



# NATIONAL SURFACE TRANSPORTATION SAFETY CENTER FOR EXCELLENCE

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The National Surface Transportation Safety  
Center for Excellence

## Message From the Director

**Dr. Tom Dingus**



As we end the second year of the National Surface Transportation Safety Center for Excellence at the Virginia Tech Transportation Institute, it serves us well to reflect on the successes and challenges we have faced as a Center and Institute.

The National Surface Transportation Safety Center for Excellence (NSTSCE) was formally awarded to VTTI through the Federal Highway Administration (FHWA) in July 2006. We owe Senator John Warner, now retired, a debt of gratitude as he was instrumental in designating VTTI as a Center for Excellence in the 2005 transportation bill titled Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU).

In year two we have proven the value of the NSTSCE stakeholders model whereby federal and state agencies as well as industry have provided multi-year funding commitments due to a shared vision of a safer national transportation system. We would like to thank the FHWA, the Virginia Department of Transportation, the Virginia Transportation Research Council, the General Motors Corporation and Virginia Tech for continued support and to welcome the Federal Motor Carriers Safety Administration as a likely new stakeholder. Our stakeholders make it possible for NSTSCE to make a significant difference in transportation safety well into the future far beyond the initial SAFETEA-LU designation. In fact, the initial investment made by the federal designation has been returned nearly 10-fold as additional safety research funding awarded approaches \$10 million.

In terms of research results, in just two short years we have already made a positive impact on transportation safety. NSTSCE research results are beginning to lead to enhanced technology developments as engineers work to translate research findings into transportation safety applications. For instance, NSTSCE's support in studying commercial driver fatigue has led to a field operational test examining the impact of new driver monitoring and safety technologies. This study will put 250 drivers on the road to collect driving data. Data from this study will allow researchers not only to evaluate current safety technologies but also to use the data to explore other transportation safety applications and countermeasures for many years to come.

NSTSCE research results are also providing insights into transportation safety policies and informing policy makers as they decide legislation. NSTSCE funding has seeded programs to research special driving populations such as older drivers, teen drivers, and motorcycle riders. One example of a national transportation safety concern is the growing issue of texting while driving. NSTSCE researchers provided testimony of their findings before the Virginia General Assembly's Joint Commission on Science and Technology which most assuredly led to tighter restrictions on the use of communication devices while driving.

While research programs such as NSTSCE continue to make significant inroads to improving transportation safety, there are still many miles to go. We are continuing to answer the Nation's call for safer highway and transportation systems. And we will need continued support.

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## Mission of the Center

The mission of NSTSCE is defined as using state-of-the-art facilities, including the Virginia Smart Road, to develop and test transportation devices and techniques that enhance driver performance, examine advanced roadway delineation and lighting systems, address age-related driving issues, and address fatigued driver issues.

NSTSCE's vision is to become recognized as The National Center for Surface Transportation Safety, make a significant impact in improving surface transportation safety, and leverage partnership and sponsor relationships to disseminate results.

NSTSCE has formed a stakeholders' committee comprised of organizations that share our vision for improving road user safety both locally and across the nation. Initially, the Stakeholders' Committee members are Carl Andersen, Federal Highway Administration (FHWA); Tom Dingus, VTTI; Rich Deering, General Motors Corporation (GM); and Gary Allen, Virginia Department of Transportation (VDOT) and Virginia Transportation Research Council (VTRC). The role of stakeholders is to provide direct funding to NSTSCE, input to research direction, and oversight of research results. NSTSCE's approach is to build on VTTI's strengths and capabilities to make a measurable impact in road-user safety. NSTSCE uses a synergistic approach across the four research focus areas to maximize resources. These research focus areas include developing and testing transportation devices and techniques, examining advanced roadway delineation and lighting systems, addressing age-related driving issues, and addressing fatigued driver issues. VTTI, through NSTSCE, will analyze existing datasets to answer questions where possible. Building upon existing naturalistic driving databases (e.g., the 100-Car Naturalistic Driving Study), researchers will develop experiments and collect additional data to answer questions where needed. Additionally, VTTI continues to further develop its strengths and capabilities in transportation safety research.

## Goals of the Center

In order to satisfy the mission of NSTSCE, the stakeholders and the research team have developed overarching strategic goals and specific focus area goals. These goals are designed with the purpose of improving road-user safety using an integrated and dynamic approach. Each goal is further described by a roadmap for achieving these goals. Partnerships with relevant agencies and industries are a critical component to achieving maximum impact of NSTSCE, thus each specific focus area lists potential research partners. Note that it is assumed that the stakeholders are partners in each project. While the primary mission of NSTSCE is transportation safety research and development, all stakeholders and researchers will work to optimize outreach and technology transfer opportunities.

### Goal 1:

Identifying age-related deficiencies in driving performance and developing methods and countermeasures to mitigate the associated risks.

### Goal 2:

Understanding the role fatigue plays in crashes of both heavy and light vehicles and developing and evaluating countermeasures to reduce fatigue-related traffic incidents.

### Goal 3:

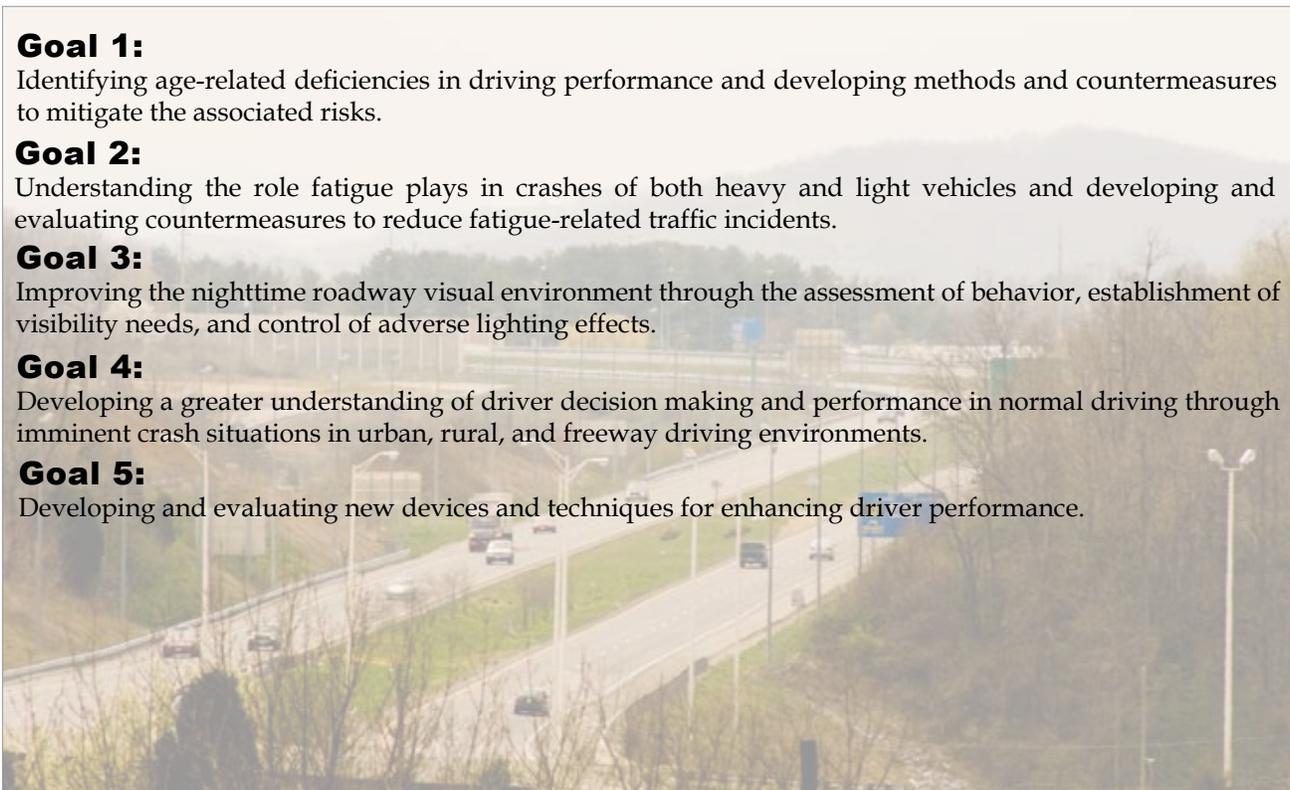
Improving the nighttime roadway visual environment through the assessment of behavior, establishment of visibility needs, and control of adverse lighting effects.

### Goal 4:

Developing a greater understanding of driver decision making and performance in normal driving through imminent crash situations in urban, rural, and freeway driving environments.

### Goal 5:

Developing and evaluating new devices and techniques for enhancing driver performance.





## Role of Stakeholders

NSTSCE stakeholders are comprised of organizations that derive direct benefit from the work to be performed by NSTSCE. Stakeholders provide direct funding to NSTSCE, provide input to research direction, and serve as overseers of research results. The Center's AOIR, Carl Andersen, serves as the chair of the Stakeholders' Committee. Initial Stakeholders' Committee members are Tom Dingus, VTTI; Rich Deering, General Motors Corporation; and Gary Allen, VDOT and VTRC. Each of these members provides additional funding for NSTSCE research. The Stakeholders' Committee is joined by research partners from industry and federal and state governments that are willing to provide additional funding for specific research projects.

With input from the Stakeholders' Committee and other experts, VTTI continually reviews surface transportation safety research needs. VTTI incorporates strategic research needs in developing potential transportation safety projects. A prioritized list of potential projects and a multi-year strategic plan are presented to the Stakeholders' Committee. The plan strives to coordinate NSTSCE research efforts with those of FHWA and other federal research programs. The Stakeholders' Committee will review and approve the strategic plan. Once the plan is approved, the potential research project list will serve as input to the next stage, project planning.

## Marketing Approach

NSTSCE subject matter experts and project managers accelerated NSTSCE marketing and outreach efforts in the second full year of NSTSCE. Research entities with similar transportation safety goals were targeted. An overarching strategy continues to be to seek out representation from primary research areas in transportation safety as well as to draw membership from a proportionate mix of industry, state, and federal agencies.

As a result of sharing preliminary results from NSTSCE and heightened awareness about the NSTSCE program, Federal Motor Carrier Safety Administration will likely participate as a stakeholder.

NSTSCE representatives attended several conferences and workshops to garner interest in stakeholder participation and to disseminate NSTSCE research results.

- Several NSTSCE researchers participated in relevant Transportation Research Board workshops and meetings. VTTI/NSTSCE researchers serve as TRB committee members within primary research areas.
- NSTSCE researcher testified about the dangers of texting while driving before the state legislative subcommittee.
- NSTSCE researchers presented at the 4th International Conference on Traffic and Transportation Psychology.
- NSTSCE researchers moderated a panel at the Driver Metrics Workshop.
- NSTSCE researchers presented at the 1st International Symposium on Road Surface Photometric Characteristics.
- Several NSTSCE researchers participated in the Illuminating Engineering Society meeting.

## Outreach Strategy

While research and technology development are the primary goals of NSTSCE, the stakeholders and research team understand the importance of disseminating the results to the surface transportation research community and the public as a whole. While NSTSCE and its research programs are products of the entire team and are meant to stand on their own merits, creation of an independent identity for NSTSCE will provide a focal point for the public, policy makers, and the research community, and thereby improve access and dissemination of research results.

## Outreach Accomplishments

- A project presentation was made at the Driver Metrics Workshop in San Antonio, TX, and will result in a publication. Dr. Miguel Perez presented on the Distraction Index project.
- Dr. Jon Antin has made contact with the following organizations to recruit project involvement and possible NSTSCE stakeholdership: AARP, Allstate Insurance, Virginia Tech's Institute for Critical Technology and Applied Science (ICTAS), Insurance Institute for Highway Safety (IIHS), NHSTA, and a private company potentially interested in proprietary work.
- Jason Meyer did a poster presentation on "Development and Validation of a Luminance Camera" in November 2008 at the Illuminating Engineering Society Annual Conference in Savannah, GA.

## The NSTSCE Human Factors Symposium

The first bi-annual NSTSCE Human Factors Symposium: Naturalistic Driving Methods & Analyses was held August 26-27, 2008. The event was well received and drew 130 speakers and participants from across the world representing the following countries: Japan, Canada, Germany, and The Netherlands. Select comments from the participants include:

- "Good conference overall. Videos were especially compelling."
- "I thought this was one of the best conferences I've attended."
- "Consider a bit more balance toward application of research in the real world."

All presentations were posted to the NSTSCE website for participants to download as needed.



## Outreach Goals: Publication Analysis

Numerous publications were submitted to scientific agencies and journals during 2008, and several fresh observations are presently under research analysis to create additional publications. Resulting analyses and publications currently focus on naturalistic driving data while also addressing the foundational concerns of NSTSCE: age-related driving issues, fatigue, lighting and infrastructure, and driver performance. Utilizing the largest repository of naturalistic driving data in existence, this project is focused on the development of an inclusive data mining, analysis, and publication plan. VTTI's metadata collection of over 35 terabytes (TB) includes datasets from several large-scale studies and encompasses heavy- to light- vehicle naturalistic driving in rural and urban locals. These data are examined under all relevant perspectives for identified events and driving behavior to further interpret causal/associative factors.

# Safety Devices and Techniques that Enhance Driver Performance

## Modeling Crash Data 100-Car

The 100-Car Naturalistic Driving Study (released in 2006) was able to provide new levels of detail in naturalistic driving research with its database of nearly 7 TB of information. The data continues to provide a wealth of information for transportation research, with many opportunities for reanalysis for new discoveries about driver behavior. However, in order to conduct subsequent analyses on over 42,000 hours of driving data, new information must be obtained.

The objective of the 100-Car Study reanalysis project was to obtain information about each data file that is not available in the 100-Car dataset but would be useful to researchers in subsequent data analyses. Specifically, it was designed to provide information for all 100-Car data files including who was driving the vehicle, whether the driver wore a seat belt, whether the driving occurred during the day or night and which, if any, video views were missing. This project has also allowed researchers to assign identification numbers to new secondary drivers. This supplemental information will strengthen many of the secondary analyses of this data and allow for more accurate estimates of exposure and risk.

During the 2008 reporting year, reviews of all trip files were completed (approximately 187,350 readable data files). Accuracy assessments and data validation are currently in progress and are expected to be complete this quarter. Over 200 new secondary drivers have been identified during this project, bringing the total number of drivers to over 400. A preliminary look at the reanalysis reveals that 74 percent of trips occur during the day (including dawn and dusk). The remaining 26 percent occur at night. Drivers are recorded as wearing a seatbelt in 78 percent of trip files. Other secondary calculations that will be possible using these data include exposure and risk based on age/gender and miles/time driven.

NHTSA has expressed an interest in mining the data that result from this reanalysis to examine seatbelt usage and the factors that affect a driver's decision to wear or not wear a seatbelt, especially among "occasional" seatbelt wearers. A preliminary assessment categorized 15 of the 106 primary drivers as occasional users, and these will be compared to consistent and resistant users. Occasional use is defined as wearing a seatbelt in 25 to 75 percent of trips. A contract is expected to be awarded for this work in spring 2009.

## Bayesian Model for Naturalistic Driving Study

The safety outcomes of naturalistic study data are typically classified as crash, near crash, critical incident, and baseline event. In classical statistical paradigm, the Generalized Linear Model (GLM) is widely used but lacks the ability to incorporate information from previous studies or expert opinions. Bayesian method can conveniently address those issues.

A literature review for Bayesian method in traffic safety study was conducted. The data from the NSTSCE Modeling 100-Car project were used in the initial model fitting. The Markov Chain Monte Carlo method was used to simulate the posterior distribution of odds ratio.



## Distraction Index

Progress in the Distraction Index project consisted primarily of the development and testing of advanced event detection techniques. These techniques were tested in experimental form and supported two different analysis approaches with two diverse goals. Some analysis techniques will be used to identify events and observe how they are affected by instances of infotainment system use. Another set of analysis techniques will be used to identify particular instances of system use and observe if and when they lead to driving events of interest. The difference between these approaches is that the events in the latter don't have to be detected pre-analysis, which may yield a richer set of events than otherwise available (e.g., due to missed events when event detection is required). To aid in the reduction of confounding factors, events of interest may be classified based on factors such as complexity of the interaction and the driving environment in which it occurs.



The project was highlighted at the most recent Driver Metrics Workshop, held in San Antonio, TX, during summer 2008. As a result of this presentation, a manuscript was generated expanding on some potential

applications of naturalistic data as they relate to the project's goal. That manuscript has been accepted for publication as part of a book compiled by the Society of Automotive Engineers (SAE).

The next year will see completion of tests of both analysis approaches described above and analyses of epochs identified through both of these approaches. These analyses will yield the final results for the project and ideas for further research.

## Privacy's Impact on Emerging Safety Technology

Public safety versus personal privacy in transportation policy has become a timely issue. A major driving force behind this issue is the potential for a host of new and emerging technologies in transportation could have on personal privacy. The usage of imaging technology, for example, is an evolving application that poses questions regarding the appropriate use, legality, system management, and public and political acceptance. This project objective is to help define the scope and nature of the issue, address reasons for acceptance or objection and look for common ground to ensure legal and desirable safety-related deployments. VTTI's analysis will span the full range of technical, social, legal and political issues. While this project has the goal of examining privacy, it has multiple objectives. Generally, it is inventorying and defining the characteristics that comprise the concept of "privacy" in transportation applications. Once the first phases are complete, the team is going to focus on potential transportation safety applications of emerging technologies and their impact on privacy.

In the past year the research team has completed a number of tasks that will lead to the successful completion of this study. A research team was assembled consisting of Principal Investigator and Team Leader Ray Pethel, Leslie Bellas, Esq., General Council for the Intelligent Transportation Society of America (ITSA), Jim Phillips Esq., Director, Conflict Resolution Institute L. Douglas Wilder School of Government and Public Affairs, Virginia Commonwealth University, and Gene Hetherington, MPA, Graduate Research Assistant. Each member performed a preliminary search of the current body of literature in their specialty as it relates to privacy. This led to the development of a set of primary questions that needed to be addressed in the course of the study.

Since technology plays a fundamental role in this study the team felt there was a need develop of a survey of ITSA's membership inquiring what technologies they were involved with and how it related to personal privacy. The survey was developed during the November through January time frame and administered to

the membership on February 6, 2009. The survey is currently in the data collection phase with data analysis is scheduled to begin around the 2nd or 3rd week of March.

Simultaneously, with the survey work the team has continued with the research tasks of the project. Team members based in Washington D.C. (Leslie Bellas) have contacted the appropriate members of government and the academic community to collect information and data such as any pending federal legislation or NGO initiatives that deal with privacy. Jim Chapman is creating a document that will comprehensively illustrate the privacy legal environment at the state level. VTTI team members are concentrating on investigating all current and emerging technologies that might prove relevant to personal privacy. The data is being organized so it can be readily cross referenced with the responses of the ITSA membership survey.

### **Data Mining of the Independence by Franklin Intersection**

The purpose of this study is to investigate the factors related to red-light intersection violations at three signalized intersections in the New River Valley. This is being accomplished by mining an existing database that was collected as part of the Cooperative Intersection Collision Avoidance System for Violations (CICAS-V) project.

The database includes two months of continuous intersection approach data measured by roadside data acquisition equipment. The equipment recorded kinematic information for each vehicle along with corresponding signal phase information at a 20 Hz rate. As part of the CICAS-V project, vehicles that violated



the traffic signal were identified. These violating vehicles then underwent a manual validation and reduction process to extract additional data from the video stream.

The present study is performing the next step by extracting a comparative set of baseline intersection approaches. The data analysis is focused on identifying factors that are related to the likelihood of violation at the three intersection sites. In addition, within the two-month data collection 2,057 straight crossing path violations were found at the Independence by Franklin intersection. This violation frequency is higher

than was identified at the other two collection sites (630 at Depot by Franklin and 797 at Pepper's Ferry by Franklin). An additional goal of this project is to investigate the potential causes of the higher rates of violation at the Independence by Franklin intersection.

Depending on the outcome of this effort, an intersection treatment to reduce the number of violations at the Franklin Intersection may be identified. A proposal for a second phase centered on implementation of the treatment would then be drafted. The second phase would include reinstating the collection system and conducting a before/after comparison of violation frequency.

### **Method for Extracting Rural Driving**

The primary objective of the Method for Extracting Rural Driving work was to develop data mining methods for locating rural driving from within large naturalistic driving datasets. The developed methods integrate Geographic Information Systems (GIS), database, and numerical processing tools to classify location-based data according to categorical variables of interest. By employing the functionality of GIS, code was written to allow for an automated process to compare the Global Positioning System (GPS) data recorded in the naturalistic driving data with geographic map data from the U.S. Census Bureau and road data from various sources, such as state departments of transportation (e.g., Virginia Department of Transportation) or other providers. Points recorded in the naturalistic driving data which fall outside the boundaries of the Census Bureau's urbanized areas or urban clusters are determined to be rural. The points are further evaluated to determine whether or not the vehicle was being driven on an interstate highway. Points that are determined to be rural and not on

interstate highways are segments of interest in addressing the rural road crash problem. The method is easily adapted to address other variables of interest that could be tied to geospatial locations and to look at other vehicle-based measures present. Specifically, various multivariate query and visualization techniques are also possible, such as combining location-based data mining with additional measures, such as speed, travel time, and travel direction. This type of adaptability is already being exercised in the follow-on work, which is exploring driving behavior in high-crash areas on Virginia roadways.

### **Driver Behavior in Crash Hot Spots and Rural Areas**

Methods developed during the Method for Extracting Rural Driving project will be used in this project to locate cases of drivers passing through high crash rate locations, also referred to as “Hot Spots,” as well as to study drivers on rural roads. The objective of the present task is to identify contributing causes of crashes in these two types of areas, and to identify potential countermeasures.

Work progressed in two areas during 2008. General GIS methods were pursued including work to integrate additional data sources with naturalistic data. These data sources include roadway inventories as well as a commercial roadway database product describing roadway data for the lower 48 states. Additionally, the server which will be used for this analysis was installed and is undergoing evaluation to determine the optimal setup for datamining of the type needed in this investigation.

During the next year, the server configuration will be determined, it will be configured, and software specific to geospatial datamining will be installed. Work will also be done to define research questions which address hot spots which are not found in rural areas. This effort will be performed in a similar manner to previous literature review and question formulation which emphasized rural road issues.

### **Naturalistic Observation of Motorcycle Riders**

Motorcycle fatalities and injuries have been increasing over the last 10 years, a period during which those same measures of transportation safety have been decreasing for other vehicle types. The objective of this project is to develop naturalistic data collection capabilities for motorcycles in support of research efforts to develop countermeasures to reverse this trend. While much of the equipment used for light- and heavy-vehicle research can be used on motorcycles, a number of modifications are necessary for successful implementation on motorcycles. These modifications are primarily due to:

- Smaller available package space for sensors and the DAS,
- Exposure of sensors, cameras, and the data acquisition system to weather (rain, cold, heat, wind, etc.),
- More significant roll than cars and trucks, which creates more complex dynamics and may affect sensors such as radar and lane tracker,
- Harsher vibrations, and
- Greater electro-magnetic sensor interference both from the DAS itself and from the bike ignition system.



Once a DAS and sensor suite is developed for motorcycle use, it will be tested on a small number of motorcycles and the data will be analyzed to estimate the value of conducting a large-scale motorcycle naturalistic data collection.

During this reporting period, instrumentation of the test platform bike continued. Testing included reviewing radar output for feasibility and establishing connections to OEM sensors on the bike. The DAS Design Questionnaire was distributed by placing questionnaire packets on motorcycles and by mailing the questionnaire or links to the questionnaire to motorcycle riders identified in VTTI’s participant database. To date, 45 individuals have responded to the questionnaire. In addition to providing information of use in developing specifications for the motorcycle DAS, the questionnaire has provided utility in identifying

potential participants. Of the 45 respondents, 39 have indicated possible interest in participating in the on-road study.

During 2009 further work will be done to refine and validate instrumentation. The first bikes will also be released for data collection. Because the project is primarily for instrumentation development and proof of concept, the participants will be run in series rather than in parallel. Learning from earlier participants will be incorporated into the systems deployed on later participant bikes.



### Crash/Near-Crash Algorithm

One common problem in naturalistic driving research data is extracting all the crashes and near-crashes from a large dataset without having an excessive number of false alarms. This is typically accomplished through an iterative process of threshold triggering on kinematic data followed by video validation with trained reviewers. Video reviewers would determine if a given threshold trigger was valid or invalid according to a set of

operational definitions. For the valid events additional video review was conducted to evaluate such things as event severity, driver behaviors, and impairment.

Approximately 20 kinematic threshold triggers were used to identify safety relevant driving events in the 100-Car dataset. These kinematic threshold triggers were activated over 120,000 times resulting in approximately 10,000 safety relevant events. Clearly the process of video validation of so many yaw rate threshold triggers is time consuming, expensive, and prone to error. In addition to the obvious time and expense associated with culling invalid triggers, there is also a cost associated with the degradation of analysis quality as reviewer vigilance decreases due to the rare nature of safety-relevant events. Video analysis efforts need to be focused on the aspects of driving safety research in which they add the greatest value – providing contextual information that cannot be derived from kinematic and parametric data.

The threshold trigger of interest in this project is a yaw rate trigger which was developed to identify situations in which a driver performed a sudden steering maneuver as such maneuvers are possibly indicative of a safety-relevant driving events. The final 100-Car yaw rate trigger criteria were as follows:

1. Yaw rate oscillation in excess of 4 degrees/second within a 3-second window (vehicle returned to direction of travel prior to steering maneuver).
2. A minimum speed of 6.7 m/s (15 mph) at the onset of the trigger.

When this algorithm was run across the entire 100-Car dataset approximately 85,000 yaw rate triggers were identified with approximately 2 percent being declared as valid and subject to further video analysis. There were several driving scenarios in which a yaw rate threshold trigger was activated. As it seems likely that the causal mechanisms for evasive maneuvers under various scenarios differ; it is possible that scenario identification prior to classification would be beneficial.

The refinement of scenario identification showed some improvement in previous efforts. The yaw rate triggers were divided into initial movement direction groups (left or right) and partitioned based on trigger duration. Three levels of trigger duration were created: 1 second, 2 seconds, and 3 seconds. In order to ensure that enough yaw rate triggers were included in each of the duration categories any triggers with duration up to 0.3 seconds less than the stated category were included. For example, the 1-second category includes triggers with durations of 0.7 s, 0.8 s, 0.9 s, and 1.0 s.

It should be noted that although the dataset was partitioned in such a manner this remained a two-class problem. Classifiers were applied to distinguish between valid and invalid triggers for each trigger duration category within each initial movement group. Currently two types of discriminant analysis are being applied to the task of distinguishing between driving safety-relevant events and innocuous driving situations using yaw rate kinematic triggers. The first method is linear discriminant analysis (LDA) and the second penalized discriminant analysis (PDA). PDA is an extension to linear discriminant analysis and is designed to handle situations with many highly correlated predictors such as arises from the discretization of analog signals.

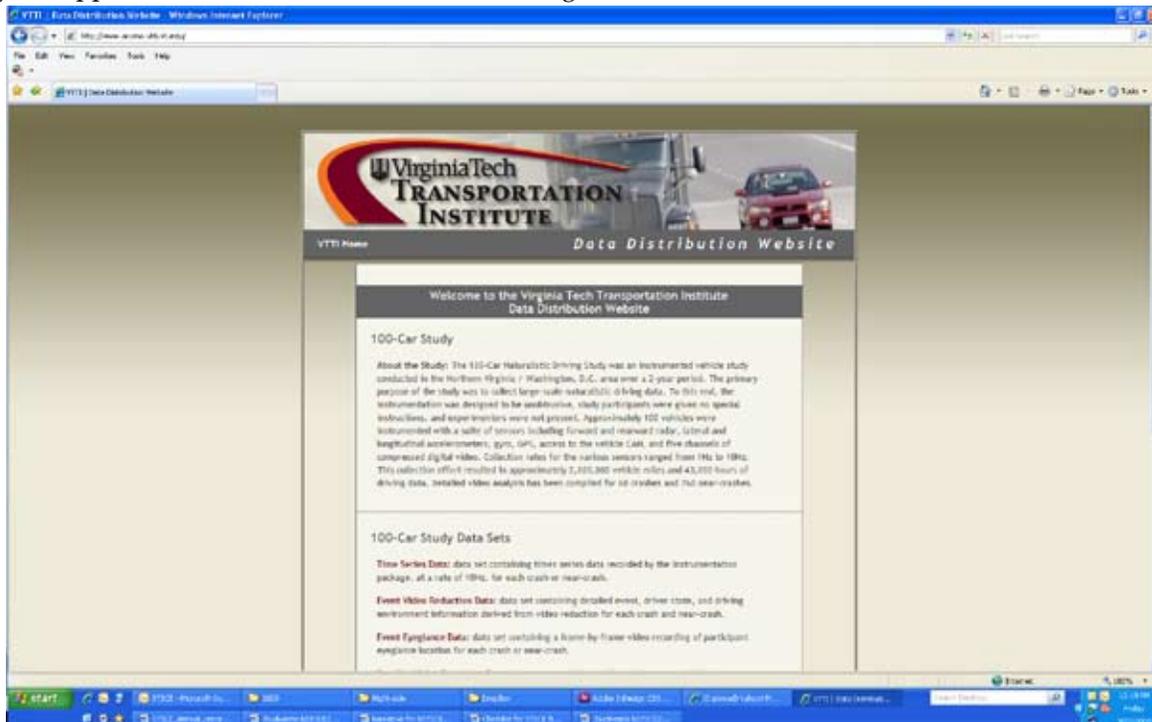
### Public Access

VTTI maintains naturalistic databases relevant to many driving safety research efforts. The ability to make portions of these datasets publicly available is currently under development. There are two primary objectives for this project: develop the tools and procedures necessary to provide timely access to datasets, and allow VTTI personnel to gain experience in providing appropriate levels of service to external researchers.

Initial efforts focused on preparing datasets and the web interface for public access. The following datasets have been compiled for distribution: 100-Car event video reduction data, 100-Car event time series data, and 100-Car event eyegance data. Supporting documentation for the 100-Car Study and the datasets was also compiled and formatted for distribution. This supporting documentation included data dictionaries, vehicle sensor information, and guidelines for secondary analysis. Web interface development included support elements such as user surveys, FAQs, and the creation of an email account to be used for analysis support. The data distribution website URL is [www.access.vtti.vt.edu](http://www.access.vtti.vt.edu).

Additional datasets will be added to the website as preparation tasks are completed. These datasets include 100-Car baseline video reduction data and 100-Car baseline eyegance data.

Following the addition of these datasets to the website, the project will enter a support and measurement phase in which efforts will directed at determining how much demand exists for naturalistic datasets and providing analysis support for those who access the data through the website.



## Advanced Roadway Delineation and Lighting Systems

### Development of the Luminance Camera System

There are many visual aspects apparent to a driver when driving at night. These items include overhead lighting, headlights, signage, pavement markings, and billboards. Given the chaotic nighttime environment researchers are unaware of what information a driver seeks when driving in these conditions. In order to understand the information present to a driver when driving at night, a variety of data must be captured and analyzed. One such measure is the luminance information present during nighttime driving.

Current methods to capture luminance data are slow, cumbersome, and static snapshots in time that often do not reflect actual dynamic luminance information drivers experience. In an effort to gather dynamic luminance information, the purpose of the project is to create a video capture system. Capturing the luminance data dynamically will provide researchers a dynamic range of data that impacts driver behavior.

In order to capture this information the current project has tested a variety of digital video devices. In addition to these devices, the research team has also tested a luminance calibration model that can be used to process the dynamic image information. A field test has been accomplished in an effort to gauge the video capture system and calibration model.

Multiple tests of reliability and repeatability of the video capture system among different users were also conducted in order to determine whether resulting data is consistent over time and among multiple users. Concerning the calibration model, a method of calibrating the luminance camera has been established. The calibration is a semi-automated method involving simultaneous image capture and overlays of pixel data.



Primarily, the calibration is completed through the automatic setting of image acquisition variables (such as camera gain and shutter speed) through a wide range of settings in a controlled environment. Images are simultaneously captured through the luminance camera and a manufacturer-calibrated Radiant Imaging photometer. Resulting luminance camera images and photometer images are then overlaid through an automated process. Pixel data is then compared, resulting in calibration factors for the multiple variable camera settings of gain and shutter speed.

A final report for this project has been issued. The video capture system is now being implemented in ongoing projects, such as the Roadway Lighting Mobile Measurement System.

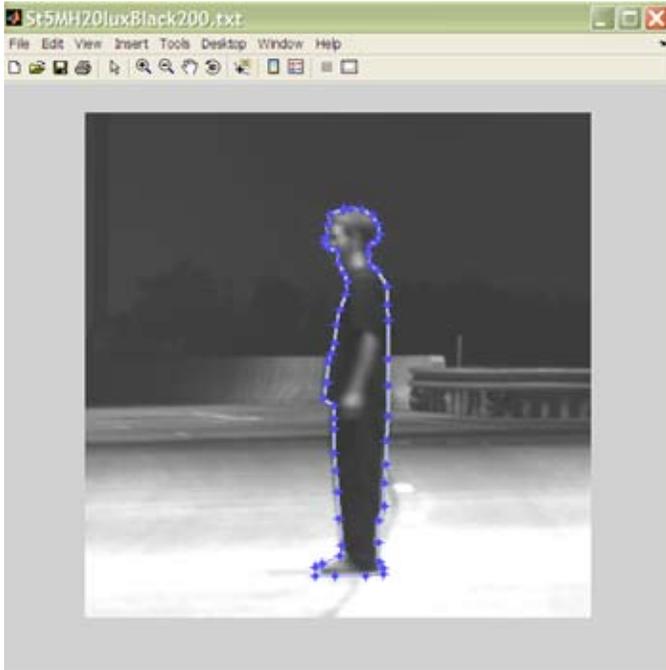
## Luminance Metrics for Roadway Lighting

The goal of this effort is to be able to analyze images from both dynamic and still-collection methods, using metrics other than the simple contrast formula ( $[\text{luminance of target} - \text{luminance of background}] / \text{luminance of background}$ ). This simple metric is limited, however, in instances when contrast is distributed unevenly across an image. Therefore, the effort has been to determine more complex metrics for the more complex, realistic natural environment. Following this, the goal is to analyze both existing and future collected data and correlate luminance metrics to real measurements of visibility.

In order to analyze the dynamic information captured by the luminance camera, the research team is reviewing and enhancing current luminance metrics for roadway luminance data. Multiple metrics of contrast are being applied to existing images, such as the Weber, Michelson, and Simple contrast measurements.

These traditional methods of determining contrast involve relatively simple comparisons of average target luminance to average background luminance, or ratios of maximum to minimum luminance. The International Commission on Illumination (CIE) and the Illuminating Engineering Society of North America (IESNA) also define contrast through similar comparisons.

All of these metrics are being taken into consideration in the ongoing analysis of images. The team has further improved these metrics through the use of Root Sum of Squares (RSS) and Power Spectrum Signature (PSS)



methods in an effort to identify contrast information through the use of the variation of luminance within the target itself.

The strengths and weaknesses of the mentioned metrics are being explored. The preliminary results of these methodologies have provided interesting contrast information in addition to different automation techniques for identifying this information.

Continual steps are being taken to analyze a large set of in-house photometric images to validate the metric and automation process. The process of analysis has reached a point of automation that allows researchers to select images and identify targets which results in the automatic calculation of multiple metrics. An example of the selection of a target for analysis is presented in the photo.

The final goal of the project is to incorporate these additional metrics and automation when analyzing the luminance camera data. This incorporation has

begun in the Glare Metric project. A final report of the Luminance Metric project is currently under review.

## Glare Metric

The Glare Metric project will allow the research team to create a universal metric for measuring glare and how it affects driver safety and comfort. Two types of glare must be considered: disability glare and discomfort glare. Disability glare is glare that reduces a person's ability to see other objects in the presence of the glare source. Discomfort glare is glare that a person finds uncomfortable to a greater or lesser extent.

During data collection, several different glare scenarios were presented to participants as they drove around the Virginia Smart Road. These scenarios included different combinations of glare sources, glare intensities, and overhead lighting. Disability glare was measured by determining how each glare scenario affected the participants' ability to see objects on the roadway, such as pedestrians and small targets. Discomfort glare was measured by having each participant rate their level of discomfort on a nine point Likert-type scale.

In addition, several other factors were recorded to better understand these two types of glare. An illuminance meter was placed by the driver's head at approximately eye-level. This allowed the research team to see how much light was reaching the participants' eyes. This gives insight into why a participant rates a glare scenario a certain way. To help better understand disability glare, the Glare Metric experimental vehicle utilized the Luminance Camera system described above. The camera system recorded images during the entire study. This allowed the research team to analyze the images that corresponded with the point at which a participant could first detect an object in the road when in the presence of glare.

Using an image from when a participant detected a pedestrian in the roadway, the research team can determine the luminance and contrast values of the pedestrian. This gives insight into what factors are important for detecting an object in the presence of glare. The next step for the Glare Metric project is to complete the analysis of the Luminance Camera images, and use all the information collected to create a universal method for measuring and predicting discomfort and disability glare.



## Roadway Lighting Design and Safety

This project is the assessment of existing roadway lighting analyses to establish an initial model of the relationship of roadway lighting design level and driver safety. This project requires an extensive literature review which will then provide the data required for the establishment of a Bayesian statistical model.

In order to establish a model to assess the relationship between roadway lighting and driver safety a number of factors must be considered. An initial review of the literature identified a ratio calculation that can be potentially integrated into a model which evaluates illuminance as a potential safety metric. Other alternatives from the previous literature are also being considered as part of the model components. These alternatives will need to be investigated in greater depth before integration can be accomplished. These components will also likely include other safety metrics which have not been identified.

The next step or component of the model planning is a regression-based process. The purpose of the modeling is to connect the selected safety metric with a set of covariates. The example above uses illumination as a safety metric when comparing daytime and nighttime crashes and this condition variable(s) can be integrated into the model as a covariate. The statistical significance and absolute value of the coefficient(s) for illumination will help with understanding the impact of illumination on safety.



Additional variables of interest that can be added

to the model and likely influence driver safety include: traffic volume (AADT), driving lane count, and defined locations (e.g., urban versus rural), weather, surface condition, traffic control influences, etc. The most convenient way is to also include them as independent variables in the regression.

Depending on the final metric, a number of statistical techniques can be used. For example, a Poisson or negative binomial regression can integrate the previously described variables of interest and the number of crashes can be modeled. The final form of the model will be based on available data and engineering metrics of each alternative.

## Roadway Lighting Mobile Monitoring System

The Roadway Lighting Mobile Measurement System (RLMMS) will allow the research team to collect lighting data dynamically and also incorporate a number of previous NSTSCE project features in the data collection process. The RLMMS will capture illuminance, luminance, and GPS information in an effort to monitor lighting levels. This information can also then be synchronized to the Data Acquisition System currently in use at VTTI. The overall system has the potential to provide valuable data that incorporates illuminance, luminance, and a number of vehicle variables such as speed, acceleration, and steering behavior. The integration of illuminance and luminance information adds another valuable data source for understanding the quality of lighting and potential safety impacts within the nighttime driving environment.

A prototype RLMMS system has been created and contains a number of data collection components. The prototype system contains five Minolta T-10 Illuminance meters that are attached to a data collection box through networked cables. Four of the illuminance meters are horizontally mounted directly to the roof of the vehicle in such a way that two illuminance meters are positioned over the right and left wheel paths and the other two meters are placed along the center line of the vehicle. An additional vertically mounted illuminance meter is positioned in the vehicle windshield. The luminance camera, previously described, is also positioned in the vehicle windshield. A NovaTel GPS device is positioned on the vehicle roof in the center of

the horizontally mounted illuminance meters. The GPS device is directly connected to the data collection box and provides latitude and longitude measurements positional data.

The RLMMS hardware components are connected to a PC computer and are controlled by a program created in LabVIEW™. The entire hardware suite is synchronized through the software program and data collection rates are set at 10Hz. Video image capture rate for the luminance camera is currently below desired levels and requires further development. A text output file is created containing a synchronization data stamp, GPS information (e.g., Latitude, Longitude), camera image (filenames) from the luminance camera and the illuminance meter data from each of the Minolta T-10s.

The addition of a more hardware components that includes a color camera, spectral radiometer, increasing the efficiency of data collection, and validating the data stream will be the next step in the RLMMS project.

The RLMMS has already been utilized in several other projects. The first being an assessment of alternative lighting systems for Anchorage Alaska following by a test in San Diego and Honolulu.

### **Rural Intersection Lighting Safety Analysis**

Recent research from Iowa State University showed that lighting may have a positive impact on the safety of drivers as they drive through rural intersections. The research results showed that the ratio of night-to-day and total-night crashes were lower at lighted rural intersections compared to unlighted rural intersections that had similar configuration data. While the data presented the potential safety benefit of having lighting at rural intersections, the research treated the lighting component in a strictly binary format. This meant that comparisons



were only performed based on if lighting was present or absent and did not account for the amount or quality of lighting within the rural intersections of interest. These preliminary results suggest that lighting can benefit drivers at night, however it does not reveal information about the lighting level or the quality of lighting that may enhance driver safety at night. Identifying similar lighting conditions within Virginia and comparing that data to the Iowa data can provide important insights into an initial lighting safety analysis. Moreover, additional data collection efforts that incorporate the quality and amount of lighting required at rural intersections will provide further insight into lighting safety at rural intersections.

To analyze the impact of lighting at rural intersections within Virginia a number of steps are required. The initial analysis will be similar to that conducted at Iowa State University, where state crash data specific to rural intersections was obtained. Initial efforts of the research team have identified elements of the VDOT crash database and have team has acquired a “snapshot” of the database for the years 2002-2007. The VDOT crash database incorporates the data from the FR-300 reporting forms filed for each police reported collision. The data contains numerous columns of project relevant and non-relevant information and the current effort is to reduce the database information to identify rural intersection items of interest. Upon completion of the data cleaning an initial analysis will be conducted to identify crash frequency and a day to night crash ratio for intersections of interest. Depending on the quality and outcome of the initial analysis, additional statistical techniques similar to the roadway lighting safety analysis can be incorporated where a model is created to measure the relationship between illumination and driver safety.

The next step for identifying the influence of lighting at rural intersection locations will be to gather naturalistic data that measures the lighting levels directly. The information from actual measurements at a set of chosen rural intersection locations can then be incorporated into a predictive model that can potentially establish the effect of lighting and driver safety specifically at rural intersection locations. The naturalistic measures taken at the identified rural intersection locations will be incorporated into the overall model in an effort to assess the impact of lighting quality and lighting level on crashes. The additional data will be collected using the Roadway Lighting Mobile Measurement System. The results obtained from the extra data collection and the incorporation of that data into the overall model has the potential to provide additional data concerning nighttime driving safety specifically at rural intersection locations.

# Development of Techniques to Address Age-Related Driver Issues

## Driver Coach: Bedford/Montgomery Virginia Evaluation Project

The purpose of this project is to forward the concept of teen driver coaching and monitoring to eliminate behaviors that can lead to injury and fatal crashes. Teen drivers are three times more likely to get into fatal crashes than their adult counterparts. The causes of teen crashes include: excessive speed, alcohol use, distraction, and failure to recognize hazards, among others. VTTI has been independently approached by two Virginia counties (Bedford and Montgomery) to help design a program to mitigate what they believe is a tragic and growing problem in their communities. VTTI has recommended a “three-pronged” approach to help reduce teen deaths and injuries. The three parts include: 1) Parent-Teen contracts with elements of an enhanced graduated driver’s licensing (GDL) program, 2) Training of specific skills at a specially designed training facility, and 3) A teen driver monitoring and coaching program using advanced in-vehicle technology. This project will support all three parts, with special emphasis on the driver monitoring and coaching program. The driver monitoring and coaching will be accomplished by means of an unobtrusive data collection system that will provide both real-time monitoring (with instantaneous feedback for the teenage driver) and delayed summary feedback (for the parent).

In the fall of 2008, VTTI researchers attended Teen Driver Programs at seven high schools throughout Bedford and Montgomery Counties. The purpose of the Teen Driver Night Programs was to educate 10th graders (who usually obtain their learner’s permit and/or driver’s license) and their parents about the challenges that are unique to new drivers. Challenges include the licensing process, driver’s education classes, legal issues, insurance issues, and parent effectiveness. During the meetings, researchers presented current research opportunities at VTTI. Altogether, there were 165 people in attendance in Montgomery County (including both parents and teens), and 160 in Bedford County. In the spring of 2009, VTTI researchers will attend another three Teen Driver Programs in Bedford County, and will focus on recruiting participants for the Driver Coach project and for other upcoming VTTI teen driving studies. VTTI researchers will also host a visit from Montgomery County driver’s education teachers to plan for a way to use the Smart Road in training their students. VTTI researchers are actively designing the feedback portion of the Driver Coach system. It is anticipated that participants will be enrolled into the monitoring and feedback portion of the Driver Coach study beginning in December of 2009. This research directly supports FHWA and DOT’s research in traffic safety, in particular, the emphasis on developing new technologies for saving lives.



## Older Driver Data Collection

Older drivers (75+) generally experience elevated crash and injury risks relative to all but the youngest, most inexperienced drivers. These problems may be greatly exacerbated in the coming decades by the fact that older drivers are expected to comprise an ever-growing portion of the driving population going forward. For these reasons, research into transportation safety for this segment of the driving population is increasing in importance.

The current project entails a naturalistic driving study whereby 20 older drivers have had their private vehicles instrumented with an extensive yet unobtrusive data acquisition system (DAS) for one year each. All 20 vehicles are currently on-the-road and collecting data with the first scheduled to come off the road in April 2009. Data continuously being gathered include the following: 4-channel video (driver's face, instrument cluster, and forward and rear roadway images), GPS, lane tracking, lateral and longitudinal accelerometers, gyro yaw, forward radar, and vehicle network information (e.g., brake, accelerator, transmission status). An incident button is also available to participants, so that when any safety-related incident occurs the participant may press the button which is located near the rear-view mirror. This briefly opens an auditory recording channel and places a marker in the data stream for future analysis. Researchers estimate that this study will capture approximately 5,000 hours and 130,000 miles of naturalistic driving, generating some 2.5 TB of raw video, driving behavior, vehicle kinematics, and crash data. At approximately the half-way point in the data collection, researchers have thus far gathered over 17,835 trip files representing over 2,754 hours of driving data.



The primary goals of this aspect of the research program are to better understand typical driving behaviors as well as the situations and contributing factors that lead to crashes for this growing segment of the population. In

addition, as physical frailty is a major contributor to the elevated crash risk for older drivers, researchers have also implemented a highly capable accelerometer assembly in a test vehicle within the older driver fleet. The goal here is to gather the accelerometer data for any crash or near-crash with sufficient frequency, resolution, range, and accuracy to be used in the development of improved crash injury biomechanical models. The results of this pilot implementation are currently being tallied.

## Development of Techniques to Address Fatigued Driver Issues

### Developing and Validating a Naturalistic Observer Rating of Drowsiness (ORD) Measure

Two large-scale naturalistic driving databases, Drowsy Driving Warning System Field Operational Test (DDWS FOT), and the 100-Car Naturalistic Driving Study, were used to identify video examples for the development and evaluation of the Observer Rating of Drowsiness (ORD) training protocol. The current method for performing ORD is based on subjective assessments of the driver's facial tone, behavior, and mannerisms, and is set to a 100-point continuous scale. ORD is assessed based on the 60 seconds of video prior to a trigger event (or baseline epoch). Therefore, ORD is a relatively quick/efficient method for assessing one's drowsiness level, which can then be used to describe a driver's state and investigate whether drowsiness was a contributing factor to a safety-critical event. However, because ORD was developed and evaluated using simulated driving

data, there had been no formal training protocol in place for data reductionists who would perform the ratings.

The first step in the development of the ORD training protocol was to identify the relative indicators of drowsiness (i.e., physical characteristics, behaviors, and mannerisms). Video examples from both the DDWS FOT and 100-Car studies were identified for each relative indicator of drowsiness. A behavior and mannerism checklist was also developed for the protocol as a tool for individuals to use while performing ORD ratings. In addition to the relative indicators of drowsiness, individual driver data were reviewed to select six drivers who exhibited a range of drowsiness during the DDWS FOT and 100-Car studies. Video examples were selected from the six drivers and identified as driving while alert, slightly drowsy, moderately drowsy, very drowsy, and extremely drowsy. Each of these video clips was reviewed, evaluated, and edited in the same manner as the relative indicators of drowsiness videos, and the research team developed a written description of how each one was classified. The written descriptions were directly below the links to the video examples in the training protocol. The final training protocol contains the definition and purpose of ORD, the ORD Continuum, five levels of drowsiness descriptions, tips for rating drowsiness, driver appearance, ORD examples (driver progressions), the ORD behavior and mannerism checklist, and instructions for determining and recording ORD ratings. Once developed, a peer review meeting was held to solicit feedback from senior research faculty at VTTI regarding the protocol, video examples, and study design for evaluating the training protocol. All feedback was incorporated into the finalized protocol document. Scientific evaluation of the training protocol revealed that intra-rater reliability, inter-rater reliability, and indications of validity were satisfactory.



Finally, it is recommended that the protocol developed continues to be used as a training tool for data reductionists who will perform ORD ratings.

### Commercial Motor Vehicle Driver Health and Fatigue Study

An existing naturalistic dataset from the DDWS FOT, conducted by researchers at VTTI, was reanalyzed to investigate fatigue as a contributing factor to safety-critical incidents involving large trucks. The DDWS FOT is the largest CMV naturalistic driving study ever conducted by the United States Department of Transportation (U.S. DOT). Forty-six trucks were instrumented with VTTI's DAS and 103 CMV drivers participated in this study, resulting in almost 46,000 driving-data hours covering 2.3 million miles traveled over a 16-month period.

The focus of this study was on the driver characteristic of body mass index (BMI) and its relation to fatigued driving. Researchers at VTTI used the naturalistic video data to implement two independent measures of fatigue (ORD and Estimated Manual PERCLOS [EMP]) allowing comparisons to be made between drivers classified as being normal weight, overweight, or obese to determine if increased body mass is linked to a greater risk for fatigued driving. For the ORD measure, drivers were rated as fatigued in 26 percent of the total safety-critical events identified (n=952) and in 41 percent of 1,736 randomly selected baseline driving epochs. Using the second measure, PERCLOS (percent of eye closures over time), it was found that fatigue was a factor in 21 percent



of the total safety-critical events identified (n=952) and in 41 percent of 1,736 randomly selected baseline driving epochs. Using the second measure, PERCLOS (percent of eye closures over time), it was found that fatigue was a factor in 21 percent

of the total safety-critical events (n=807) and 29 percent of 1,530 randomly selected baseline driving epochs when using a threshold of PECLOS>8 percent.

Results indicated that of the 103 drivers, 82 percent were considered overweight or obese based on BMI. Odds ratio calculations revealed these individuals were 8.95 times more likely than normal BMI individuals to be rated as fatigued based on the ORD measure. Using the PERCLOS measure, overweight/obese drivers were found to be 1.69 times more likely to be rated as fatigued than normal BMI drivers.

As a whole, these results indicate a clear relationship between BMI and fatigued driving as well as BMI to safety-critical event involvement. This finding suggests that obese individuals are at greater crash risk than non-obese individuals. The results support other research in the field of health and well-being which suggests a strong link between being overweight/obese and fatigue, particularly daytime sleepiness. This issue is especially relevant to commercial vehicle drivers whose work schedules present few opportunities for exercise and proper nutrition. Improvements to organizational design and driver behavior will be discussed in terms of encouraging a healthier lifestyle for commercial drivers.

### **Assessment of Fatigue from the Drowsy Driver Warning System Field Operational Test (DDWS FOT)**

An existing naturalistic dataset from the DDWS FOT, conducted by researchers at VTTI, was expanded and analyzed to gain a greater understanding the conditions which are associated with fatigue in commercial motor vehicle (CMV) driving.



The DDWS FOT is the largest CMV naturalistic driving study ever conducted by the U.S. DOT. Forty-six trucks were instrumented with VTTI's DAS and 103 CMV drivers participated in this study, resulting in almost 46,000 driving-data hours covering 2.3 million miles traveled over a 16-month period.

A total of 1,217 valid safety-critical events were identified in this dataset (14 crashes, 15 tire-strikes, 120 near-crashes, and 1,068 crash-relevant conflicts). In addition, 2,053 baseline driving epochs were randomly selected and validated for comparison purposes. Each safety-critical event and baseline epoch was coded using video data to describe the driving parameters (e.g., driving environment, driver behaviors). In addition, two independent measures of driver fatigue were implemented using video data.

The Observer Rating of Drowsiness (ORD) measure is a subjective procedure by which data analysts observe drivers' facial features and behavior for one minute prior to an event trigger (or randomly selected baseline epoch) to rate drowsiness on a scale from 0-100, with 100 representing "extremely drowsy." Estimated manual PERCLOS is a somewhat more objective measure whereby data analysts manually code whether the drivers' eyes are open or 80 to 100 percent closed (non-inclusive of rapid eye blinks) at 1/10 of a second for three minutes prior to an event trigger (or randomly selected baseline epoch). This manual coding is then used to produce a percentage of time the eyes were 80 to 100 percent closed for that time interval.

The fatigue measures were used to identify the driving parameters associated with a greater likelihood of driver fatigue by means of odds ratio calculations. By identifying and examining the driving parameters associated with fatigue, future efforts can be directed at developing countermeasures to prevent fatigued driving or otherwise raise awareness of the increase in risk of fatigue associated with these driving parameters.

The final report for this study is now available on the NSTSCE website.

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