer than 4 seconds



Bar graph
(light up for 4 seconds)

Auditory & Visual Warnings

- To stop the full warning…
  - Press the **OK button** to stop the auditory warning and the bar graph from flashing
  - Once you press the OK button, The **RATE** and **TOTAL** will be displayed

OK button

Auditory & Visual Warnings

- **RATE**
  The number of full warnings that you have received over the past hour
- **TOTAL**
  The total number of warnings that you have received since the truck (and the DFM) was turned on

RATE and TOTAL

Auditory & Visual Warnings

- To clear the numbers of **RATE** and **TOTAL**
  – Press the **OK button** again, or
  – Wait 10 seconds and the numbers will be automatically disappeared
- Press the **OK button** at any time to see the **RATE** and **TOTAL** numbers

Changing DFM settings

- You can change any settings at any time during your drive
- Change the setting ***only when it is safe*** to do so
  e.g., When you are awake
  No other vehicle is around

ANY QUESTIONS?

APPENDIX P: DFM TRAINING MANUAL

Manual for the Driver Fatigue Monitor (DFM)

This manual is to describe the functions of the Driver Fatigue Monitor (DFM) and guide you in using the DFM during your participation in the study.

Driver Fatigue Monitor (DFM)

The purpose of the DFM is to monitor the eyes of the driver (you) and to assess whether you are too drowsy to continue driving safely. Figure 48 is a picture of the DFM. The DFM will be mounted on the dash of the cab during the study.

Figure 48. Driver Fatigue Monitor (DFM)

The DFM is composed of two main parts: (i) the camera (upper part of DFM), and (ii) the driver vehicle interface (DVI) (lower part of DFM). Each will be described below in more detail.

Camera

The camera is the small box mounted on top of the DFM (Figure 49).

Figure 49. Camera of the DFM

When the DFM is operational, you will see two circles of red LED lights, one inside of the other (Figure 50). The LED lights are used to monitor your eyes to determine if and for how long your eyes are closed. These lights are harmless to you.

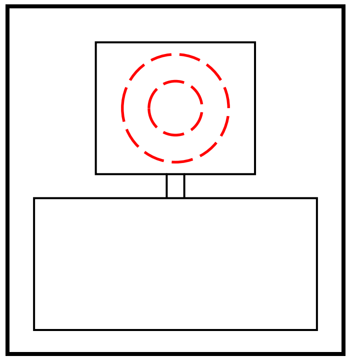


Figure 50. LEDs Inside of the Camera

Driver Vehicle Interface (DVI)

The driver vehicle interface (DVI) is the bottom part of the DFM (Figure 51). This component of the DFM produces auditory and visual warnings when the DFM detects that you are too drowsy to continue driving safely.

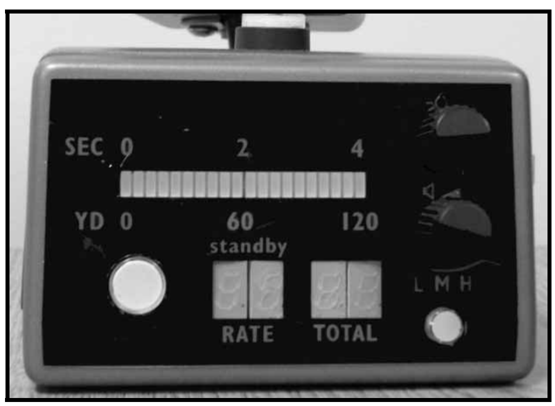


Figure 51. Driver Vehicle Interface (DVI)

DVI Features

<u>Auditory warning</u>
There are six different sounds that serve as the auditory warnings on the DFM. These sounds range from a mellow tone to a loud buzzer.

Choosing a sound. You may choose which sound you would like the DFM to use when producing the warning. This can be done by pressing the **INFO button** (Figure 52). You can cycle through the six different sounds until you reach one that you would like to use. Please let the sound finish playing before pressing the button again, or the next sound will be skipped.

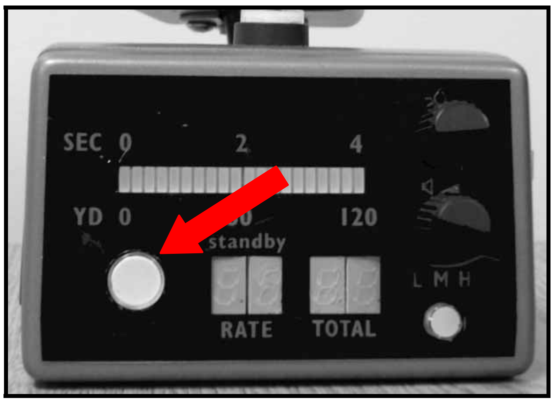


Figure 52. INFO Button Used to Choose a Sound

Adjusting the volume. You may increase the volume of the auditory warning by turning the **Volume knob** clockwise on the front of the DVI (Figure 53).

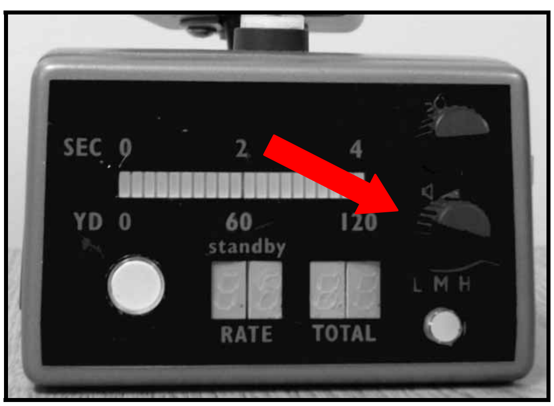


Figure 53. Volume **K**nob to **A**djust the **S**ound **Volume**

Visual Display

Adjusting the display brightness. You can increase the brightness of the DVI by turning the **Brightness knob** clockwise on the front of the DVI (Figure 54).

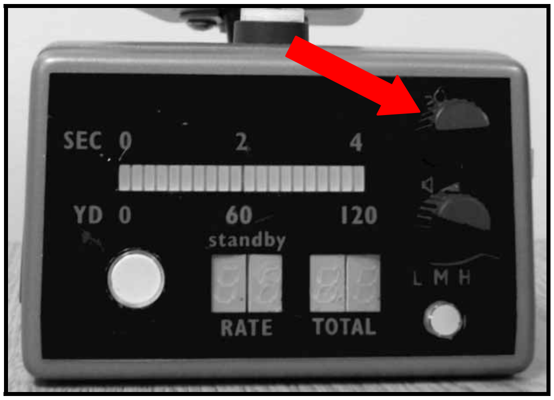


Figure 54. Brightness **K**nob to **A**djust **B**rightness of the DVI

Sensitivity

The Sensitivity refers to thresholds for activating the warnings. The DFM has three sensitivity settings: (i) low (L), (ii) medium (M), and (iii) high (H). The high (H) Sensitivity setting has the lowest threshold (sensitivity) for producing warnings: the alarm goes off with the short length of eye closure. The low (L) sensitivity setting has the highest threshold: the alarm goes off with longer length of eye closure.

Changing the Sensitivity level. You may change the Sensitivity setting at any time by pressing the **Sensitivity button** (Figure 55). The light on the "L", "M", and "H" indicate which Sensitivity setting you are on.

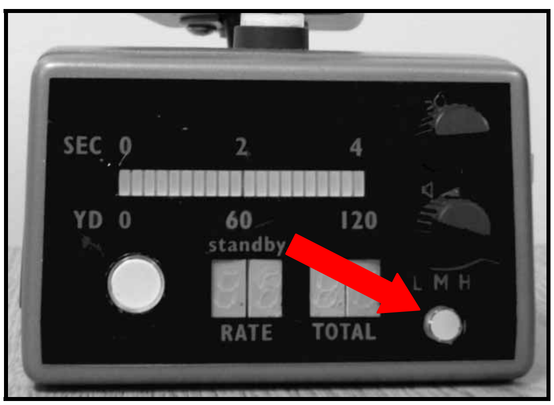


Figure 55. Sensitivity **B**utton to **C**hange **S**ensitivity **L**evel

Operation modes

The DFM has two operation modes: **dark** and **active**. Researchers will set the DFM to the appropriate mode for drivers.

In the **dark** mode, the DFM collects data but does NOT present neither visual or auditory alert to drivers. The arrow in the key hole points to the right in the dark mode (see Figure 56).

Figure 56. DFM "Dark" Mode Setting (The Arrow Points to the Right)

In the **active** mode, the DFM collects data and present visual and auditory alerts to the drivers. The arrow in the key hole points to the left or top in the active mode (see Figure 57)

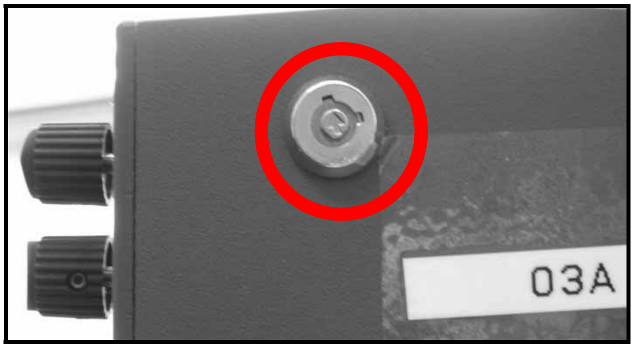


Figure 57. DFM "**A**ctive" **M**ode (**T**he **A**rrow **P**oints **U**p/to the **L**eft)

Changing the modes. Use the key to switch the arrow in the key hole. The key hole is located on the right side of the DFM.

Basic Steps for Using the DFM

1. The DFM will be switched on about one-minute after the battery of the truck is turned on. Once the DFM is on, a sound will be presented and the word **Standby** will be lit in red (Figure 58).

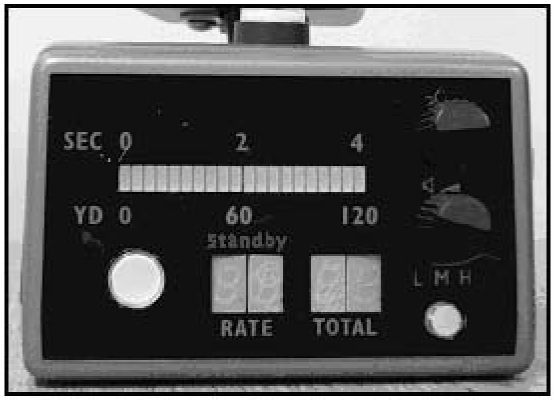


Figure 58. Standby sign on the DVI

2. When the vehicle speed is above 35 MPH and the cab is dark, the Brightness and Volume signs and the Sensitivity setting will be lit in green. The DFM will automatically be set to the medium (M) sensitivity setting (Figure 59).

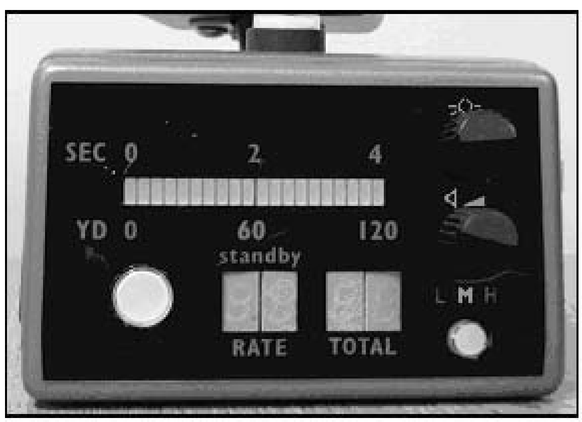


Figure 59. Sensitivity setting as medium (M) on the DVI

3. You can change the Sensitivity setting by pressing the **Sensitivity button** (Figure 8) until the setting that you would like to choose is lit up (L, M, or H). It is strongly recommended that you ***set the Sensitivity setting to H (high)*** when you start to feel tired (e.g., near the end of shift). You can later change to M or L if there are too many false warnings.

4. When the Sensitivity setting is lit, you can also change the display brightness and warning sound volume by turning the **Volume knob** (Figure 6) or **Brightness knob** (Figure 7), respectively.

The Auditory and Visual Warnings

The DFM will produce auditory and visual warnings as you progress through your drive. You will receive an ***initial advisory tone*** and a ***full warning,*** each of which are based upon how long you have been closing your eyes.

Initial Advisory Tone
The first warning that you will receive is called ***initial advisory tone***. This auditory warning will sound after a predetermined length of time (depending on the Sensitivity setting) that your eyes have been closed. For this warning, you will hear the sound (tone) one time.

You **do not** need to press any button to stop this warning, since it will end by itself.

Full Warning
The second warning that you will receive is the ***full warning***. This warning will follow several seconds after the *initial advisory tone* if the DFM continues to detect your eyes closed. There will be several auditory and visual components associated with this warning.

a. *Auditory warning*
You will repeatedly receive the sound that you have chosen. You can stop this by pressing the **OK button** at the top of the DVI (Figure 60).

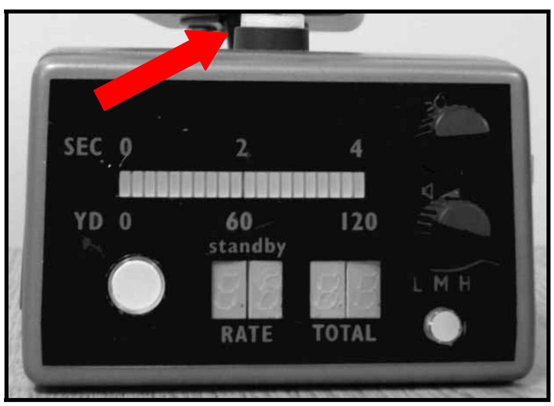


Figure 60. OK Button Used to Let the DFM Know that the Driver has Received the Warning

b. *Visual warning*
You will also receive visual warnings when the auditory warning is presented. The visual warning will include the following information:

i. Bar Graph – When the full warning goes off, the bar graph will light up in red (Figure 61). The bar graph represents the length of time (1, 2, 3, 4 seconds or longer) of the longest eye closure that you had during the time period that was measured.

Note that a four-second eye closure at 60 mph (88 ft/sec) equals driving blind for 352 feet, or more than the length of a football field.

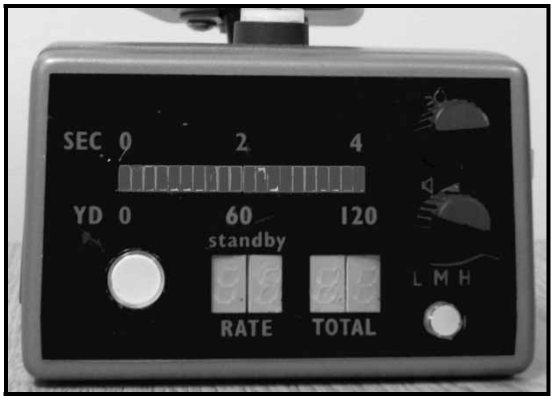


Figure 61. Bar Graph Lit Up on the DFM

ii. TOTAL – A number will be displayed in the box labeled “TOTAL” (Figure 62). This number indicates the total number of warnings that you have received since the truck (and the DFM) was powered on.

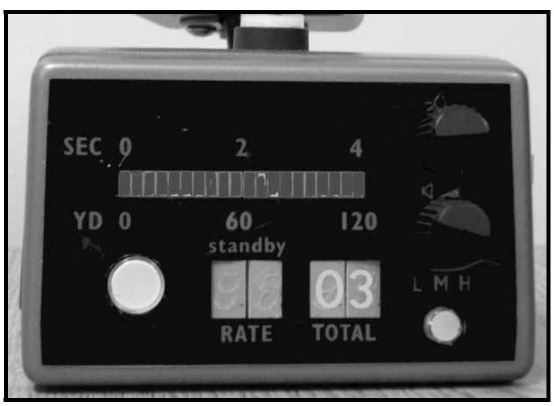


Figure 62. Total and Bar Graph Lit Up on the DFM

iii. RATE – A number will also be displayed in the box labeled "RATE" (Figure 63). This number indicates how many full warnings you have received over the past hour.

Figure 63. Rate, Total and Bar Graph Lit Up on the DFM

Once the full warning is activated, press the **OK button** on top of the DVI (Figure 13) to stop the auditory warning and the bar graph flashing. Once the **OK button** has been pressed, the numbers of RATE and TOTAL will appear. Press the **OK button** again to clear the numbers from the display, or they will automatically be disappeared after ten seconds.

You can also press the **OK button** at any time to see the most recent data for both RATE and TOTAL. Once the **OK button** has been pressed for the second time, the DFM will be reset the DVI will get back to normal (Figure 12) and will start warning you again after your eyes have been closed for a predetermined length of time.

You may change any of the settings at any time during your drive, but you should **only make changes when it is safe** to do so.

Participant Number: E_________ CONFIDENTIAL
Administration Date: _________ Verification Date: __________ Mailing Date: _________

APPENDIX Q: POST-STUDY SURVEY FOR EXPERIMENTAL GROUP

Thank you for taking the time to complete this survey. It should take you about 30 minutes to fill out. The information that you give will not be shared with any of your managers or other operators, and your responses will be kept strictly confidential. This survey asks you questions about your health and well being, use of the drowsy driver warning system (DDWS), and your current work schedule and environment. You are not required to give answers to any survey items that make you uncomfortable. However, the more data you give, the better we will be able to understand the potential benefits of the device for drivers like yourself.

Health and Well Being:

The questions below will allow us to better understand your health. Please carefully follow any additional instructions.

1. Draw a line through the bar to show how healthy you usually feel.

Very healthy |————————————————| Not healthy at all

2. The questions below concern some of your body functions. Please try to answer each question by checking the correct box that shows how often you experienced each of the items *during the course of the study*. Check one space for each item below.

Items:	*Never*	*Less than once a month*	*Once or twice a month*	*Once a week*	*2 or 3 times a week*	*About every day*
Back Pain						
Acid indigestion, heartburn, or acid stomach						
Gastrointestinal problems						
Constipation						
Tight feeling in stomach						
Blurred vision						
Trouble falling asleep						
Feeling tired upon awaking						
Trouble staying asleep						
Other:						
Other:						

3. Did any major stressful events take place in your life during the study? ☐ No ☐ Yes
If "yes," what was the event(s)? ____

4. *Instructions:* The questions in this scale ask you about your feelings and thoughts during the last month. In each case, please check how often you felt or thought a certain way.

a. In the last month, how often have you felt that you were unable to control the important things in your life?
☐ Never ☐ Almost never ☐ Sometimes ☐ Fairly often ☐ Very often

b. In the last month, how often have you felt confident about your ability to handle your personal problems?
☐ Never ☐ Almost never ☐ Sometimes ☐ Fairly often ☐ Very often

c. In the last month, how often have you felt that things were going your way?
☐ Never ☐ Almost never ☐ Sometimes ☐ Fairly often ☐ Very often

d. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?
☐ Never ☐ Almost never ☐ Sometimes ☐ Fairly often ☐ Very often

DDWS Device:
The questions below will help us to better understand what you think about the DDWS device now that you have used it.

1. Please describe…
   b. how you think that the DDWS works (functions): ______________________________________
   ____
   c. how the DDWS may have helped you handle your fatigue while driving: ________________
   ____

2. Do you know of any situations where the DDWS device did not work right during the study?
   ☐ No ☐ Yes

   If "yes," how did you know that the device was not working right? *(Check all that apply)*

   ☐ Device gave no warnings
   ☐ Device gave constant warnings
   ☐ No visual display present
   ☐ Other: ____

3. How did you use DDWS warnings immediately while you were driving? *(Check all that apply)*

   ☐ I stopped driving and pulled over to sleep
   ☐ I drank a beverage that had caffeine in it
   ☐ Other: ____

4. Along with a fatigue management program, how useful do you think the DDWS was in helping you manage your fatigue while at work?

☐ Not at all useful ☐ A little useful ☐ Quite useful ☐ Extremely useful

5. Not considering what you know about fatigue management, how useful do you think the DDWS was in helping you manage your fatigue at work?

☐ Not at all useful ☐ A little useful ☐ Quite useful ☐ Extremely useful

6. The DDWS was designed for use by many different types of drivers. It may not always have correctly measured the alertness level of each person. How did you know whether this device was giving you correct information about your level of alertness? *(Check all that apply)*

☐ It only sounded warnings when I was fatigued
☐ It never sounded warnings when I was alert
☐ Other: ____

7. How much do you believe the DDWS improved the safety of your driving?

☐ Not at all ☐ A little ☐ Quite a bit ☐ Extremely

Why? ____

8. Before getting a warning, how often did you usually look at the DDWS device?

☐ Once or more a minute
☐ Once every 5 to 10 minutes
☐ Once every 15 to 30 minutes
☐ Once every 30 to 60 minutes
☐ Never

9. Once the DDWS gave a warning, how often did you usually look at the device?

☐ Once or more a minute
☐ Once every 5 to 10 minutes
☐ Once every 15 to 30 minutes
☐ Once every 30 to 60 minutes
☐ Only when an additional alarm was sounded

10. Draw a line through the bar to show how much effort you gave in checking the DDWS.

None |———————————————| Extreme

11. Draw a line through the bar to show how much effort you gave in reacting to the DDWS warnings.

None |———————————————| Extreme

12. How often did you feel that the DDWS correctly measured your level of alertness by giving you appropriate warnings?

☐ Almost never ☐ Occasionally ☐ Frequently ☐ Almost always

13. Draw a line through the bar to show how annoyed you were with incorrect DDWS warnings.

Not at all |————————————————| Extremely

14. How did you decide whether or not the DDWS was giving you correct warnings? *(Check all that apply)*

- ☐ I almost always got warnings when I was tired
- ☐ I knew that I was alert while driving and did not expect to get any warnings
- ☐ Other:____

15. What did you do when the device gave you incorrect warnings? *(Check all that apply)*

☐ Ignored the device ☐ Reset the device ☐ Covered the device
☐ Other:____

16. How often did you feel that the device gave you an incorrect warning about your level of fatigue?

☐ Almost never ☐ Occasionally ☐ Frequently ☐ Almost always

17. Under each clock time, use the scale below to write down how difficult it was to quickly understand and react to DDWS warnings.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

18. Draw a line through the bar to show how easy it was to read the DDWS display while driving.

Not at all |————————————————| Extremely

19. Draw a line through the bar to show how easy it was to hear the DDWS warnings.

Not at all |————————————————| Extremely

20. List the steps you usually took when the DDWS gave you a warning:____________________________

____

____

21. Under each clock time, use the scale below to write down how often, in general, the DDWS gave you an incorrect warning.

1 = Almost never 2 = Occasionally 3 = Frequently 4 = Almost always

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

22. Did the DDWS give you all of the information that you needed to make good decisions about managing your fatigue while driving? ☐ Yes ☐ No
    What more information would you have liked? ____

23. Was the location of the DDWS acceptable? *(Check one)* ☐Yes ☐No
    If "no," what was the problem?____

24. When were you most likely to use the DDWS warning information? *(Check all that apply)*
    ☐ When I felt very tired ☐ During poor driving conditions
    ☐ When there was very little traffic ☐ Other:______________________________________

25. Draw a line through the bar to show how much you felt that you relied on the DDWS device to warn you about your level of fatigue.

    Not at all |———————————————————————| Extremely

26. How often were you unable to take actions to improve your alertness once the DDWS gave a warning?

    ☐ Almost never ☐ Occasionally ☐ Frequently ☐ Almost always

27. How often were you unwilling to take actions to improve your alertness once the DDWS gave a warning?

    ☐ Almost never ☐ Occasionally ☐ Frequently ☐ Almost always

28. In what situations did you most often not do something to improve your alertness after the DDWS gave a warning?____

29. What was your biggest problem when using the DDWS? *(Check one)*

    ☐ Reading the display ☐ Turning off the alarm
    ☐ Changing device sensitivity ☐ Hearing the warning
    ☐ No problem ☐ Other:______________________________________

30. During your non-driving time, how did you use the DDWS feedback that you received while you were driving? *(Check all that apply)*

    ☐ Planned my sleep/wake schedule
    ☐ Planned meal times
    ☐ I did not think about the DDWS feedback I received during non-driving time
    ☐ Other: ____

31. Did you use DDWS information to help with your other fatigue management activities (for example, changing the time you sleep, etc.)? ☐ No ☐ Yes
    If "yes," how did you use the DDWS information? _____________________________________

32. Draw a line through the bar to show how comfortable you were using DDWS information to help with your other fatigue management activities (for example, changing the time you sleep, etc.).

Not at all |————————————————| Extremely

33. How long did it take you to understand how you could use DDWS information in your other fatigue management activities?

☐ One day ☐Less than 1 week ☐ Less than 1 month ☐ Still learning

34. Could you easily understand the written materials that you received about the DDWS? ☐ No ☐Yes

35. Would it have helped you if DDWS training materials were written in a language *other* than English?

☐ No ☐Yes If "yes," which language?___________________________

36. Draw a line through the bar to show how useful the DDWS was, in addition to the other steps you take to manage your fatigue.

Not at all |————————————————| Extremely

37. Draw a line through the bar to show how complete the DDWS training that you got was.

Not at all |————————————————| Extremely

38. Draw a line through the bar to show how complete your company's fatigue management training was.

Not at all |————————————————| Extremely

39. Do you believe that the DDWS information was kept confidential as discussed at the beginning of the study? Yes ☐ No ☐ If "no," why not? _________________________________

40. How many warnings did the DDWS need to give you before you tried to do something to improve your alertness? ☐ 1 ☐ 2 ☐ 3 ☐ 4 or more

41. Do you find the information given to you by the DDWS useful for managing your fatigue?
☐ Yes ☐ No Why or why not?____

42. Have you found uses for the DDWS other than as a tool to manage your fatigue? ☐ No ☐ Yes
If "yes," what are the uses?____

43. How do you feel that the DDWS has affected your health? *(Check one)*

☐ Improved my health
☐ Impaired my health
☐ No effect on my health
Why?________________________________

44. Draw a line through the bar to show how likely it is for you to be involved in a fatigue-related accident or incident when not using the DDWS.

Not at all |————————————————| Extremely

45. Draw a line through the bar to show how likely it is for you to be involved in a fatigue-related accident or incident when using the DDWS.

Not at all |————————————————| Extremely

46. Do you feel that, for whatever reason, using the DDWS made you feel more fatigued when you drove your usual hours? ☐ No ☐ Yes
Why? ____

47. Would you be willing to continue using the DDWS device after the study is over if the information it gives you is not recorded or available to your company and others? ☐ No ☐ Yes

Why or why not? ____

48. I would be willing to: (Check all *that apply)*
- ☐ Purchase a DDWS myself, if I could afford it
- ☐ Share the cost of the purchase of a DDWS for my truck cab with my employer
- ☐ Ask that my employer buy a DDWS device for my truck
- ☐ Ask that my employer buy DDWS devices for the fleet

49. Have you recommended the use of this device to your management? ☐ No ☐ Yes

50. Have you recommended the use of the DDWS to other drivers in your company? ☐ No ☐ Yes

51. Have you recommended the use of the DDWS device to professional drivers outside your company?
☐ No ☐ Yes

52. How often did you ignore DDWS warnings?

☐ Almost never ☐ Occasionally ☐ Frequently ☐ Almost always

53. How often did you trick the DDWS device so that it would no longer give you warnings?

☐ Almost never ☐ Occasionally ☐ Frequently ☐ Almost always

54. Draw a line through the bar to show how well you feel that you were able to include the DDWS into your fatigue management habits.

Not at all |————————————————| Extremely

55. In the boxes below, write down any other fatigue-fighting actions or activities you do when driving. Please also fill in the spaces for how frequently you use each with this scale:
1 = Nightly 2 = Weekly 3 = Monthly 4 = Only rarely

Fatigue-fighting Action or Activity	*Frequency*

56. Please describe what you do personally to try to control your on-duty fatigue:_______________
____

57. Do you feel that the DDWS helped you to avoid an accident or a close call when it was turned on during the study? ☐ No ☐ Yes If "yes," how often?___________________________

58. Did you take any fatigue or safety management classes, other than what was given for the DDWS, during the time when you were in this study?
☐ No ☐ Yes If "yes," what class? ______________________________

59. How annoying were the DDWS auditory alerts?
- ☐ Unacceptably annoying
- ☐ Somewhat annoying
- ☐ Tolerable
- ☐ Only slightly annoying
- ☐ Not at all annoying

60. Draw a line through the bar to show how much you agree that the DDWS increased your driving safety.

Strongly disagree |————————————————| Strongly agree

61. Draw a line through the bar to show how satisfied you usually were with the DDWS system.

Very unsatisfied |————————————————| Very satisfied

62. On average, how often per duty period do you feel that the DDWS device gave you an incorrect warning about your level of fatigue? _______ times per duty period.

63. Draw a line through the bar to show how comfortable you felt using the DDWS device.

Very uncomfortable |————————————————| Very comfortable

64. Draw a line through the bar to show how easy or difficult you found it to drive using the DDWS device.

Very difficult |————————————————| Very easy

65. Draw a line through the bar to show how easily you were able to recognize alerts from the DDWS device.

Not easily |————————————————| Very easily

66. Draw a line through the bar to show how much you agree that the DDWS device got your attention quickly when it gave an alert.

Strongly disagree |————————————————| Strongly agree

67. Were there ever situations when the DDWS device worked in a way that you did not understand?
☐ No ☐ Yes If "yes", please explain:

____

68. On average, how often per duty period do you feel that the DDWS device did not give you a warning about your level of fatigue when you felt that one was needed? _______ times per duty period

69. Draw a line through the bar to show how easy it was to use the DDWS device while driving.

Not at all |————————————————| Extremely

70. Overall, I found myself relying too much on the DDWS device.

Not at all |————————————————| Extremely

71. Did you stop relying on the DDWS because of incorrect warnings? ☐ No ☐ Yes

72. While operating a commercial motor vehicle during the study, did you ever, even for a moment, fall asleep behind the wheel? ☐ No ☐ Yes

73. While operating a commercial motor vehicle during the study, did you ever find yourself somewhere and not remembering how you got there? ☐ No ☐ Yes

74. Please indicate your overall acceptance rating of the DDWS system.

For each choice you will find 5 possible answers. When a term is completely appropriate, please put a check (•) in the square next to that term. When a term is appropriate to a certain extent, please put a check to the left or right of the middle at the side of the term. When you have no specific opinion, please put a check in the middle.

Participant Number: E_________ CONFIDENTIAL
Administration Date: _________ Verification Date: __________ Mailing Date: _________

The DDWS system was:

useful						useless
pleasant						unpleasant
bad						good
nice						annoying
effective						superfluous (ineffective)
irritating						likeable
assisting						worthless
undesirable						desirable
raising alertness						sleep-inducing

Participant Number: E_________ CONFIDENTIAL

Administration Date: __________ Verification Date: __________ Mailing Date: __________

Current Work Schedule and Environment:

The questions below will help us to better understand the impact of your work schedule and work environment.

Instructions: The questions below ask about your stress *level while driving using the DDWS.*

1. Draw a line through the bar to show how stressed you usually felt when driving in the early morning hours through rural interstates using the DDWS:

   Not at all |————————————————| Extremely

2. Under each clock time, use the scale below to write down how stressed you usually felt when driving at that time through rural interstates using the DDWS.

   1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

3. Draw a line through the bar to show how stressed you usually felt when driving in the early morning hours through city streets and highways using the DDWS:

   Not at all |————————————————| Extremely

4. Under each clock time, use the scale below to write down how stressed you usually felt when driving at that time through city streets and highways using the DDWS.

   1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

Instructions: The questions below ask about your fatigue *level while driving using the DDWS.*

5. Draw a line through the bar to show how fatigued you usually felt when driving in the early morning hours through rural interstates using the DDWS:

   Not at all |————————————————| Extremely

6. Under each clock time, use the scale below to write down how fatigued you usually felt when driving at that time through rural interstates using the DDWS.

   1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

Participant Number: E_________ CONFIDENTIAL
Administration Date: _________ Verification Date: __________ Mailing Date: _________

7. Draw a line through the bar to show how fatigued you usually felt when driving in the early morning hours through city streets and highways using the DDWS:

Not at all |————————————————| Extremely

8. Under each clock time, use the scale below to write down how fatigued you usually felt when driving at that time through city streets and highways using the DDWS.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

9. How well do you now think that you will be able to follow your company's fatigue management program, using DDWS feedback?

☐ Not at all ☐ A little ☐ Quite a bit ☐ Very much

10. How likely are you to doze off or fall asleep in the following situations, in contrast to feeling just tired? This refers to your usual way of life in recent times. Even if you have not done some of these things recently, try to work out how they would have affected you. Use the following scale to choose the most appropriate number for each situation:

0 = no chance of dozing
1 = slight chance of dozing
2 = moderate chance of dozing
3 = high chance of dozing

SITUATION CHANCE OF DOZING :

Sitting and reading ____________
Watching TV ____________
Sitting inactive in a public place (e.g., a theater or a meeting) ____________
As a passenger in a car for an hour without a break ____________
Lying down to rest in the afternoon when circumstances permit ____________
Sitting and talking to someone ____________
Sitting quietly after a lunch without alcohol ____________
In a car, while stopped for a few minutes in traffic ____________

Participant Number: C_________ CONFIDENTIAL
Administration Date: __________ Completion Date: __________ Mailing Date: _________

Instructions: The questions below ask about your alertness level while driving using the DDWS.

11. Draw a line through the bar to show how alert you usually felt when driving in the early morning hours through rural interstate areas using the DDWS:

Not at all |————————————————| Extremely

12. Under each clock time, use the scale below to write down how alert you usually felt when driving at that time through rural interstate areas using the DDWS.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

13. Draw a line through the bar to show how alert you usually felt when driving in the early morning hours through city streets and highways using the DDWS:

Not at all |————————————————| Extremely

14. Under each clock time, use the scale below to write down how alert you usually felt when driving at that time through city streets and highways using the DDWS.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

15. Did you drive any new or unfamiliar runs over the time of the study?
☐ No ☐ Yes If "yes," please list the runs below.

Run
Example: Pittsburgh to Boston via Routes 80, 84, 90

Participant Number: C________ CONFIDENTIAL
Administration Date: __________ Completion Date: __________ Mailing Date: _________

APPENDIX R: POST-STUDY SURVEY FOR CONTROL GROUP

Thank you for taking the time to complete this survey! It should take you about 15 minutes to fill out. The information that you give will not be shared with any of your managers or other operators, and your responses will be kept strictly confidential. This survey asks you questions about your health and well being, fatigue management, and your current work schedule and environment. You are not required to give answers to any survey items that make you uncomfortable. However, the more data you give, the better we will be able to understand the potential benefits of the device for drivers like yourself.

Health and Well Being:
The questions below will allow us to better understand your health. Please carefully follow any additional instructions.

1. Draw a line through the bar to show how healthy you usually feel.

Very healthy |——————————————————| Not healthy at all

2. The questions below concern some of your body functions. Please try to answer each question by checking the correct box that shows how often you experienced each of the items *during the course of the study*. Check one space for each item below.

Items:	*Never*	*Less than once a month*	*Once or twice a month*	*Once a week*	*2 or 3 times a week*	*About every day*
Back Pain						
Acid indigestion, heartburn, or acid stomach						
Gastrointestinal problems						
Constipation						
Tight feeling in stomach						
Blurred vision						
Trouble falling asleep						
Feeling tired upon awaking						
Trouble staying asleep						
Other:						
Other:						

3. Did any major stressful events take place in your life during the study? ☐ No ☐ Yes
If "yes," what was the event(s)? ____

4. *Instructions:* The questions in this scale ask you about your feelings and thoughts during the last month. In each case, please check how often you felt or thought a certain way.

   a. In the last month, how often have you felt that you were unable to control the important things in your life?
   ☐ Never ☐ Almost never ☐ Sometimes ☐ Fairly often ☐ Very often

   b. In the last month, how often have you felt confident about your ability to handle your personal problems?
   ☐ Never ☐ Almost never ☐ Sometimes ☐ Fairly often ☐ Very often

   c. In the last month, how often have you felt that things were going your way?
   ☐ Never ☐ Almost never ☐ Sometimes ☐ Fairly often ☐ Very often

   d. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?
   ☐ Never ☐ Almost never ☐ Sometimes ☐ Fairly often ☐ Very often

Fatigue Management:
The questions below will allow us to better understand your views on fatigue management.

1. How useful do you think your company's fatigue management program was in helping you manage your fatigue at work?

   ☐ Not at all useful ☐ A little useful ☐ Quite useful ☐ Extremely useful

2. How well do you now think that you will be able to follow your company's fatigue management program?

   ☐ Not at all ☐ A little ☐ Quite a bit ☐ Very much

3. Draw a line through the bar to show how good you felt your company's fatigue management training program was.

   Not at all |————————————————| Extremely

4. Draw a line through the bar to show how likely it is for you to be involved in a fatigue-related accident or incident after you finished your company's fatigue management training.

   Not at all |————————————————| Extremely

5. In the boxes below, write down any fatigue-fighting actions or activities you do when driving. Please also fill in the spaces for how frequently you use each with this scale:

1 = Nightly 2 = Weekly 3 = Monthly 4 = Only rarely

Fatigue-fighting Action or Activity	*Frequency*

6. Please describe what you do personally to try to control your on-duty fatigue: _________________
____
____

7. Did you take any fatigue or safety management classes, other than that given at the start of this study, during the time when you were a participant?
☐ No ☐ Yes If "yes," what class? ____

Current Work Schedule and Environment:
The questions below will help us to better understand the impact of your work schedule and work environment.

Instructions: The questions below ask about your stress level while driving.

1. Draw a line through the bar to show how stressed you usually felt when driving in the early morning hours through rural interstates:

Not at all |————————————————| Extremely

2. Under each clock time, use the scale below to write down how stressed you usually felt when driving at that time through rural interstates.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

3. Draw a line through the bar to show how stressed you usually felt when driving in the early morning hours through city streets and highways:

Not at all |————————————————| Extremely

4. Under each clock time, use the scale below to write down how stressed you usually felt when driving at that time through city streets and highways.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

Instructions: The questions below ask about your fatigue level while driving.

5. Draw a line through the bar to show how fatigued you usually felt when driving in the early morning hours through rural interstates:

Not at all |————————————| Extremely

6. Under each clock time, use the scale below to write down how fatigued you usually felt when driving at that time through rural interstates.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

7. Draw a line through the bar to show how fatigued you usually felt when driving in the early morning hours through city streets and highways:

Not at all |————————————| Extremely

8. Under each clock time, use the scale below to write down how fatigued you usually felt when driving at that time through city streets and highways.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

9. While operating a commercial motor vehicle during the study, did you ever, even for a moment, fall asleep behind the wheel? ☐ No ☐ Yes

10. While operating a commercial motor vehicle during the study, did you ever find yourself somewhere and not remembering how you got there? ☐ No ☐ Yes

11. How likely are you to doze off or fall asleep in the following situations, in contrast to feeling just tired? This refers to your usual way of life in recent times. Even if you have not done some of these things recently, try to work out how they would have affected you. Use the following scale to choose the most appropriate number for each situation:

    0 = no chance of dozing
    1 = slight chance of dozing
    2 = moderate chance of dozing
    3 = high chance of dozing

SITUATION CHANCE OF DOZING :

Sitting and reading ____________
Watching TV ____________
Sitting inactive in a public place (e.g., a theater or a meeting) ____________
As a passenger in a car for an hour without a break ____________
Lying down to rest in the afternoon when circumstances permit ____________
Sitting and talking to someone ____________
Sitting quietly after a lunch without alcohol ____________
In a car, while stopped for a few minutes in traffic ____________

Instructions: The questions below ask about your alertness level while driving.

12. Draw a line through the bar to show how alert you usually felt when driving in the early morning hours through rural interstate areas:

Not at all |————————————————| Extremely

13. Under each clock time, use the scale below to write down how alert you usually felt when driving at that time through rural interstate areas.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

14. Draw a line through the bar to show how alert you usually felt when driving in the early morning hours through city streets and highways:

Not at all |————————————————| Extremely

15. Under each clock time, use the scale below to write down how alert you usually felt when driving at that time through city streets and highways.

1 = Not at all 2 = A little 3 = Quite a bit 4 = Extremely

9 PM – Midnight	Midnight – 3 AM	3 AM – 6 AM

16. Did you drive any new or unfamiliar runs over the time of the study? ☐ No ☐ Yes

If "yes," please list the runs below.

Run
Example: Pittsburgh to Boston via Routes 80, 84, 90

Participant Number: **Confidential**

APPENDIX S: DEBRIEFING SURVEY FOR EXPERIMENTAL GROUP

The entire study staff would like to thank you for your participation in this experiment. We realize that this was not an easy or a short study and very much appreciate your willingness to complete all of the requested tasks. The data collected from this experiment will be used to evaluate and further develop drowsy driver warning systems for the American trucking industry. You have made a major contribution to our understanding of the safety benefits of this device and how we may improve upon it.

Instructions: Please write your answers under each question. Use the back of the page if you need additional space.

1. What part(s) of the experiment did you object to, or caused you hardship?

2. What did you enjoy or find interesting about the study?

3. How do you think the *training* on using the DDWS can be improved to be more helpful?

4. Was the amount of money you received for participating in the study a fair amount for the work that you had to do? (Check one) ☐ No ☐ Yes

   If you answered "No", what amount would have been fair?

5. Do you feel that a *reward* (for example, receiving an amount of money for reducing the number of warnings you received over the duration of the study) would have changed the way you used the DDWS feedback? (Check one) ☐ No ☐ Yes

   If "Yes", how?

6. Did you find any part of the study (for example, the training, explanation, focus groups, etc.) to be too rushed or poorly timed? (Check one) ☐ No ☐ Yes

   If "Yes", what part of the study was rushed and how might it be fixed?

7. What problems, if any, did you notice in how the study was conducted?

8. How aware were you of the DDWS and being in a study when the device was *not turned on*?

9. Did you feel *more alert* throughout the night *during the study*, in general, than you would have otherwise? ☐ No ☐ Yes

   If "yes", why do you think that you felt this way?

10. Overall, how did you feel that you were treated during the experiment? How could we improve the experience of future participants?

11. General comments and observations:

APPENDIX T: DEBRIEFING SURVEY FOR CONTROL GROUP

The entire study staff would like to thank you for your participation in this experiment. We realize that this was not an easy or a short study and very much appreciate your willingness to complete all of the requested tasks. The data collected from this experiment will be used to evaluate and further develop technology for the American trucking industry. Thank you again for your contribution and for your efforts.

Instructions: Please write your answers under each question. Use the back of the page if you need additional space.

1. What part(s) of the experiment did you object to, or caused you hardship?

2. What did you enjoy or find interesting about the study?

3. Was the amount of money you received for participating in the study a fair amount for the work that you had to do? (Check one) ☐ No ☐ Yes
   If you answered "No", what amount would have been fair?

4. Did you find any part of the study (for example, the fatigue management training, explanation, focus groups, etc.) to be too rushed or poorly timed? (Check one)
   ☐ No ☐ Yes
   If "Yes", what part of the study was rushed and how might it be fixed?

5. What problems, if any, did you notice in how the study was conducted?

6. Did you feel *more alert* throughout the night *during the study*, in general, than you would have otherwise? ☐ No ☐ Yes
   If "yes", why do you think that you felt this way?

7. Overall, how did you feel that you were treated during the experiment? How could we improve the experience of future participants?

8. General comments and observations:

APPENDIX U: VERIFICATION PROCEDURE FOR SURVEY

Post-Study Survey Answer Check

EXPERIMENTAL VERSION

SECTION: HEALTH AND WELL BEING

Question: 2

- Verify that checklist does not exhibit fixed responses under "Once a week", "2 or 3 times a week," or "About every day"
- Inquire drivers if all the responses are fixed under one of the previous
- "Never" responses may be ignored

SECTION: DDWS DEVICE (DDWS)

Question: 4 & 36

- Compare Question 4 and 36 responses
- Expect corresponding responses
- Inquire drivers about their responses if under the following conditions:
  - ➨ Q.4: "Not at all useful" is checked and VTTI researcher judges the response on Q.36 lies approximately within the right half of the bar (toward "Extremely")
  - ➨ Q.4 "Extremely useful" is checked and VTTI researcher judges the response on Q.36 lies approximately within the left half of the bar (toward "Not at all")

Question: 12 & 16

- Compare Question 12 and 16 responses
- Expect opposing responses
- Inquire drivers when inconsistent responses are found, as the following:

Pattern	Response on Question 12	Response on Question 16
1	Almost never	Almost never
2	Almost always	Almost always

Question: 18 & 29

- Compare Question 18 and 29 responses
- Inquire drivers about their responses if under the following condition:
  - ➡ Q.29: "Reading the display" is checked and VTTI researcher judges the response on Q.18 lies approximately within half inch from "Extremely"

Question: 19 & 29

- Compare Question 19 and 29 responses
- Inquire drivers about their responses if under the following condition:
  - ➡ Q.29: "Hearing the warning" is checked and VTTI researcher judges the response on Q.19 lies approximately within half inch from "Extremely"

Question: 74

- Verify that checklist responses do not exhibit fixed responses
- All "Neutral" responses may be ignored
- Inquire drivers about their responses if all of them are fixed under other than the center

---

CONTROL VERSION

SECTION: HEALTH AND WELL BEING

Question: 2

- Verify that checklist does not exhibit fixed responses under "Once a week", "2 or 3 times a week", or "About every day"
- Inquire drivers if all the responses are fixed under one of the previous
- "Never" responses may be ignored

SECTION: CURRENT WORK SCHEDULE AND ENVIRONMENT

Question: 5 & 12

- Compare Question 5 and 12 responses
- Expect <u>opposing</u> responses
- Drivers' responses should follow the following tendency:
  - ➡ Q.5: Response lies approximately within half inch from "Not at all" fatigued; Q.12: Response lies approximately within half inch from "Extremely" alert

APPENDIX V: EXAMPLE OF DAILY DRIVING RECORD SHEET

Driver:
Truck:
Group: **Experiment**
First Day of Data Collection: **01/27/05**
Last Day of Data Collection: **05/05/05**

EXAMPLE

Pattern	*Condition*
√	Valid data assumed to be collected since (i) truck is in service, and (ii) subject driver is on the truck. Some data may be intermittent or discontinuous.
	Valid data collected but portions of the data are invalid
	No valid data collected due to (i) corrupt files, (ii) truck is out of service, (iii) driver is sick, (iv) different driver is in the truck, (v) data collection system is down, or (v) driver has a day off, vacation, or holiday
	Data is assumed to be collected but hard drive has not yet been received

Note: "Valid data" denotes valid video data plus a corresponding data file.

	assigned DFM mode	M	Tu	W	Th	F	Sat	Sun	# of days data was not collected	data collected by week (0.2 per day)	Cumulated	data collected by week (1 or 0)	Cumulated
Week 1		1/24/05	1/25/05	1/26/05	1/27/05	1/28/05	1/29/05	1/30/05					
	Dark				√ - 1st day	√			2	0.4	**0.4**	1	**1**
Week 2		1/31/05	2/1/05	2/2/05	2/3/05	2/4/05	2/5/05	2/6/05					
	Dark								5	0.4	**0.8**	1	**2**
Week 3		2/7/05	2/8/05	2/9/05	2/10/05	2/11/05	2/12/05	2/13/05					
	Dark					√			4	0.6	**1.4**	1	**3**
Week 4		2/14/05	2/15/05	2/16/05	2/17/05	2/18/05	2/19/05	2/20/05					
	Dark	√		√	√	√			2	1	**2.4**	1	**4**
Week 5		2/21/05	2/22/05	2/23/05	2/24/05	2/25/05	2/26/05	2/27/05					
	Dark		√	√	√				3	0.8	**3.2**	1	**5**
Week 6		2/28/05	3/1/05	3/2/05	3/3/05	3/4/05	3/5/05	3/6/05					
	Dark/Active (3/1)			√	√	√			3	0.8	**4**	1	**6**
Week 7		3/7/05	3/8/05	3/9/05	3/10/05	3/11/05	3/12/05	3/13/05					
	Active		√	√	√	√			2	1	**5**	1	**7**
Week 8		3/14/05	3/15/05	3/16/05	3/17/05	3/18/05	3/19/05	3/20/05					
	Active	√	√	√	√	√			2	1	**6**	1	**8**
Week 9		3/21/05	3/22/05	3/23/05	3/24/05	3/25/05	3/26/05	3/27/05					
	Active	√		√	√				3	0.8	**6.8**	1	**9**
Week 10		3/28/05	3/29/05	3/30/05	3/31/05	4/1/05	4/2/05	4/3/05					
	Active		√	√	√	√	√		1	1.2	**8**	1	**10**
Week 11		4/4/05	4/5/05	4/6/05	4/7/05	4/8/05	4/9/05	4/10/05					
	Active	√		√		√			2	1	**9**	1	**11**
Week 12		4/11/05	4/12/05	4/13/05	4/14/05	4/15/05	4/16/05	4/17/05					
	Active	√	√						5	0.4	**9.4**	1	**12**
Week 13		4/18/05	4/19/05	4/20/05	4/21/05	4/22/05	4/23/05	4/24/05					
	Active	√	√		√	√			2	1	**10.4**	1	**13**
Week 14		4/25/05	4/26/05	4/27/05	4/28/05	4/29/05	4/30/05	5/1/05					
	Active	√	√			√			2	1	**11.4**	1	**14**
Week 15		5/2/05	5/3/05	5/4/05	5/5/05	5/6/05	5/7/05	5/8/05					
	Active	√	√	√	√ - End Day				0	0.8	**12.2**	1	**15**

APPENDIX W: INFORMED CONSENT FORM

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants

in Research Projects Involving Human Subjects

Title of Project: Drowsy Driver Warning System (DDWS) Field Operational Test (FOT)
Task 23: Post FOT Focus Groups

Investigators: Dr. Richard Grace, Attention Technology, Inc.
Akiko Nakata, Virginia Tech Transportation Institute

I. Purpose of this Research/Project

The purpose of this focus group meeting is to gather information regarding your experiences in using the Driver Fatigue Monitor (DFM) in the Field Operational Test (FOT) data collection. Your comments together with the data collected in the FOT will allow researchers to asses the value of the DFM for use in commercial trucking operations.

II. Procedures

We would like you to participate in a focus group meeting in which participants will exchange their opinions of the DFM used in the FOT data collection. You will be asked to give your opinions regarding the value and the use of the DFM in a group setting with seven to ten other drivers. The meeting will last approximately 2 to 3 hours. The discussion will be recorded in video for analysis after the meeting.

III. Risks and Discomforts

The physical and psychological risks associated with participation are minimal. Since you will be asked to provide comments regarding the DFM while seated at a conference table, the physical risk is negligible. However, there is a normal risks associated with transportation to and from the focus group meeting site. The psychological risk primarily includes the potential stress associated with expressing opinions regarding the DFM in front of peers and researchers.

IV. Benefits

No promise or guarantee of benefits is being made to encourage you to participate. Research, such as that being conducted here, is important because it may improve driving safety and help reduce crashes. Drivers' participation is necessary to assess the efficacy of a drowsiness monitor (such as the DFM used in the FOT data collection) that aims at reducing fatigue-related crashes. Past experience with previous studies involving commercial drivers indicates that you may find the discussion interesting.

V. Extent of Anonymity and Confidentiality

The information gathered in the focus group meeting will be treated with confidentiality. Shortly after participating, your name will be separated from the data and replaced with a number. That is, your data will not be attached to your name, but rather to a number (e.g., Driver No.1).

The focus group meetings will be recorded in video with audio. The video and other data from this meeting will be stored in a secured area at the Volpe Center (the independent evaluator for this project). Access to the digital video files will be under the supervision of the researchers at Volpe Center involved in the project. The video files will be accessible to the government sponsor and to those researchers and data analysts associated with this project and for follow-up analysis at the Volpe Center (the independent evaluator for this project). The video files will not be released to unauthorized individuals without your written consent.

VI. Compensation

You will be paid $100 for participation in the focus group meeting. The payment will be mailed to you by check following your participation.

VII. Freedom to Withdraw

As a participant in the focus group meeting, you are free to withdraw at any time without penalty. If you choose to withdraw, you will be compensated for the portion of time of the meeting in which you participated. Furthermore, you are free not to answer any question without penalty.

VIII. Approval of Research

This research project has been approved, as required, by the Institutional Review Board for Research Involving Human Subjects at Virginia Polytechnic Institute and State University.

August 29, 2005	August 28, 2006
IRB Approval Date Approval	Approval Expiration Date

IX. Subject's Responsibility

Your responsibility is to participate in the discussion to the extent you are comfortable.

XI. Subject's Permission

I have read and understand the Informed Consent and conditions of this Post-FOT Focus Group. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this focus group meeting. If I participate, I understand that I may withdraw at any time without penalty. I agree to abide by the rules of this meeting.
I understand that the focus group will be recorded in video with audio.

______________________________ Date ____________________
Subject signature

XII. Voluntary Use of Data for Presentations

You have agreed to participate in the DDWS FOT Focus Group meeting. The purpose of this meeting is to obtain drivers' opinions regarding the use of the DFM in the FOT. In support of this meeting, video cameras will be used to record discussion during the meeting. We realize that the video files could be used to clarify the methods used and to demonstrate the findings at technical conferences and for other presentations.

With your permission, we would like to have the opportunity to show and release portions of videotape displaying your image. The purpose of this form is to obtain your consent to do so. If you agree, please sign below. If you do not agree, you will still be able to participate in this meeting, but your data will not be used for demonstration or presentation purposes.

____Date__________________________

Subject signature

Should I have any questions about this research or its conduct, I may contact:

___Richard Grace__________ __[redacted]

Investigator(s) ***Telephone / e-mail***

___Akiko Nakata___________ __[redacted]

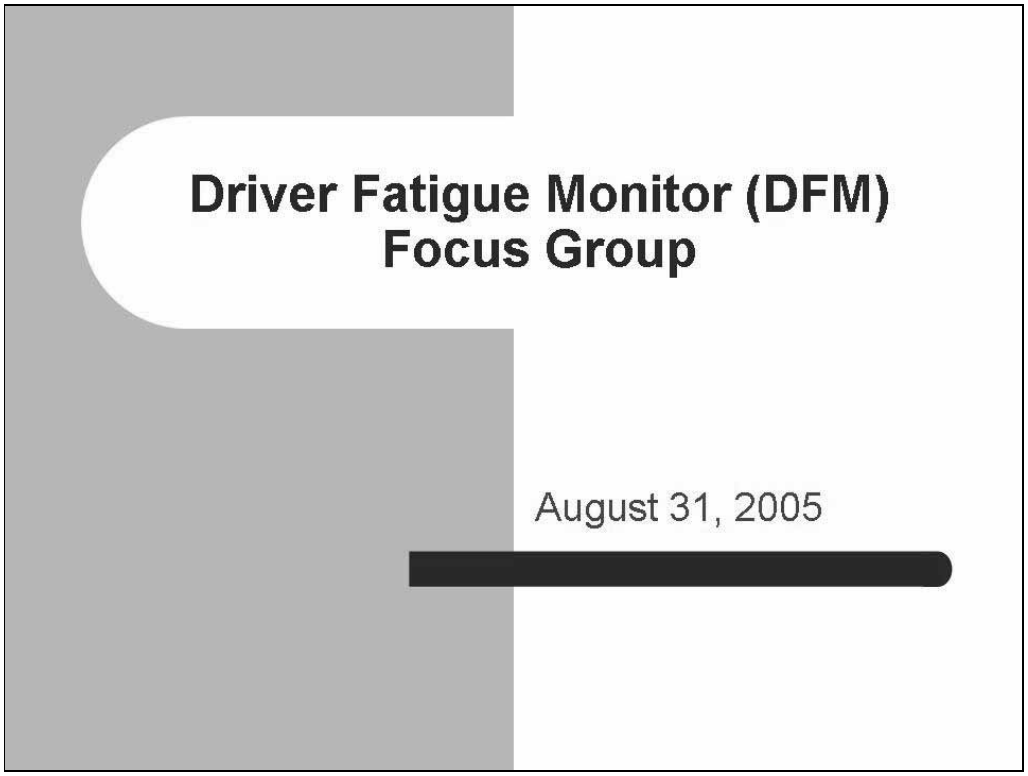
Senior Research Associate ***Telephone / e-mail***

___David M. Moore_________ __[redacted]

Chair, IRB ***Telephone / e-mail***
Office of Research Compliance
Research & Graduate Studies

Subjects must be given a complete copy (or duplicate original) of the signed Informed Consent.

APPENDIX X: PRESENTATION FOR FOCUS GROUP



The DFM System

- Tell me what you know about how the Driver Fatigue Monitor (DFM) functions.

3

Using the DFM

Tell me about how easy or difficult you found the DFM to use.

- Do you feel that using the DFM had an impact on your workload while driving?
  - If yes, how much?
- Did you receive false warnings from the DFM?
  - If so, what did you think about them?
- How easy or difficult did you find the warnings to understand?

4

Using the DFM, cont.

Tell me about how easy or difficult you found the DFM to use.

- How much did the DFM feedback about your level of fatigue match how fatigued you felt?
- Tell me what you liked or disliked about the controls and positioning of the DFM.
- How did you usually respond when the DFM gave you a warning?

5

Using the DFM, cont.

If you worked the DFM into your daily routine, how did you do it, and why?

- DFM feedback:
  - When did you use it?
  - When did you ignore it?
- Did the DFM feedback change your off duty activities (sleep patterns, schedule, etc.)?
  - If "yes", how did it change them?

6

Perceived Value

What do you see as the overall value, if any, of having this device in your truck?

- Did the DFM affect how you managed your fatigue?
- Are you concerned that a third party may have access to information about your fatigue level?
  - Did this concern have an effect on how you used the DFM?

7

Perceived Value, cont.

What do you see as the overall value, if any, of having this device in your truck?

- Do you think that the DFM warnings had an effect on how you drove?
- Do you feel that the DFM had an effect on your health?
- Please identify any good points or bad points about using the DFM (for yourself or others).

8

Learning the DFM

Were the instructions and training sessions useful to you?

- Did you find it necessary to review the instructions on how to use any part of the DFM?
  - If yes, what part(s)?
- How useful was the "Quick Reference for the DFM" instructions?
- How useful was the "Understanding Fatigue and Alert Driving" training session Virginia Tech provided?

9

Purchase & Recommendation

- Would you consider purchasing the DFM?
- Would you recommend the DFM to your company or other drivers?

10

Suggested Improvements

- How would you suggest improving the DFM system?

11

Thank You!

APPENDIX Y: DISCUSSION GUIDE

Tell me what you know about how the DFM functions.
Ease of Use
Tell me about how easy or difficult you found the DFM to use.
Demands on Driver
Do you feel that using DFM had an impact on your daily workload? If yes, how much? *-monitoring and reacting to the device*
Tolerance of False or Nuisance Warnings
Did you receive false warnings from the DFM, and if you did, what did you think about them?
To what degree did you find the false alarms tolerable or annoying? How so?
Did you feel that DFM output matched how fatigued you felt?
What did you do if or when DFM output didn't match how fatigued you felt?
Do you feel that the false warnings affected your safety while driving?
Did you change how you used the information from the device because of inaccurate DFM output?
Understanding of Warnings
How easy or difficult did you find the warnings to understand?
Tell me about your understanding of the different types of warnings. *-there are two types of warnings* *1)the initial advisory tone (auditory only-requires no action from the driver)* *2) the full warning (repeated auditory and visual alerts-the bar graph lights up in red to display yards covered with eyes closed and driver needs to press "ok" button to stop it).*
Tell me about your understanding of how the warnings changed in different driving situations.
What did you think of the LED colors, sizes, and bar graph flash rates? *-the word "Standby" and the bar graph were lit in red; brightness, volume, and sensitivity settings were lit in green* *-drivers were able to adjust the brightness* *-bar graph flashes when driver is given a full warning and he must press "ok" button to stop it from flashing*
What did you think of the volume and tone of the auditory alerts? *-drivers had the ability to adjust both volume and tone* *-there were 6 different tones ranging from mellow tone to loud buzzer*
Was the DFM output displayed in a manner that you thought matched the severity of the warning?
Understanding of DFM State
How much did the DFM feedback about your level of fatigue match how fatigued you felt?
Usability of DFM Controls
Tell me what you liked or disliked about the controls and positioning of the DFM.
What did you think about the content of the display? Was it appropriate?
What did you think of the location of the DFM in your vehicle?
What did you think of the automatic on/off feature of the DFM?
If you changed the device settings, how many times did you do it? *-there are 4 settings drivers could change: type of sound, volume, display brightness, and device sensitivity*
If you changed the device settings, how long did it take you to do so?
Use Patterns
How did you usually respond when the DFM gave you a warning?
Approximately how many times were you unable or unwilling to heed the DFM output?
In what types of situations were you unable or unwilling to heed the DFM output?

Adaptation and Integration
If you worked the DFM into your daily routine, how did you do it and why?
Awareness
DFM feedback : When did you use it? When did you ignore it?
How many times did you purposely foil the DFM? If so, what were the circumstances?
How many times did you ignore DFM output? If you ignored DFM output, what were the circumstances?
Did you incorporate DFM into your work routine? If yes, how?
How successful do you think you were at incorporating DFM into your work routine?
While driving, how often did you use techniques other than the DFM to fight fatigue, and what were they?
Lifestyle
Did the DFM feedback change your off duty activities (sleep patterns, schedule, etc.)? If "yes", how did it change them?
Did you integrate DFM into your personal life? If yes, how?
In your personal life, how often did you use techniques other than DFM to fight fatigue, and what were they?
Did you use DFM information in conjunction with any other fatigue fighting techniques? If yes, how?

Perceived Value
What do you see as the overall value, if any, of having this device in your truck?
Alertness Management Enhancement
Did the DFM affect how you managed your fatigue?
When DFM issued a warning, how often, and in what situations, did you respond to the warning? *- Other than pressing the "OK" button, did they change their behaviors?*
Would you continue to use DFM to help manage your fatigue? If yes, how? If no, why not?
Confidentiality Concerns
Are you concerned that a third party may have access to information about your fatigue level? Did this concern have an effect on how you used the DFM?
Who do you think had access to the DFM data, and how did this affect you?
Did you use the DFM information differently because of who you thought could view it?
Describe how accurate you feel your data are. Did issues of confidentiality affect your data? If yes, how?
Driving Skill Enhancement
Do you think that the DFM warnings had an effect on how you drove?
How did you decide if a warning was accurate?
Overall, were you able to act on the information the DFM gave you while driving?
Did the DFM give you information that was helpful for managing your fatigue?
Did you find any uses for the DFM other than managing your fatigue?
Health Concerns
Do you feel that the DFM had an effect on your health?
Do you think that the infrared light on the DFM had any effect on your health?
What kind of information could be provided that would have changed your perceptions of any potential?
Safety
Please identify any good points or bad points about using the DFM (for yourself or others).

Ease of Learning
Were the instructions and training sessions useful to you?
Ability to Retain Instructions
Did you find it necessary to review the instructions on how to use any part of the DFM? If yes, what?
Utility of Instructions and Training
How useful was the "Quick Reference for the DFM" instructions? How useful was the "Understanding Fatigue and Alert Driving" training session?
How many times did you need to refer back to the instructions, or ask someone about DFM function after
How long were the training sessions your company provided? *-fatigue training and DFM instructions*
What types of questions did you and other drivers ask during the training sessions? How many?
Do you have any suggestions as to how to make the training sessions more helpful?

Advocacy
Would you consider purchasing the DFM? Would you recommend the DFM to your company or other drivers?

APPENDIX Z: DATA CODING DIRECTORY

1.0 Detailed Analysis of DFM Alerts

A sample of 1000 alerts (P=12%) will be retrieved from the data set. For each alert, the items listed below will be determined.

Note: Unless otherwise specified in the "comments" section, each item should be assessed at the time of the alert.

1.1 Driver Information

- Driver number
- File name
- Date
- Time
- Sync number
- Operating mode
- Sensitivity setting

1.2 Severity

Note: The option will be marked if it is present during the 3 minutes prior to the alert; analysts can mark up to four options. If the same behavior occurs multiple times, it will only be marked one time [Option list based on GES V26]
00 = None observed

THIS VEHICLE TRAVELING
20 = Over the lane line on left side of travel lane
21 = Over the lane line on right side of travel lane
22 = Off the edge of the road on the left side
23 = Off the edge of the road on the right side
24 = End departure
25 = Turning left at intersection
26 = Turning right at intersection
26a = Take exit ramp on left
26b = Take exit ramp on right
27 = Crossing over (passing through) intersection
28 = This vehicle decelerating
29 = Unknown travel direction

OTHER MOTOR VEHICLE IN LANE
50 = Other vehicle stopped
51 = Traveling in same direction with lower steady speed
52 = Traveling in same direction while decelerating
53 = Traveling in same direction with higher speed
54 = Traveling in opposite direction
55 = In crossover
56 = Backing
59 = Unknown travel direction of other motor vehicle in lane

OTHER MOTOR VEHICLE ENCROACHING INTO LANE
60 = From adjacent lane (same direction) – over left lane line
61 = From adjacent lane (same direction) – over right lane line
62 = From opposite direction - over left lane line
63 = From opposite direction - over right lane line
64 = From parking lane
65 = From crossing street, turning into same direction
66 = From crossing street, across path
67 = From crossing street, turning into opposite direction
68 = From crossing street, intended path not known
70 = From driveway, turning into same direction
71 = From driveway, across path
72 = From driveway, turning into opposite direction
73 = From driveway, intended path not known
74 = From entrance to limited access highway
78 = Encroachment by other vehicle - details unknown

PEDESTRIAN, PEDALCYCLIST, OR OTHER NONMOTORIST
80 = Pedestrian in roadway
81 = Pedestrian approaching roadway
82 = Pedestrian - unknown location
83 = Pedalcyclist or other nonmotorist in roadway
84 = Pedalcyclist or other nonmotorist approaching roadway
85 = Pedalcyclist or other nonmotorist - unknown location

OBJECT OR ANIMAL
87 = Animal in roadway
88 = Animal approaching roadway
89 = Animal - unknown location
90 = Object in roadway
91 = Object approaching roadway
92 = Object - unknown location

OTHER
98 = Other critical pre-crash event
99 = Unknown

Severity in Relation to Lane and Shoulder Departure
01 = Never departed lane
02 = Right: partial lane break
03 = Right: full lane break
04 = Right: partial 2nd lane/shoulder break
05 = Right: full 2nd lane/shoulder break
06 = Left: partial lane break
07 = Left: full lane break
08 = Left: partial 2nd lane/shoulder break
09 = Left: full 2nd lane/shoulder break

1.3 Ambient Conditions

Light Condition [GES A19, Light Condition]
01 = Daylight
02 = Dark
03 = Dark but lighted
04 = Dawn
05 = Dusk
09 = Unknown

Weather [GES A20, Atmospheric Condition]
01 = No adverse conditions
02 = Rain
03 = Sleet
04 = Snow
05 = Fog
06 = Rain & fog
07 = Sleet & fog
08 = Other (smog, smoke, sand/dust, crosswind, hail)
09 = Unknown

1.4 Driver Characteristics

Driver Attention
Note: Observe the location of the driver's eyes during an interval spanning 5-seconds before the alert. If the driver appears to be looking at locations other than forward view for a particular instance for 2 or more seconds, choose "off road".
01 = On road
02 = Off road
03 = Unknown

Driver 1 Distracted By [GES D07]

Note: Analyst codes all behaviors observed during 10 seconds prior to trigger.

00 = None observed

01 = Looked but did not see (e.g., driver looked in direction of crash threat but apparently did not recognize threat)

02a = Interact with or look at other occupant(s)

02b = Interact with or look at pet in vehicle

03a = Look at, or for, object in vehicle

03b = Reach for object in vehicle (including hand-held cell phone, hands-free cell phone, PDA, CB microphone/other communications device, or other object).

04a = Talk or listen to hand-held phone

04b = Talk or listen to hands-free phone

04c = Talk or listen to CB microphone or other communications device

05a = Dial hand-held phone

05b = Dial hands-free phone

05c = Operate PDA (inputting or reading)

06 = Adjust instrument panel (including climate control, radio, or cassette/CD)

07a = Look at left-side mirror/out left-side window

07b = Look at right-side mirror/out right-side window

07c = Look back in Sleeper Berth

07d = Shift gears

07e = Looks down (at lap, or at something on the floor)

08 = Use or reach for other devices

09 = Appears drowsy, sleepy, asleep, fatigued

10a = Look at previous crash or highway incident

10b = Look at construction zone signs, barriers, flagperson, etc.

10c = Look at outside person

10d = Look at outside animal, object, store, etc.

10e = Look at undetermined outside event, person, or object.

11a = Eat with utensil

11b = Eat without utensil (includes chewing, other than gum; e.g., toothpick)

11c = Drink from covered container (e.g., with straw)

11d = Drink from open container

11e = Chewing gum

12a = Smoking-related behavior – reaching, lighting, extinguishing

12b = Smoking-related behavior – other (e.g., cigarette in hand or mouth)

13a = Read book, newspaper, etc.

13b = Read or look at map

14 = Talk/sing/”dance” with no indication of passenger

15a = Handle or interact with dispatching, electronic recording, or navigational device

15b = Read or look at dispatching, electronic recording, or navigational device

16a = Comb/brush/fix hair

16b = Apply make-up

16c = Shave

16d = Brush/floss teeth

16e = Bite nails/cuticles

16f = Remove/adjust jewelry
16g = Remove/insert contact lenses
16h = Other personal hygiene
16i = Put on/remove/adjust sunglasses
16j = Put on/remove/adjust seat belt
16k = Put on/remove/adjust hat
17 = Look at or handle Driver Fatigue Monitor (DFM)
18 = Look at or handle Data Acquisition System (DAS) (e.g., in-vehicle camera)
20 = Other potentially distracting behavior

1.5 Road and Lane Characteristics

Available Maneuvering Room
Left (availability of room for the driver to move to the left)
01 = Adjacent lane: opposite direction
01a = Adjacent lane: opposite direction, cones/barrels present
02 = Adjacent lane: same direction, vehicle present
02a = Adjacent lane: same direction, no vehicle present
02b = Adjacent lane: same direction, cones/barrels present
03 = No adjacent lane – available shoulder or median: narrow
04 = No adjacent lane – available shoulder or median: medium
05 = No adjacent lane – available shoulder or median: wide
06 = No adjacent lane – boundary: jersey barrier
07 = No adjacent lane – boundary: guardrail
07a = No adjacent lane – boundary: curb

Right (availability of room for the driver to move to the right)
08 = Adjacent lane: opposite direction
08a = Adjacent lane: opposite direction, cones/barrels present
09 = Adjacent lane: same direction, vehicle present
09a = Adjacent lane: same direction, no vehicle present
09b = Adjacent lane: same direction, cones/barrels present
10 = No adjacent lane – available shoulder or median: narrow
11 = No adjacent lane – available shoulder or median: medium
12 = No adjacent lane – available shoulder or median: wide
13 = No adjacent lane – boundary: jersey barrier
14 = No adjacent lane – boundary: guard rail
14a = No adjacent lane – boundary: curb

Relation to Junction [GES A09]
Non-interchange area:
00 = Non-Junction
01 = Intersection
02 = Intersection-related
03 = Driveway, alley access, etc.
03a = Parking Lot

04 = Entrance/exit ramp
05 = Rail grade crossing
06 = On a bridge
07 = Crossover related
08 = Other, non-interchange
09 = Unknown, non-interchange

Trafficway Flow [GES A11]
00 = Not physically divided (center 2-way left turn lane)
01 = Not physically divided (2-way trafficway)
02 = Divided (median strip or barrier)
03 = One-way trafficway
09 = Unknown
Comment: GES variable changed in 2003.

Number of Travel Lanes [GES A12]
Note: If road is divided, only lanes in travel direction are counted. If undivided, all lanes are counted. Coded in relation to subject vehicle.
01 = 1
02 = 2
03 = 3
04 = 4
05 = 5
06 = 6
07 = 7+
09 = Unknown

Roadway Alignment [GES V A13]
Note: Code in relation to subject vehicle.
01 = Straight
02a = Curve right
02b = Curve left
09 = Unknown
Comment: GES V A13, with expansion of curve choices.

Roadway Profile [GES V A14]
Note: Code in relation to subject vehicle.
01 = Level
02a = Grade up
02b = Grade down
03 = Hillcrest
04 = Sag
09 = Unknown
Comment: GES V A14, with expansion of grade choices.

Roadway Surface Condition [GES A15]
01 = Dry
02 = Wet
03 = Snow or slush
04 = Ice
05 = Sand, oil, dirt
08 = Other
09 = Unknown

Lane Marker
Lane marker left:
01 = Solid
02 = Striped
03 = None

Lane marker right:
04 = Solid
05 = Striped
06 = None

Traffic Density
01 = LOS A: Free flow – Individual users are virtually unaffected by the presence of others in the traffic stream. Freedom to select desired speeds and to maneuver within the traffic stream is extremely high. The general level of comfort and convenience provided to the motorist, passenger, or pedestrian is excellent.

02 = LOS B: Flow with some restrictions – In the range of stable traffic flow, but the presence of other users in the traffic stream begins to be noticeable. Freedom to select desired speeds is relatively unaffected, but there is a slight decline in the freedom to maneuver within the traffic stream from level-of-Service A, because the presence of others in the traffic stream begins to affect individual behavior.

03 = LOS C: Stable flow, maneuverability and speed are more restricted – In the range of stable traffic flow, but marks the beginning of the range of flow in which the operation of individual uses becomes significantly affected by the interactions with others in the traffic stream. The selection of speed is now affected by the presence of others, and maneuvering within the traffic stream requires substantial vigilance on the part of the user. The general level of comfort and convenience declines noticeably at this level.

04 = LOS D: Unstable flow: temporary restrictions substantially slow driver – Represents high-density, but stable traffic flow. Speed and freedom to maneuver are severely restricted, and the driver or pedestrian experiences a generally poor level of comfort and convenience. Small increases in traffic flow will generally cause operational problems at this level.

05 = LOS E: Flow is unstable; vehicles are unable to pass, temporary stoppages, etc. – Represents operating conditions at or near the capacity level. All speeds are reduced to a

low, but relatively uniform value. Freedom to maneuver within the traffic stream is extremely difficult, and it is generally accomplished by forcing a vehicle or pedestrian to “give way” to accommodate such maneuvers. Comfort and convenience levels are extremely poor, and driver or pedestrian frustration is generally high. Operations at this level are usually unstable, because small increases in flow or minor perturbations within the traffic stream will cause breakdowns.

06 = LOS F: Forced traffic flow condition with low speeds and traffic volumes that are below capacity. Queues' forming in particular locations – This condition exists whenever the amount of traffic approaching a point exceeds the amount which can traverse the point. Queues form behind such locations. Operations within the queue are characterized by stop-and-go waves, and they are extremely unstable. Vehicles may progress at reasonable speeds for several hundred feet or more, then be required to stop in a cyclic fashion. Level-of-Service F is used to describe the operating conditions within the queue, as well as the point of the breakdown. It should be noted, however, that in many cases operating conditions of vehicles or pedestrians discharged from the queue may be quite good. Nevertheless, it is the point at which arrival flow exceeds discharge slow which causes the queue to form, and level-of-Service F is an appropriate designation for such points.

09 = Unknown/unable to determine

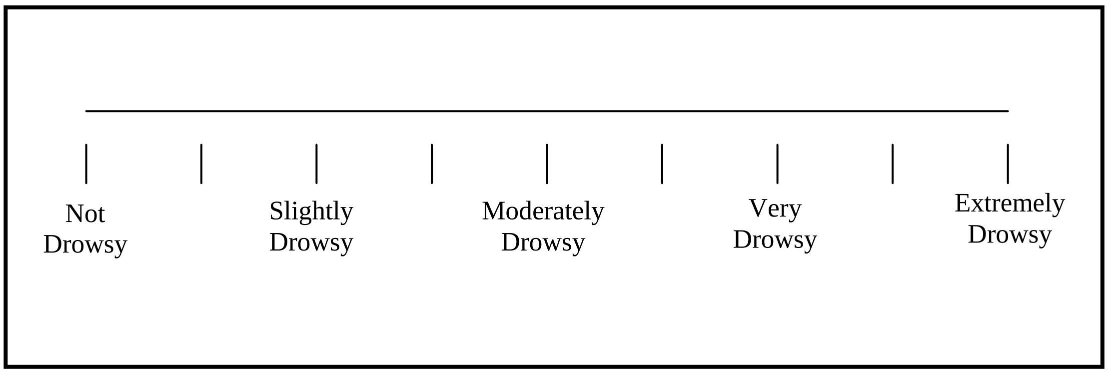
1.6 Vehicle Conditions

Location when alert issued
01 = Straight
02 = In curve
03 = Curve entry
04 = Curve exit
05 = Unknown

Maneuver
01 = Curve
02 = Going straight
03 = Lane change
04 = Merge
05 = Passing
06 = Turn
07 = Unknown

1.7 Alert Assessment

Pre-Alert ORD Classification
Analysts will rate each video segment by taking into account this description of the drowsiness continuum. However, if he/she feels that the below descriptions overlook something important or do not properly describe what is being viewed, then analysts will supplement the description with his/her own best judgment in making the rating. Analysts will review one minute of video prior to the onset of the trigger.



- **Not Drowsy:** A driver who is not drowsy while driving will exhibit behaviors such that the appearance of alertness will be present. For example, normal facial tone, normal fast eye blinks, and short ordinary glances may be observed. Occasional body movements and gestures may occur.

- **Slightly Drowsy:** A driver who is slightly drowsy while driving may not look as sharp or alert as a driver who is not drowsy. Glances may be a little longer and eye blinks may not be as fast. Nevertheless, the driver is still sufficiently alert to be able to drive.

- **Moderately Drowsy:** As a driver becomes moderately drowsy, various behaviors may be exhibited. These behaviors, called mannerisms, may include rubbing the face or eyes, scratching, facial contortions, and moving restlessly in the seat, among others. These actions can be thought of as countermeasures to drowsiness. They occur during the intermediate stages of drowsiness. Not all individuals exhibit mannerisms during intermediate stages. Some individuals appear more subdued, they may have slower closures, their facial tone may decrease, they may have a glassy-eyed appearance, and they may stare at a fixed position.

- **Very Drowsy:** As a driver becomes very drowsy eyelid closures of 2 to 3 seconds or longer usually occur. This is often accompanied by a rolling upward or sideways movement of the eyes themselves. The individual may also appear not to be focusing the eyes properly, or may exhibit a cross-eyed (lack of proper vergence) look. Facial tone will probably have decreased. Very drowsy drivers may also exhibit a lack of apparent activity and there may be large isolated (or punctuating) movements, such as providing a large correction to steering or reorienting the head from a leaning or tilted position.

- **Extremely Drowsy:** Drivers who are extremely drowsy are falling asleep and usually exhibit prolonged eyelid closures (4 seconds or more) and similar prolonged periods of lack of activity. There may be large punctuated movements as they transition in and out of intervals of dozing.

False Alarm Assessment (Pre-Alert ORD ≤ Slightly Drowsy)
Why was the event considered to be a false alarm? (analyst may choose up to four options):
00 = None observed
00a = Not applicable (Pre-Alert ORD > Slightly Drowsy)
01 = DFM not aligned properly
02 = DFM not working properly
03 = DFM is covered
04 = Too much driver head movement: looking out window(s)
05 = Too much driver head movement: eating/drinking
06 = Too much driver head movement: reading
07 = Too much driver head movement: talking to passenger
08 = Too much driver head movement: reaching for something inside cab
09 = Too much driver head movement: other
10 = Driver is not in the DFM's view (e.g., leaning against the door)
11 = Driver is not in the camera's view
12 = Driver is wearing glasses
13 = Too bright outside
14 = Traveling under streetlights
15 = Truck is traveling below 35mph
16 = Driver is not in the truck
17 = Truck is parked
18 = Bad video
19 = Other
20 = Unknown
21 = Not Applicable

False Alarm Annoyance (Pre-Alert ORD ≤ Slightly Drowsy)
Does the driver appear to be annoyed when the DFM alerts? If yes, what does he/she do? (analyst may choose up to four options):
00 = None observed
00a = Not applicable (Pre-Alert ORD > Slightly Drowsy)
00b = Not applicable (DFM in Dark Mode)
01 = Makes a face at the DFM
02 = Hits the reset button hard
03 = Hits the DFM
04 = Unplugs the DFM
05 = Covers up the DFM

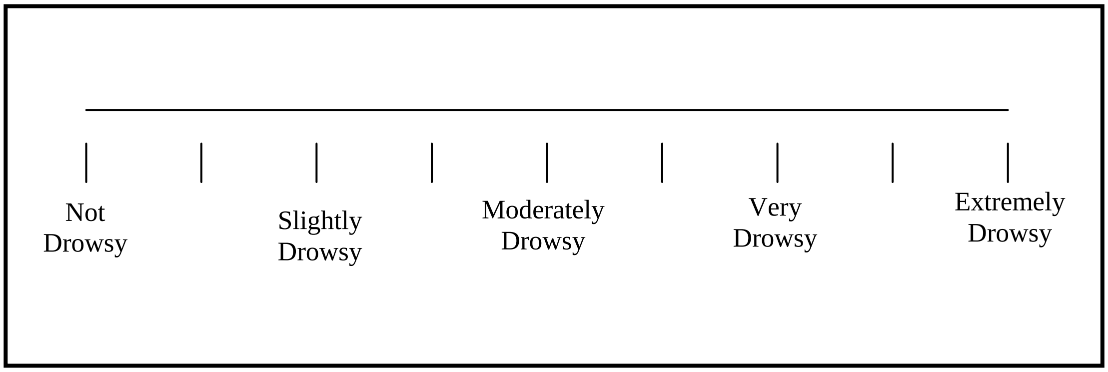
06 = Yells at the DFM
07 = Does not reset the DFM
08 = Other
09 = Not Applicable

Hit Assessment (Pre-Alert ORD ≥ Very Drowsy)
Drowsy Behaviors
What kind of drowsy behaviors does the driver show during the 1 minute prior to the alert? (analyst may choose up to four options):
00 = None observed
00a = Not applicable (Pre-Alert ORD < Very Drowsy)
01 = Yawns
02 = Heavy eyes
03 = Rubs face
04 = Nods off
05 = Shakes head
06 = Rubs face
07 = Slaps face
08 = Squirms in seat
09 = Rolls down window
10 = Turns on radio
11 = Falls asleep
12 = Smokes
13 = Other
14 = Not applicable

Alerting behaviors:
What kind of behaviors does the driver show during the 1 minute period after the alert? (analyst may choose up to four options):
00 = None observed
00a = Not applicable (Pre-Alert ORD < Very Drowsy)
00b = Not applicable (DFM in Dark Mode)
01 = Turns off alert and continued driving
02 = Ignores alert
03 = Shakes head
04 = Rubs face
05 = Slaps face
06 = Takes a drink
07 = Eats food
08 = Smokes
09 = Rolls down window
10 = Turns on radio
11 = Pulls over to the side of the road
12 = Other
13 = Unknown
14 = Not applicable

Post-Alert ORD Classification (conduct for all events)[1]

Analysts will rate each video segment by taking into account this description of the drowsiness continuum. However, if he/she feels that the below descriptions overlook something important or do not properly describe what is being viewed, then analysts will supplement the description with his/her own best judgment in making the rating. Analysts will review one minute of video after the onset of the trigger.



- **Not Drowsy:** A driver who is not drowsy while driving will exhibit behaviors such that the appearance of alertness will be present. For example, normal facial tone, normal fast eye blinks, and short ordinary glances may be observed. Occasional body movements and gestures may occur.

- **Slightly Drowsy:** A driver who is slightly drowsy while driving may not look as sharp or alert as a driver who is not drowsy. Glances may be a little longer and eye blinks may not be as fast. Nevertheless, the driver is still sufficiently alert to be able to drive.

- **Moderately Drowsy:** As a driver becomes moderately drowsy, various behaviors may be exhibited. These behaviors, called mannerisms, may include rubbing the face or eyes, scratching, facial contortions, and moving restlessly in the seat, among others. These actions can be thought of as countermeasures to drowsiness. They occur during the intermediate stages of drowsiness. Not all individuals exhibit mannerisms during intermediate stages. Some individuals appear more subdued, they may have slower closures, their facial tone may decrease, they may have a glassy-eyed appearance, and they may stare at a fixed position.

- **Very Drowsy:** As a driver becomes very drowsy eyelid closures of 2 to 3 seconds or longer usually occur. This is often accompanied by a rolling upward or sideways movement of the eyes themselves. The individual may also appear not to be focusing the eyes properly, or may exhibit a cross-eyed (lack of proper vergence) look. Facial tone will probably have decreased. Very drowsy drivers

[1] At the time this report was written, this variable was being checked for accuracy. VTTI will submit the results to the Volpe Center upon completion.

may also exhibit a lack of apparent activity and there may be large isolated (or punctuating) movements, such as providing a large correction to steering or reorienting the head from a leaning or tilted position.

- **Extremely Drowsy:** Drivers who are extremely drowsy are falling asleep and usually exhibit prolonged eyelid closures (4 seconds or more) and similar prolonged periods of lack of activity. There may be large punctuated movements as they transition in and out of intervals of dozing.

Manual PERCLOS Assessment
Manual PERCLOS assessment will be conducted for all 1000 events. The manual PERCLOS assessment will begin 3-min prior to the alert (or less if the video file does not have a 3-min pre-alert window), and end at the alert.

The tracks from the DFM and manual assessment will be plotted together and, based on the similarity of the two tracks; a subjective assessment will be made as to whether the alert was "valid", "potentially valid", or "invalid".

2.0 Analysis of DFM Alert Validity

A sample of 5,000 30-second epochs will be taken. For each of these 5,000 epochs, the PERCLOS value, from the DFM, at the end of the 30-second epoch will be identified. Additionally, an Observer Rating of Drowsiness (ORD) will be made. A detailed classification of these events will not be conducted (as in Section 1).

The following assessments will be made based upon the DFM value and the ORD assessment. DFM+ indicates an alert, DFM- indicates no alert. ORD+ indicates an ORD value of 5, ORD- indicates an ORD value <5.

1. Hit (DFM+, ORD+)
2. Nuisance/false alarm (DFM+, ORD-)
3. Miss (DFM-, ORD+)
4. Correct rejection (DFM-, ORD-).

The DFM output data and the ORD data will be tabulated (frequencies for each cross category) as shown in the example below.

Hypothetical DFM/ORD "Truth Table"

The following hypothetical data is for a DFM that is designed and calibrated to provide warnings to drivers in the highest 1 percent of drowsiness. ORD is assumed, in this analysis, to be a "gold standard" of alertness, and both the DFM+ percentage and ORD 5 percentages are assumed to be 1 percent.

	ORD 0 Not Drowsy	**ORD 25** Slightly Drowsy	**ORD 50** Moderately Drowsy	**ORD 75** Very Drowsy	**ORD 100** Extremely Drowsy	**TOTAL**
DFM + ($\geq$ 12%)	0.20%	0.10%	0.10%	0.08%	0.52%	1.0%
DFM - (< 12%)	81.80%	9.90%	4.90%	1.92%	0.48%	99.0%
TOTAL	82.0%	10.0%	5.0%	2.0%	1.00%	100.0%
Hit %					52.00%	52.00%
Nuisance / False Alarm %	0.24%	1.00%	2.00%	4.00%		0.48%
Correct Rejection %	99.76%	99.00%	98.00%	96.00%		99.52%
Miss %					48.00%	48.00%

Note in the above that, even though the nuisance/false alarm rate is very low (0.48 percent overall) and the correct rejection rate very high (99.52%), that 48 percent of alarms (DFM+) would be associated with ORD levels below 5, and also that 48 percent of ORD 5 episodes would be missed (i.e., DFM-).

APPENDIX AA: LIST OF DFM PROGRAM/SOFTWARE-RELATED PROBLEMS

DFM S/N	Truck #	Activating DFM	No output from DFM	Perclos values	Eyes found	Program damaged	Operating mode (Dark, Active)	Display mode (Standby, Active)	Sensitivity	Old software	Reason for repair	Repair by VTTI or ATI?
10121	7			X							The DFM program was not working correctly approximately 50 percent of the time (e.g., the driver was extremely tired, but the DFM produced very low numbers).	ATI
10123	No truck # (Repair was needed before installed in trucks)									X	The DFM was installed with an older program and therefore needed the latest program installed.	ATI
10123	3					X					The DFM program was most likely damaged by the speaker falling off and thereby exposing the microchip to sunshine (UV light), which most likely caused the DFM to remain in "Standby" status even at 60 MPH at night.	ATI
10123	3							X			The DFM program was most likely damaged by the speaker falling off and thereby exposing the microchip to sunshine (UV light), which most likely caused the DFM to remain in "Standby" status even at 60 mph at night.	ATI
10124	No truck # (Repair was needed before installed in trucks)									X	The DFM was installed with an older program and therefore needed the latest program installed.	ATI
10124	2			X							The Perclos value was not calculating correctly. Perclos values went back and forth among several values (8, 9, 10, 11). Perclos values came back to 0 gradually, instead of being reset, when the speed reached 35 mph.	ATI
10125	No truck # (Repair was needed before installed in trucks)									X	The DFM was installed with an older program and therefore needed the latest program installed.	ATI
10125	27						X				The DFM kept beeping during daytime even though it was in dark mode.	ATI
10126	No truck # (Repair was needed before installed to trucks)									X	The DFM was installed with an older program and therefore needed the latest program installed.	ATI
10127	No truck # (Repair was needed before installed in trucks)									X	The DFM was installed with an older program and therefore needed the latest program installed.	ATI
10132	32	X									The DFM kept turning on and off both when the truck ignition was turned on at the parking lot and when the truck was running over 35 mph at night.	ATI
10134	25				X						The DFM program demonstrated the "Eyes found" as 0 when the driver was facing toward the DFM camera in which case one or both eyes should be found.	ATI
10137	1			X							The Perclos value was not calculating correctly. The Perclos values were increasing when the vehicle was parked (the value should stay). Also, the values stayed steady, sometimes for over 45 min even though the driver moved around and appeared to be sleepy in video.	ATI
10138	1				X		X				The DFM operation mode remained in active mode even though the mode switch was set to dark. The signal from DFM remained in active mode and the word "Standby" was lit. No alarm was presented.	ATI
10138	23										The DFM program calculated the "Eyes found" as 0 when the driver was facing toward the DFM camera and one or both eyes should have been found.	ATI
10140	12			X							The DFM program was not working correctly; (i) Perclos was only reaching up to 2 or 3 percent.	ATI
10140	12				X						(i) the DFM program was not working correctly; (ii) the driver was not in the truck but the DFM detected 2 eyes periodically; (iii) when the DFM detected 0 eyes for a time period. Perclos values remained at 0.	ATI
10144	38					X					The DFM program was most likely damaged by the speaker falling off and exposing the microchip to sunshine (UV light), which most likely caused the DFM to remain in "Standby" status over 35 MPH at night.	ATI
10144	38							X			The DFM program was most likely damaged by the speaker falling off and exposing the microchip to sunshine (UV light), which most likely caused the DFM to remain in "Standby" status over 35 mph at night.	ATI
10144	No truck # (just returned from ATI for repair)		X								DFM could not produce any outputs.	ATI
10145	4								X		DFM program was malfunctioning; (i) the Sensitivity output included "3" when the outputs should be either 0, 1, 2 (for H, M, L); (ii) when DFM was in dark mode (low sensitivity), the output showed spikes of high sensitivity.	ATI
10145	36	X									The DFM could not be activated, e.g., no flashing of the IR sensor or no initial tone when the DFM received power via truck ignition.	ATI
10145	36		X								The DFM could not produce any output to the data collection system; therefore, no data was collected.	ATI
10147	2					X					The DFM program was erased, most likely because the speaker fell off and exposed the microchip to sunlight (UV light).	ATI
10158	Unknown (from uninstall)	X									The DFM could not be activated, e.g., no flashing of the IR sensor or no initial tone when the DFM received power via truck ignition.	ATI
10158	Unknown (from uninstall)		X								The DFM could not produce any output to the data collection system; therefore, no data was collected.	ATI
10159	34	X									The DFM kept turning on and off both when the truck ignition was turned on at the parking lot and when the truck was running over 35 mph at night	ATI
10159	2		X								The DFM did not produce any output to the data collection system.	ATI

	Total	Activating DFM	No output from DFM	Perclos values	Eyes found	Program damaged	Operating mode (Dark, Active)	Display mode (Standby, Active)	Sensitivity	Old software
Number of problems	28	4	4	4	3	3	2	2	1	5

APPENDIX BB: LIST OF DFM HARDWARE-RELATED PROBLEMS

DFM S/N	Truck #	Speaker	Rattle inside/loose screw	IR sensor in DFM camera	Ambient light sensor	DFM camera	Pin/cable	Hole size for button	OK button	Power	DFM display	Reason for repair	Repair by VTTI or ATI?
10121	No truck # (Repair was needed before installed in trucks)	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10122	No truck # (Repair was needed before installed in trucks)							X				The INFO button became stuck due to an inadequate size and location of the hole for the button.	ATI
10122	No truck # (Repair was needed before installed in trucks)	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10123	3	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	ATI
10123	No truck # (Repair was needed before installed in trucks)	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place	VTTI
10124	No truck # (Repair was needed before installed in trucks)	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10125	27		X									DFM had a rattle inside.	ATI
10125	1					X						DFM camera did not send signals to produce the view.	ATI
10125	No truck # (Repair was needed before installed in trucks)	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10125	1	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10125	No truck # (just returned from ATI)		X									DFM had rattle inside.	VTTI
10126	No truck # (Repair was needed before installed in trucks)	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10126	43	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10127	No truck # (Repair was needed before installed in trucks)	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10128	No truck # (Repair was needed before installed to trucks)	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10129	No truck # (Repair was needed before installed to trucks)	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10129	2		X									Screws to hold DFM camera became loose.	VTTI
10130	No truck # (Repair was needed before installed in trucks)	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10131	No truck # (Repair was needed before installed in trucks)	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10132	21						X					No warning sound was presented, although DFM data was collected.	ATI
10132	21			X								The length of the IR sensors flashing was inconsistent: some periods of flashing were longer than other periods.	ATI
10132	No truck # (just returned from ATI)						X					No warning sound was presented, although DFM data was collected.	ATI
10132	No truck # (just returned from ATI)			X								The length of the IR sensors flashing was inconsistent: some periods of flashing were longer than other periods.	ATI
10132	No truck # (just returned from ATI for repair)	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10132	No truck # (just returned from ATI)		X									DFM had a rattle inside.	VTTI
10133	45				X							The Ambient light sensor was mechanically damaged and produced the output as 0 (dark), therefore the DFM considered it was dark all the time and was active even during daytime.	ATI
10133	45		X									DFM had a rattle inside.	ATI
10133	10	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10133	10		X									DFM had a rattle inside.	VTTI

DFM S/N	Truck #	Speaker	Rattle inside/loose screw	IR sensor in DFM camera	Ambient light sensor	DFM camera	Pin/cable	Hole size for button	OK button	Power	DFM display	Reason for repair	Repair by VTTI or ATI?
10134	No truck # (Repair was needed before installed in trucks)			X								Half of the IR sensor lights stopped blinking.	ATI
10134	25					X						The view from the DFM camera became fuzzy and the driver's face could not be displayed through it.	ATI
10134	No truck # (Repair was needed before installed in trucks)	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10135	No truck # (Repair was needed before installed in trucks)			X								Half of the IR sensor lights stopped blinking.	ATI
10135	30			X								Half of the IR sensor lights stopped blinking.	ATI
10135	30		X									DFM had a rattle inside.	ATI
10136	9	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10137	No truck # (Repair was needed before installed in trucks)			X								Half of the IR sensor lights stopped blinking.	ATI
10137	1								X			The cover of the OK button came off.	VTTI
10138	21									X		DFM drew too much power, enough to shut down the main data collection system, therefore, none of the driving or DFM data was collected.	ATI
10138	No truck # (just returned from ATI)									X		DFM drew too much power, enough to shut down the main data collection system, therefore, none of the driving or DFM data was collected.	ATI
10139	2	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10140	No truck # (Repair was needed before installed in trucks)							X				The INFO button got stuck due to inadequate size and location of the hole for the button.	VTTI
10140	No truck # (Repair was needed before installed in trucks)	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10144	No truck # (just returned from ATI)				X							The ambient light sensor was broken.	ATI
10144	38	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10146	17					X						The view from the DFM camera was blurry.	ATI
10147	2	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10147	22								X			The switch for the OK button became loose and unattached from the DFM.	VTTI
10147	22		X									DFM had a rattle inside.	VTTI
10151	21				X							The ambient light sensor fell off of the DFM.	VTTI
10155	No truck # (Repair was needed before installed in trucks)	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10159	2			X								None of the IR sensors were flashing.	ATI
10159	2										X	The display "Standby" was not lit even during the Active mode.	ATI
10159	No truck # (just returned from ATI for repair)	X										Speaker fell off due to type of glue (hot glue); applied two-port epoxy glue to keep it in place.	VTTI
10159	No truck # (just returned from ATI for repair)							X				The OK button became stuck at the hole.	VTTI
10159	No truck # (just returned from ATI for repair)								X			The LED was unplugged inside of the DFM, and a part of the LED was stuck to the bottom.	VTTI
10160	Used for driver screening				X							The ambient sensor was not working correctly and the light level was considered as dark even during the daytime.	ATI
10160	10						X					Pin 8 in the cable was not working, therefore the DFM could not produce the LED signal to the additional IR sensor	ATI

	Total	Speaker	Rattle inside/loose screw	IR sensor in DFM camera	Ambient light sensor	DFM camera	Pin/cable	Hole size for button	OK button	Power	DFM display
Number of problems	58	24	8	7	4	3	3	3	3	2	1

APPENDIX CC: LIST OF TECHNICAL PROBLEMS ENCOUNTERED WITH ACTIGRAPH WATCH

	No or partial data collected: Watch could not interact with software	No or partial data collected: Watch status changed to "Asleep" or "Delaying" instead of "Taking data"	No or partial data collected: Data with wrong dates collected	No or partial data collected: Data collected only first few days	**Total # of "No or Partial data collected"**	**Watch could not be initialized**	**Battery runtime hour decreased or 0**	**Watch physically damaged**	**Total**
Number of old watches	10	4	2	0	**16**	**21**	**2**	**6**	**45**
Percentage*	66.7%	50.0%	66.7%	0.0%	**57.1%**	**87.5%**	**28.6%**	**60.0%**	**65.2%**
Number of new watches	5	4	1	2	**12**	**3**	**5**	**4**	**24**
Percentage*	33.3%	50.0%	33.3%	100.0%	**42.9%**	**12.5%**	**71.4%**	**40.0%**	**34.8%**
Subtotal (Old and New watches)	15	8	3	2	**28**	**24**	**7**	**10**	**69**
Percentage**	21.7%	11.6%	4.3%	2.9%	**40.6%**	**34.8%**	**10.1%**	**14.5%**	**100.0%**

*Percentages under Old and New watches are the percentages under the particular reason for returning watch. For example, 10 old (66.7%) and 5 new (33.3%) watches were returned due to "Watch could not interact with software."

**Percentages under Subtotal (both old and new watches) are the percentages under the particular reason for returning the watch. For example, 15 watches (21.7%) were returned due to the reason of "Watch could not interact with software." Old and New watches are the percentage under the particular reason for returning watch. For example, 10 old (66.7%) and 5 new (33.3%) watches were returned due to "Watch could not interact with software."

Serial Number	Received from Volpe or AMI	Old or New Watch	No or partial data collected: Watch could not interact with software	No or partial data collected: Watch status changed to "Asleep" or "Delaying" instead of "Taking data"	No or partial data collected: Data with wrong dates collected	No or partial data collected: Data collected only first few days	Watch could not be initialized	Battery runtime hour decreased or 0	Watch physically damaged	Return Explanation	Returned to AMI/Volpe
635	3/27/2004	Old	X						X	Damaged by water, could not interact with software.	8/6/2004
688	9/1/2004	Old	X							Could not download after successful initialization (after status became "taking data").	10/4/2004
777	3/27/2004	Old		X						Status became "Asleep" and the unit did not collect data after successful initialization.	2/22/2005
858	9/30/2004	Old			X				X	Had a rattle; dates on the actigraph data not correctly recoded after successful initialization.	2/9/2005
989	4/28/2004	Old	X							Could not download data after successful initialization.	9/16/2004
993	3/27/2004	Old					X			Could not be initialized; header information could not be downloaded.	3/30/2004
993	4/28/2004	Old					X			Could not be initialized; header information could not be downloaded.	5/5/2004
1006	9/1/2004	Old					X			Could not be initialized; header information could not be downloaded.	9/9/2004
1057	3/27/2004	Old					X			Could not be initialized; header information could not be downloaded.	3/30/2004
1057	4/28/2004	Old					X			Could not be initialized; header information could not be downloaded.	5/5/2004
1081	4/28/2004	Old	X						X	Had a rattle; lost data because it could not interact with software.	9/16/2004
1085	4/28/2004	Old					X			Could not be initialized; header information could not be downloaded.	9/2/2004
1150	4/28/2004	Old	X				X			Could not download data or could not be initialized.	9/9/2004
1220	9/1/2004	Old		X						Status became "asleep" after a successful initialization from the previous meeting (could not download data); Battery run time reduced to 432.	1/24/2005
1230	9/1/2004	Old	X							Could not download data after successful initialization.	10/4/2004
1232	4/28/2004	Old					X			Able to download header but could not initialize after multiple attempts.	5/5/2004
1232	9/15/2004	Old					X			Able to download header but could not initialize after multiple attempts.	9/16/2004
1232	9/21/2004	Old			X				X	Had a rattle; took data with wrong dates.	1/17/2005
1266	4/28/2004	Old					X			Could not be initialized.	8/6/2004
1299	4/28/2004	Old					X			Could not be initialized; header information could not be downloaded.	9/2/2004
1299	9/9/2004	Old	X							Could not download data after successful initialization.	10/4/2004
1300	9/9/2004	Old					X			Could not be initialized.	9/16/2004
1374	3/27/2004	Old					X			Could not be initialized; header information could not be downloaded.	9/2*2004
1409	3/27/2004	Old		X				X		The watch had no data. The status kept reporting "Delaying" after a successful initialization.	1/19/2005
1483	3/27/2004	Old	X							Could not download data after successful initialization.	10/21/2004
1556	3/27/2004	Old	X						X	Damaged by water, could not interact with software.	8/6/2004
1806	4/12/2008	New	X						X	Could not download data because the clock plate with 2 holes was twisted and the interface could not communicate with the 2 sensors located inside of the unit.	5/31/2005
1850	3/27/2004	Old					X			Could not be initialized; header information could not be downloaded.	3/30/2004
1850	4/28/2004	Old					X			Could not be initialized; header information could not be downloaded.	5/5/2004

Serial Number	Received from Volpe or AMI	Old or New Watch	No or partial data collected: Watch could not interact with software	No or partial data collected: Watch status changed to "Asleep" or "Delaying" instead of "Taking data"	No or partial data collected: Data with wrong dates collected	No or partial data collected: Data collected only first few days	Watch could not be initialized	Battery runtime hour decreased or 0	Watch physically damaged	Return Explanation	Returned to AMI/Volpe
1851	5/13/2004	Old					X			Could not be initialized; header information could not be downloaded.	9/2/2004
1851	9/9/2004	Old					X			Could not be initialized; header information could not be downloaded.	9/16/2004
1851	9/21/2004	Old					X			Could not be initialized with 3 different interface units; header information could not be downloaded.	10/4/2004
1852	4/28/2004	Old					X			Showed "Asleep" status and could not be changed to "taking data" on initialization.	6/18/2004
1870	3/27/2004	Old		X				X		Data could not be downloaded and showed "Asleep" status; was able to initialize but battery runtime hour was 0 h.	12/2/2004
1875	3/27/2004	Old					X			Could not be initialized; header information could not be downloaded.	3/30/2004
1875	4/28/2004	Old					X			Could not be initialized; header information could not be downloaded.	5/5/2004
1885	5/13/2004	Old							X	Had a rattle.	9/16/2004
2195	6/7/2005	New	X						X	Could not be initialized. The cover of the unit and the clock plate must have been removed due to discovered scratches on the faceplate. Lost 15 days worth of data (6/29 to 7/13).	7/14/2005
2778	10/4/2004	New					X	X		Could not change the status from "Asleep" to "Taking Data" after initialization; battery replacement to a new one resulted in "Low Battery" warning; manual reset for battery did not work.	10/21/2004
2794	10/4/2004	New							X	There was a crack on the side.	12/16/2004
2857	12/16/2004	New	X							Data could not be downloaded (tried 4 times with 2 different interfaces and 2 cables). The unit should have 23 days worth of data (7/8/05 to 7/31/05).	8/8/2005
2917	10/4/2004	New					X	X		Status could not be changed to "Taking Data" on initialization, instead, became "Asleep."	1/17/2005
2924	10/4/2004	New		X		X		X		The status became "Asleep," A "Low Battery" status was presented even though the Battery Runtime hour was just over 2700. It stopped taking data on the 8th day and did not collect data for the past 2 weeks.	3/10/2005
3058	10/25/2004	New		X						The status became "Asleep" on downloading data. The unit had data from 4/1 to 4/18/2005. Battery Runtime hour decreased.	4/18/2005
3139	2/14/2005	New		X						Data could not be downloaded. The status stayed "Asleep" and never became "Taking data" after initialization. Lost data from 3/16/05 to 4/5/05 (21 days).	4/14/2005
3139	5/11/2005	New			X					No data was collected after a successful initialization on 7/11/05. The unit was initialized on 6/19/05 and downloaded and re-initialized on 7/11/05. Upon downloading data on 8/2/05, the range of data was from 5/27/05 to 6/19/05. The battery runtime hour was 1422 on 7/11/05 but it became 943 on 8/2/05. Lost data for 22 days (7/11/05 - 8/2/05).	8/8/2005
3335	2/2/2005	New				X		X		Low battery status at a battery runtime hour of 1257. Initialized on 3/14/2005 with the battery runtime hour of 1029. When downloaded on 4/5/05, the unit collected data for the first 9 days but did not for the next 13 days. AMI suggested returning the unit rather than VTTI replacing the battery.	4/14/2005
3347	2/2/2005	New	X							Not able to download data or header information.	3/22/2005
3414	3/29/2005	New	X							Not able to download data or header information.	6/7/2005
3470	4/21/2005	New		X						Status became "Asleep" after successful initialization; lost 18 days worth of data (6/1 to 6/17/05); Battery runtime hour became 0. Able to download datafile, but it was empty.	6/22/2005
3483	4/21/2005	New	X							Not able to interact with the interface or software after a successful initialization. Data might have been lost.	8/30/2005
3486	4/21/2005	New					X			It took 3 attempts to download 2 weeks worth of data, but it could not be initialized and was stuck at the downloading stage of "sending header information" during the initialization process.	6/22/2005
3563	6/29/2005	New						X		Data was downloaded but on initialization the battery runtime hour showed 0.	8/8/2005
3581	6/29/2005	New							X	Had a crack on the side of the unit.	8/30/2005

DOT HS 811 035
September 2008

U.S. Department
of Transportation

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