NATIONAL SURFACE TRANSPORTATION SAFETY CENTER FOR EXCELLENCE

ANNUAL REPORT

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The National Surface Transportation Safety Center for Excellence

Message From the Director

Dr. Tom Dingus

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

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 three we have again demonstrated 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 Federal Motor Carrier Safety Administration, the Virginia Department of Transportation, the Virginia Transportation Research Council, the General Motors Corporation, and Virginia Tech for their continued support and to welcome Travelers as a new stakeholder. Our stakeholders make it possible for NSTSCE to make a significant difference in transportation safety well into the future and beyond the initial SAFETEA-LU designation. In fact, the initial investment made by the federal designation has paid great dividends yielding nearly $15 million in additional research.

In just three years we have already made a positive impact on transportation safety in terms of research results. NSTSCE research results are beginning to lead to enhanced technology developments as engineers work to translate research findings into transportation safety applications. For instance, the support offered by NSTSCE in exploring teen driving safety has led to new approaches in training novice drivers. A new study will put robust driver monitoring systems in the cars of 90 teens with the ultimate goal of improving driving performance. The monitoring systems are designed to provide real-time feedback to the teen and post-hoc feedback to the parent. The feedback will be used to coach the drivers to learn and adopt safer driving behaviors.

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 with high crash rates such as older drivers, teen drivers, and motorcycle riders. The data collected from these populations are allowing us to further examine from both a countermeasure and policy standpoint the national transportation safety concern of distracted driving. In 2009 alone, NSTSCE researchers provided testimony of their findings before the U.S. House of Representatives Subcommittee on Commerce, Trade, and Consumer Protection and were featured presenters during the U.S. Presidential Distracted Driving Summit. Research conducted through NSTSCE allows us to provide data-driven support for policy makers in their efforts to improve transportation safety.

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, and address age-related and 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 comprising organizations that share our vision for improving road-user safety locally and across the nation. The Stakeholders' Committee members are Carl Andersen, Federal Highway Administration (FHWA); Tom Dingus, VTTI; John Capp, General Motors Corporation (GM); and Gary Allen, Virginia Department of Transportation (VDOT) and Virginia Transportation Research Council (VTRC). In 2009, VTTI welcomed Martin Walker, Federal Motor Carrier Safety Administration (FMCSA), and Chris Hayes, Travelers, as new stakeholders. 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 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 comprise 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 AOTR, Carl Andersen, serves as the chair of the Stakeholders' Committee. Other Stakeholders' Committee members are Tom Dingus, VTTI; John Capp, GM; and Gary Allen, VDOT and the 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 the FHWA, FMCSA, 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 of project planning.

Marketing Approach

NSTSCE subject matter experts and project managers accelerated NSTSCE marketing and outreach efforts in the third 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 and to draw membership from a proportionate mix of industry, state, and federal agencies.

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 (TRB) workshops and meetings. VTTI/NSTSCE researchers serve as TRB committee members within primary research areas.

•NSTSCE researchers 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

•Dr. Rich Hanowski, Dr. Justin Morgan, and Erin Mabry made contact with the following organizations to recruit project involvement and possible NSTSCE stakeholdership: the National Institute for Occupational Safety and Health, the Federal Transit Administration, the American Sleep Apnea Association, the American Academy of Sleep Medicine, the Owner Operator Independent Drivers Association, the American Transportation Research Institute, the AAA Foundation Traffic Safety Culture Center for Excellence, and Truckers for a Cause.

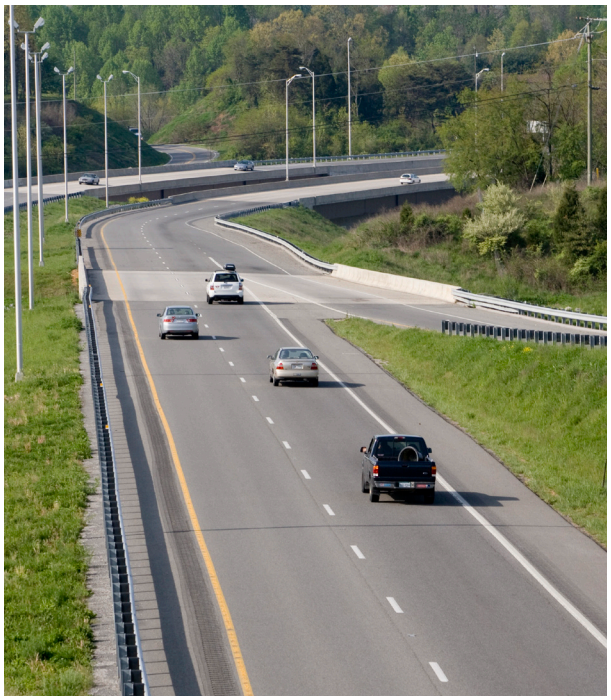
• Dr. Ron Gibbons presented NSTSCE-based projects at the Illuminating Engineering Society of North America Annual Conference, the Street and Area Lighting Conference, the Illuminating Engineering Society of North America Spring and Fall Meetings, the Commission Internationale d'Eclariage Mid Term Meeting, and the Transportation Research Board Visibility Committee Meeting. Chris Edwards and Jason Meyer presented at the Illuminating Engineering Society of North America Annual Conference.

Outreach Goals: Publication Analysis

Numerous publications were submitted to scientific agencies and journals during 2009, 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 more than 40 terabytes (TB) includes datasets from several large-scale studies and encompasses heavy- to light-vehicle naturalistic driving in rural and urban locales. 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

Method for Identifying Rural, Urban, and Interstate Driving in Naturalistic Driving Data



The emergence of naturalistic driving data has provided the capability for exploring the reasons why most fatal crashes in the U.S. occur in rural areas despite the fact that only approximately one-third of the total distance driven each year is on rural roads. Naturalistic data provide extremely rich data describing what occurs instant by instant, both in non-crash situations and during actual crashes and near-crashes. Within these data, epochs of driving in rural areas can be located and analyzed to identify countermeasures that will reduce the frequency and severity of these crashes and in some cases even test the effectiveness of proposed countermeasures.

This project, which was completed in 2009, developed data-mining methods for locating rural driving from within large naturalistic driving datasets. The developed methods integrated 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., the Virginia Department of Transportation [VDOT]) and other providers. Points recorded in the naturalistic driving data that fell outside the boundaries of the Census Bureau's urbanized areas or urban clusters were determined to be rural. The points were further evaluated to determine whether or not the vehicle was being driven on an interstate highway. Points that were determined to be rural and not on interstate highways were segments of interest in addressing the rural road crash problem.

This method may be easily adapted to address other variables of interest that could be tied to geospatial locations and to examine 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, including 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. A final report of the project is published online and available at http://scholar.lib.vt.edu/VTTI/.

Driver Behavior in Crash Hot Spots and Rural Areas

Methods developed during the *Method for Extracting Rural Driving* project were used in this project to locate cases of drivers passing through urban intersections and rural road segments with high crash rates, also referred to as "hotspots." The objective of the present task was to identify differences of driver behavior in hotspots and in baseline conditions. This was accomplished with the goal to ultimately discover contributing causes of crashes in these two types of areas and to identify potential countermeasures.

During 2009, the methods previously developed during the *Method for Extracting Rural Driving* project were refined to identify naturalistic driving data through intersections. Other GIS tools were implemented to identify areas with high crash densities. This was conducted by associating each crash location with the nearest road segment in the VDOT road network data and then counting the number of crashes on each road segment. The rural area hotspots were identified using these high crash densities. The road segments with the highest numbers of crashes and substantial naturalistic driving data from the 100-Car dataset and the Older Driver Naturalistic Data Collection were used for this work. The urban intersection

hotspots were identified from VDOT data that ranked intersections by the number of fatal and injurious crashes. The intersections with the highest numbers of crashes and a substantial number of trips in the 100-Car naturalistic dataset were used for the urban intersection analysis.

Increased GIS functionality was made possible by a new server that was acquired and setup during 2009. The server houses a PostgreSQL database with PostGIS tools, allowing the storage of larger geospatial datasets and the use of geographic tools on these large geospatial datasets. The increased functionality also includes being able to associate data from other sources such as the Highway Performance Monitoring System (HPMS) with the geospatial road data. HPMS data include information such as pavement type and the annual average daily traffic (AADT) of a road segment, which were used in identifying comparable baseline road segments.

Research questions were defined that address hotspots in both urban and rural areas. These research questions guided the development of video reduction protocols, and urban intersection and rural road segment naturalistic driving data were reduced using these protocols. Data from the 100-Car Study were reduced in the analysis of the urban intersection hotspots, and data from both the 100-Car Study and the Older Driver Naturalistic Data Collections were reduced in the analysis of the rural road segment hotspots. The addition of the Older Driver data for the rural road segment hotspots was made because those data were collected in Southwest Virginia where the prevalence or rural road driving is higher than in Northern Virginia where the 100-Car data were collected. The results of these reductions are being compared to reductions through baseline intersections and road segments to identify potential differences in driver behavior. The effort is expected to identify differences in driver behavior that do or do not exist that may contribute to the increased crash densities in the urban intersection and rural road hotspots. The project is nearing completion and will be finalized during 2010.

Crash—Near-Crash Trigger 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.

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 since 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 three-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 one-second category includes triggers with durations of 0.7 s, 0.8 s, 0.9 s, and 1.0 s.

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 is penalized discriminant analysis (PDA). PDA is an extension to linear discriminant analysis and is designed to handle situations with many highly correlated predictors that arise from the discretization of analog signals.

100-Car Re-Analysis

The 100-Car Naturalistic Driving Study (released in 2006) provided an exciting opportunity to study driver behavior in a naturalistic setting over a long period of time. The 100-Car Study collected longitudinal data for 108 primary drivers and associated secondary drivers over the course of an entire year in 2003 and 2004. This dataset continues to provide a wealth of information for transportation research. However, in order to conduct subsequent analyses efficiently on a data set of this magnitude, a complete inventory of what it contains must be available.

The objective of the 100-Car Reanalysis project was to create such an inventory. Information obtained during the re-analysis for each trip file included driver identification (using alphanumeric codes); seat belt usage; ambient lighting (day or night); and which, if any, video views were unavailable. During this complete review of files, new secondary drivers were also identified and assigned identification codes. This supplemental information will strengthen many of the secondary analyses of these data and allow for more accurate estimates of exposure and risk.

This inventory and all quality control were completed in 2009, and the draft report is currently under internal review at the VTTI. A very brief summary of the information contained in this newly appended database is provided here.

In addition to the 108 primary drivers, 299 secondary drivers are now included in the Driver Identification (ID) directory (up from 133 known secondary drivers after the original 100-Car Study). Driver IDs were associated with a total of 156,637 trip files (139,367 of these were primary drivers) covering 28,897 driving days (24,189 days were primary drivers). In all, these files represent 1.2 million vehicle miles traveled. Most driving took place during the daytime, with 73.9 percent of primary driver trip files and 71.8 percent of primary driver mileage occurring during daylight hours.

Primary drivers were observed wearing their seatbelts in an average of 81.5 percent of their trip files (ranging from 0 to 100 percent for individual drivers). Primary drivers were also assigned to one of three seatbelt usage categories. Resistant seatbelt users were defined as wearing a seatbelt in <=20 percent of trips and included 10 percent (n=11) of primary drivers. Occasional seatbelt users were defined as wearing a seatbelt in 20 percent to 80 percent of their trips and included 13 percent (n=14) of primary drivers. Consistent seatbelt wearers made up the remaining 77 percent (n=83) of primary drivers and were defined as wearing a seatbelt at least 80 percent of the time.

Modeling Crash Data for the 100-Car Naturalistic Study

The final project report has been submitted and is available online now at http://scholar.lib.vt.edu/VTTI/. This project resulted in the development of an integrated framework with a solid theoretical justification for analyzing the safety outcomes of naturalistic driving studies. The results provide a platform to quantitatively evaluate the safety impact of driver behavior and environmental factors that will help us better understand and improve traffic safety. The following is a highlight of the major conclusions of the project:

It was shown that the naturalistic driving study is analogous to the case-cohort study in an epidemiology study, which is much less prone to bias than a case-control study. It was illustrated that the risk rate is the proper measure of risk for time-variance risk factors such as drowsiness. With a proper baseline sampling method, the odds ratio from a case-cohort study will approximate the risk rate ratio. This result provides a clear interpretation for the odds ratio for naturalistic driving data and a guideline for baseline data reduction. A total of 17,344 baselines, based on the recommended method, were constructed from the original case-control baselines and the additional baseline reduction.

The developed framework was applied to the 100-Car Study data. Several statistical models, including the Generalized Estimation Equation (GEE) and random effect model, were developed to estimate the risk. The emphasis is to address: 1) the potential confounding effects of multiple factors, and 2) the driver-specific correlations. The random effect model shows advantages over the alternatives.

The modeling framework developed in this project has been adopted by several naturalistic driving studies, including the older driver study and the teen driving study. The results of this project have been presented in the Transportation Research Board (TRB) human factor workshop and the first naturalistic driving study symposium.

Distraction Index Framework

Progress in the Distraction Index project primarily consisted of the completion and analysis of the first wave of events identified. Steps in the process included:

- Initial identification of triggers for reduction (e.g., large longitudinal deceleration, large lateral accelerations);
- Analysis of these triggers to verify their validity and mark them as valid events;
- Observation of the presence of infotainment system use during the valid events;
- Judgment of whether infotainment system use was a factor in the extreme kinematics that were used to identify the events;
- Coding of the video of these events to indicate eye glance patterns;
- Assessment of the driving-related events that occurred on the forward roadway during the event; and
- Calculation of the frequency counts for the measures of interest (statistics could not be calculated due to the low number of valid events).

As the last item suggests, while there were a sizable number of triggers identified, relatively few were determined to be valid events, and fewer still were observed to be accompanied by infotainment system use.

The triggers resulted in 46 individual events (more than one trigger may have been present per event). Of these, most were lead-vehicle conflicts where the lead vehicle was decelerating, stopped, or incurring into the lane. Infotainment system use as a causal factor for the event was observed in three out of the 46 cases (six percent), and cell phone use as a causal factor was observed in two out of the 46 cases (four percent). Participants were glancing to the forward roadway on ~69 percent of cases but failed to see all the relevant events on ~15 percent of these. Braking was the most common reaction to these events (~84 percent), either by itself or in combination with steering.

As a result of the limited information provided by these initial events (given their small number), detection and analysis of additional events where particular instances of system use are identified (followed by analysis of driving performance within those events) will be completed during the next year. 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 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 appropriate use, legality, system management, and public and political acceptance. This project objective was designed 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 spanned the full range of technical, social, legal and political issues. While this project had the goal of examining privacy, it also had multiple objectives. Generally, it involved inventorying and defining the characteristics that comprise the concept of "privacy" in transportation applications. Once the first phases were completed, the team focused on potential transportation safety applications of emerging technologies and their impact on privacy.

A survey of the Intelligent Transportation Society of America (ITSA) membership was administered to the membership on February 6, 2009, inquiring what technologies they were involved with and how it related to personal privacy. The draft final report of the project is now out for external review; an appendix is being developed.

Naturalistic Observation of Motorcycle Riders

Motorcycle fatalities and injuries have been increasing during 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 data acquisition system (DAS);
- Exposure of sensors, cameras, and the DAS 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.

To gather additional inputs for the study and hardware design process, a DAS Design Questionnaire was distributed to riders by placing questionnaire packets on motorcycles and by mailing the questionnaire or links to the questionnaire to motorcycle riders identified in the VTTI participant database. Overall, 229 individuals responded to the questionnaire (90 percent male, 10 percent female). Although a significant amount of information was obtained, one of the key feasibility conclusions was the outstanding response rate and the willingness of riders to participate in the study. The questionnaire responses (such as where riders parked bikes, when they rode, how often they rode, etc.) were used to set specifications that led to the prototype systems that were developed by a combination of this NSTSCE project and the leveraged National Highway Traffic Safety Administration (NHTSA) motorcycle feasibility project. The NSTSCE project funds were focused on developing radar and brake-sensing capabilities. Furthermore, the responses were used to develop the protocols and questionnaires for a large motorcycle feasibility study that is currently being planned cooperatively by VTTI and the U.S. DOT.

During this year, VTTI equipped its Versys motorcycle with an early prototype based on the 100-Car DAS platform. This early prototype allowed engineers to select appropriate sensors such as camera locations and verify that sensors such as radar would function on a motorcycle. The first of three participants was given this bike for four weeks to use as his motorcycle. During that time the participant rode approximately 2,500 miles during which a variety of riding conditions were encountered.

While data were being collected by the first participant, development of the DAS continued and a migration to the NextGen was performed. The second participant had his Honda VFR sport bike equipped with the NextGen mounted in an inconspicuous location where a saddle bag might normally reside. This rider had the system installed for 12 weeks and rode more than 1,258 miles. The third participant had a BMW R1200R bike equipped with the NextGen and rode for four weeks and more than 1,229 miles. Overall, the three participants provided an opportunity to refine the DAS and protocols and to provide an initial dataset on which data analysis methods were developed.

A number of analyses were performed and demonstrated the feasibility of collecting and analyzing data on motorcycles. The analyses included measuring the effects of exposure (day of week, time of day, type of road, number of intersection crossings, etc.), time series (when brakes were pressed, typical deceleration, following distance, etc.), and event capture (crashes, near crashes, etc.). Although the data sample is insufficient for determining statistically significant conclusions, analysis did demonstrate the feasibility of collecting and analyzing naturalistic data on motorcycles. Interested readers should refer to the final report presented to the NHTSA, which contains a detailed discussion of the 2009 project accomplishments.

During 2010, further refinements of the instrumentation package will be performed. In particular, efforts are underway to measure brake application force independently on the front and rear brakes. A measure of engine load is also being performed through monitoring vacuum pressure of the engine. These two measures should help better characterize the rider's style and ability to appropriately control the bike.

Finally, the remaining NSTSCE funds are being held for use in a larger naturalistic motorcycle study. The VTTI motorcycle group is actively working with the NHTSA, the Motorcycle Safety Foundation, and the Motorcycle Industry Council to obtain additional funding to enable the large-scale data collection. The goal is to create the first large-scale naturalistic data collection performed on motorcycles. Similar to the four-wheel naturalistic datasets, such a database enables a virtually limitless number of detailed investigations that provide valuable information for identifying and understanding safety deficiencies as well as developing methods for mitigation.

Data Mining of the Independence by Franklin Intersection to Identify Factors Leading to Traffic Signal Violations

The purpose of this study was to investigate the factors related to red-light intersection violations at three signalized intersections in the New River Valley. This was 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 included 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.

This study performed the next step by extracting a comparative set of baseline intersection approaches. These baseline intersection approaches were carefully selected such that the team obtained a set data in which drivers were in very similar situations with respect to the signal phase and timing; however, unlike the previous dataset, they did not violate the traffic control device. Overall, this resulted in a data sample containing 6,000 violating drivers and 6,000 compliant drivers. Detailed analyses of these data were performed to identify differences between the two groups.

Although a number of descriptive statistics were performed, the analysis focused on the application of a logistic regression model. The model identified several key differences between the violating and compliant driver groups. For example, the analysis demonstrated that drivers of heavy vehicles (e.g., bus, tractor-trailers) were 300 percent more likely to violate than light vehicles such as cars and vans. Furthermore, drivers were approximately 80 percent more likely to violate at the Franklin intersection than at either of the other two locations.

The results of the logistic regression were presented at the 2009 annual meeting of the TRB. Presently, the other statistical analyses that were performed are being gathered into a publication format for submission to a journal article or conference. The paper will provide a complete review of the methods used and the results obtained. Once completed, this article will be provided to the NSTSCE stakeholders at request.

Public Access to VTTI-Maintained Datasets

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 eye-glance 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.

Additional datasets will be added to the website as preparation tasks are completed. These datasets include 100-Car baseline video reduction data, 100-Car baseline eye-glance data, along with kinematic and video reduction data from the 8-Truck study. The additional 100-Car datasets will be available by the end of Quarter 1 in 2010, and the truck datasets should be available in Quarter 2 of 2010.

Efforts were begun to expand the capabilities of the current website to include a forum with threaded discussions and a content management system to allow the hosting of user contributed files. Evaluation of software products to provide this functionality has begun.

Developing Bayesian Models for Naturalistic Driver Study

The Bayesian model has been developed for the 100-Car dataset. The Markov Chain Monte Carlo method was used to simulate the posterior distribution of odds ratio. The current focus is to develop a hierarchical model to incorporate multiple naturalistic driving studies in a joint model. This approach is analogous to the traditional meta-analysis of multiple studies but is more flexible and powerful. The research team completed the Institutional Review Board (IRB) process and obtained the truck naturalistic driving dataset.

Data Center

The purpose of this project is to integrate Virginia Tech's petabyte-scale, high performance data storage system into VTTI's data infrastructure. Once completed, data from multiple naturalistic driving studies will be migrated to this infrastructure. These data will be analyzed using high performance computational systems in order to perform more complex computational algorithms and data mining.

Texting

In this study, driver performance while texting using a handheld mobile telephone was compared to performance while texting using an integrated vehicle system with a voice interface. The study was conducted in parallel with privately funded work investigating manual versus voice control of other typically manual controlled technologies. The texting portion of the study investigated driver performance while sending and receiving text messages on the Smart Road test track using personal handheld phones and

the vehicle system. Measures included task duration, mental demand, eyes-off-road time, steering variability and maximum steering rate. Data collection for this project began in late 2009 and was completed in early 2010 with 20 participants in two age groups (11 between the ages of 19 and 34 and nine between 39 and 51 years of age). Data reduction was completed, and the results are currently being analyzed. It is expected that the results will be submitted for publication in a peer-reviewed journal in the coming months.

Mask Post-Processing

VTTI's proprietary Mask software offers an ideal opportunity to use machine-vision technology to automatically scan a naturalistic driving video database to quantify the extent of a driver's head turn from its nominal forward position, and perhaps much more. Such metrics may be particularly relevant and provide insight during maneuvers such as left turns across traffic. This research capability is intended to be applied to a related NSTSCE project, *Age-Related Driver Difficulties at Intersections*, which is designed to investigate the visual scanning of drivers, particularly during maneuvers such as left turns. In the future, this technology could be applied to other video libraries, including those of the forthcoming large-scale Strategic Highway Research Program (SHRP) 2 and the 250-Truck Naturalistic Driving Study (NDS).

The intent of the current project is to develop the necessary middleware to allow the Mask to scan a video database (or any specified subset thereof) as a batch process. Currently, the mask must be applied in a fairly labor-intensive single video basis. As of the end of 2009, development work continued on this key middleware.

Device Survey

The purpose of this project is to gather self-reported data regarding portable consumer electronics devices that are used during driving, including what devices are owned, what devices are used while driving, patterns of usage while driving, how individuals acquire their devices (i.e., as gifts or by making a purchase), and how they shop for and buy devices. The survey has been administered to two samples associated with Virginia Tech: (1) faculty, staff, graduate and undergraduate students; and (2) Blacksburg Transit drivers holding commercial driver's licenses (CDLs). Data will be separately analyzed from the two samples. The purposes of this effort are to compare CDL drivers to non-CDL drivers in terms of a variety of factors relating to the following:

1. To identify and characterize types of device users and types of buying behaviors;

2. To better understand how to develop consumer information about devices and their use during driving;

3. To better understand how to reach consumers of different types in the delivery of information about driving distraction; and

4. To supplement/confirm patterns of behavior observed in naturalistic studies with small samples of drivers.

As of the end of 2009, the survey had been administered to more than 1,455 individuals, including approximately 25 CDL drivers. In 2010, the survey will be administered to a larger group of CDL drivers and analyzed.

Advanced Roadway Delineation and Lighting Systems

Development and Validation of a Luminance Camera

There are many components of the nighttime visual environment that a driver will identify and interpret. Examples of this information presented include overhead lighting, headlights, signage, pavement markings, and billboards. In order to try and understand the information presented to a driver when driving at night, information about luminance needs to be captured. Current methods to capture luminance data are slow, cumbersome, and static snapshots in time that often do not reflect the actual dynamic luminance information that drivers experience. In an effort to gather that information, the purpose of this project was to create a video capture system. Capturing the luminance data dynamically provides researchers with a range of data that can impact a driver's visual environment at night.

In order to capture this information, a luminance camera system was developed using a digital video device. The research team also used a luminance calibration model to process dynamic image information. Reliability and repeatability tests of the video capture system among different users were conducted in order to determine whether resulting data were consistent over time and among multiple users. Concerning the calibration model, a method of calibrating the luminance camera has been established via a semi-automated method involving simultaneous image capture and overlays of pixel data.

The calibration was accomplished using pre-configured settings of image acquisition variables (e.g., camera gain and shutter speed) in a controlled environment. Images were simultaneously captured through the luminance camera and a manufacturer-calibrated Radiant Imaging photometer. Resulting luminance camera images and photometer images were then overlaid through an automated process. Pixel data were 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 and is available at http://scholar.lib.vt.edu/VTTI/. The video capture system continues to be implemented in various ongoing projects as part of the Roadway Lighting Mobile Measurement System (RLMMS).

Luminance Metrics for Roadway Lighting

The goal of this effort was to analyze images from both dynamic and still image collection methods using metrics other than the simple contrast formula ([luminance of target – luminance of background]/ luminance of background). This simple metric is limited in instances when contrast is not evenly distributed across an image. Therefore, this research effort was designed to identify metrics that can better describe the natural nighttime driving environment.

In order to analyze the information-rich data from the luminance camera, the research team reviewed and enhanced luminance metrics for roadway luminance data. Multiple metrics of contrast have been applied to existing images, such as the Weber, Michelson, and Simple contrast measurements. The team

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 an object of interest (e.g., target).

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

An initial analysis of a set of in-house images was conducted, and the calculations for the luminance metrics were automated so that users can select a target of interest and have multiple luminance metrics calculated.

The luminance metric calculations have been applied to a number of studies that include Glare Metric. A final report of the Luminance Metric project is in the final review and editing stage.

Glare Metric

The Glare Metric project allowed 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 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 drivers' heads at approximately eye-level. This allowed the research team to see how much light was reaching the participants' eyes. This provided 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.

A final report is in review and final editing; the report is expected to be released shortly.

Roadway Lighting Design and Safety

This project is an assessment of existing roadway lighting analyses in an effort to establish an initial model describing the relationship between driver safety and roadway lighting design level. This project has and continues to collect an extensive literature review that aids in 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 that 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 that have not been identified.

The model creation is continuing. 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 (i.e., annual average daily traffic [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 Measurement System (RLMMS)

The RLMMS allows 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 captures illuminance, luminance, and Global Positioning System (GPS) information in an effort to monitor lighting levels. The system has the potential to provide valuable data that incorporate illuminance, luminance, and a number of vehicle Controller Area Network (CAN) 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.

The hardware components are all interconnected to a main data collection system. For example, illuminance data are collected by four waterproof Minolta detector heads placed within a "Spider" apparatus and mounted directly on the roof of any vehicle. The heads are positioned horizontally on the vehicle roof such that two illuminance heads are positioned over the right and left wheel paths; the other two meters are placed along the center line of the vehicle. A fifth Minolta illuminance meter is positioned on the vehicle windshield and collects glare data from there. Each of the Minolta heads is connected to a single Minolta T10 body. Data from these units are then sent via Ethernet to the data collection laptop personal computer (PC). A NovaTel GPS device is positioned at the center of the four roof-mounted illuminance meters and attached to the "Spider" apparatus. The GPS device is connected to the data collection box, and the vehicle latitude and longitude position data are incorporated into the overall data file.

Two separate video cameras are mounted onto the vehicle windshield; one collects color images of the forward driving scene, and the second camera collects calibrated luminance images of the forward driving scene. Each camera connects to a stand-alone PC computer, which connects to the data collection laptop. The data collection PC is responsible for collecting illuminance and GPS data and also timestamps the camera PC images. Additional equipment includes buttons for participant responses, CAN connectivity, Spectrometer connectivity, and eye tracker connectivity.

Each component of the RLMMS is controlled by a specialized software program created in LabVIEW™. The entire hardware suite is synchronized through the software program, and data collection rates are currently set at 20Hz. The image capture rate for each camera is set at 7.5 frames per second (fps) of which an average of 3.75 fps is currently achieved. The final output file contains a synchronization index stamp, GPS latitude and longitude data, button/keyboard presses, individual images from each of the cameras inside the vehicle, and the illuminance meter data from each of the Minolta T10s.

The RLMMS has undergone hardware consolidation over the past year, and the amount of hardware components has decreased, which in turn has increased the portability and deployment of the system. The RLMMS has been heavily utilized and has contributed to projects in Anchorage, San Diego, Honolulu, and has been heavily used to characterize the lighting on the Smart Road.

Rural Intersection Lighting Safety Analysis

Research results from the University of Iowa 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 a similar configuration. This research showed the potential safety benefits of lighting at rural intersection locations; however, the data were binary in nature. This meant that crash comparisons were only performed based on whether or not lighting was present (and on). The research did not account for the lighting level or the quality of lighting at the intersection locations. In an effort to identify and enhance the crash information, the same analysis is being carried out using rural intersection locations within Virginia. However, to add to the quality of data, the research team will also physically assess the level and quality of lighting at locations of interest. To add this information to the overall analysis within Virginia, a number of steps are required.

The initial analysis is similar to what was conducted in previous research, which was to identify and locate intersections of interest that have a number of similarities. The research team obtained and used the crash data from the Virginia Department of Transportation (VDOT) crash database, looking at crashes for rural intersections (lighted and non-lighted) from 2003 to 2007. After a review of the data, the research team had to then clean and verify the data such that intersection locations of interest were checked for appropriate lighting, approach configurations, collision counts, collision types, etc. Some intersections of interest were found to contain conflicting information regarding the presence or absence of lighting in or near the intersection. These cases were verified using the Google Maps ™ mapping service to confirm the presence or absence of lighting. A final list of intersections for data collection was created and includes high and low crash intersections (lighted and non-lighted) that are matched with the intersection type (e.g., T-intersection). Data collection is anticipated to begin early 2010.

The next step for identifying the influence of lighting at rural intersection locations will be to measure the illuminance and luminance information at the chosen intersections. This is accomplished by using the

RLMMS, which uses both illuminance meters and the luminance camera. Each intersection will have data collected from every approach in order to establish the quality of lighting (or the absence) at that location. This data will then be incorporated into a model that can potentially establish the effect of lighting quality in relation to crash rates at rural intersections, in addition to other factors.

Visual Information Modeling

Analysis of a driver's nighttime visual environment requires consideration of multiple interrelated variables, including human factors as well as roadway features and lighting. A driver's field of view contains such features as the roadway, the hood of the vehicle, the instrument panel, off-roadway facilities and roadway fixtures (i.e., signs, traffic signals, and pavement markings), and the activities of other road users. From this environment, a driver must continuously draw information about the presence of potential hazards in the roadway, navigate using roadway signage and delineation, and maintain control of the vehicle. Drivers must attend to and select which objects present important information and determine those that are superfluous. Reviewing and identifying, where possible, what attracts a driver's gaze towards an object while driving at night can provide insight into visual behavior.

This research project is attempting to develop a link between driver safety and the visual environment. The project will require integrating new technology in addition to identifying a dynamic driver visual model (DDVM). A DDVM is conceptually a system of rules, statistics, and expectations that can be used to define how a driver collects visual information from the nighttime driving environment. To accomplish this research effort, the research team explored a number of components during a literature review process. The literature review included driver vision and visibility, driver eye tracking, nighttime driver eye tracking, photometric literature, and other visibility models. Once these elements were identified, an initial DDVM framework was created based on a Logistic Regression methodology. The factors can be entered into the logistic regression, and an odds ratio will be calculated. The drawback to this method is that specific odds ratios will be calculated based on specific distances from the object of interest. Defining specific distance points will be derived from the average detection distances collected during experimentation. Standard detection distance increments such as 1,000 feet, 750 feet, 500 feet, 250 feet, and 100 feet will be used.

In order to collect data for the DDVM, the research team had to integrate a number of hardware components that included the Luminance Camera, an Eye Tracker, and the VTTI Data Acquisition System (DAS). This required the creation of a common timestamp among the different data collection components in order to synchronize the data stream. This hardware suite was part of the larger experimental design to capture driver, lighting, and vehicular data.

The research team designed an experiment with data collection components occurring at the VTTI Smart Road and the Texas Transportation Institute (TTI) facility. The VTTI Smart Road portion was designed to include a number of potential target objects appearing in lighted and non-lighted sections of the roadway. The TTI portion will include the impact of signage on driver nighttime visual behavior. The Smart Road data collection was completed in late fall of 2009.

The data analysis portion of the study is currently ongoing and includes a large data reduction strategy. Current efforts have focused on identifying and matching glance information with luminance data, which in turn is synchronized with the DAS information.

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 spring of 2009, VTTI researchers continued to attend Teen Driver Night Programs at three high schools in Bedford County (Montgomery County did not hold spring sessions in 2009). 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, the licensing process, how the driver's education program works, legal issues associated with teen drivers, insurance issues regarding teen drivers, how parents can be effective driving coaches for their teens, and to present current research opportunities at VTTI. Altogether, there were 30 people in attendance in Bedford County for the spring sessions, which was considerably fewer than in the fall 2008 sessions. The attendance in the fall of 2009 was considerably better, with outreach to 295 people, as follows:

- Eastern Montgomery High School - 7 families (20 people)
- Liberty High School - 15 families (35 people)
- Staunton River High School - 14 families (35 people)
- Blacksburg High School - 52 families (115 people)
- Jefferson Forest High School - 15 families (33 people)
- Auburn High School - 15 families (32 people)
- Christiansburg High School - 54 families (125 people)

The Driver Coach research team also attended the Transportation Research Board (TRB) Young Driver Subcommittee annual meeting held in Washington, D.C., in January 2009; the mid-year meeting of the same group in June of 2009 in Washington, D.C.; and a teen driving symposium held in Ann Arbor, MI, in mid-August of 2009. The research team also continued to consult with National Institutes of Health (NIH) sponsors about the research design for Driver Coach. It is anticipated that participants will be enrolled into the monitoring and feedback portion of the Driver Coach study beginning in September 2010. This research directly supports traffic safety research of the Federal Highway Administration (FHWA) and the Department of Transportation (DOT); 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. For these reasons, research into transportation safety for this segment of the driving population is increasing in importance.

The current project entailed a naturalistic driving study whereby 20 older drivers had their private vehicles instrumented with an extensive yet unobtrusive data acquisition system (DAS) for one year each. The last vehicle came off the road in October 2009. Data are continuously being gathered, including the following: four-channel video (driver's face, instrument cluster, and forward and rear roadway images), global positioning system (GPS), lane tracking, lateral and longitudinal accelerometers, gyro yaw, forward radar, and vehicle network information (e.g., brake, accelerator, transmission status). An incident button was also available to participants. In total, approximately 30,000 data files were recorded representing more than 4,600 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. Additionally, 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 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.

Age-Related Driver Difficulties at Intersections

Because visual scanning is accomplished through both head movements and eye movements – particularly during maneuvers such as left turns – their respective contributions to scanning must be separately measured if researchers are to fully understand visual scanning during driving. Information about both head turning and eye movement is contained in the already acquired video data and will be vital in determining whether or not drivers, especially older drivers, exhibit reduced head turning and reduced breadth of eye movements. Similarly, information about both will be vital in determining how the scan patterns of teens may differ from more skilled middle-aged drivers. Although these data can be obtained through manual means, it would be beneficial to have an automated approach to obtain this information.

This project examines the behavior of drivers making left turns at intersections with an emphasis on older drivers compared to younger and middle-aged drivers. Aging drivers have historically been over-represented in multi-vehicle angled impact crashes (resulting from turns at intersections) and had a higher rate of fatality than younger drivers. For example, Staplin et al. (2001) reported that 48 to 55 percent of all fatal crashes involving drivers aged 80 years or over occurred at intersections, which was more than twice the rate for drivers under the age of 50 (23 percent). Of interest is whether older drivers show narrowed visual scanning as they prepare for and initiate their turns (both in terms of the spatial extent of their eye movements and in terms of head-rotation to look). Such reduced scanning has been reported in prior simulator work and in prior experimental work but has not yet been confirmed in the real world via naturalistic driving research. The first phase of this work will examine already collected naturalistic data to determine whether previously reported findings are also seen in natural driving of older drivers at intersections (relative to a sample of teen drivers and their parents). Additional work will be conducted in future phases to ascertain the causes of changes in visual scanning (to confirm "what goes wrong") in order to facilitate the identification of countermeasure approaches for assisting older drivers with this area of driving difficulty.

During this reporting period, we identified the existing naturalistic datasets that would be used. These were the Older Driver and 40 Teen datasets. An Institutional Review Board (IRB) proposal was submitted to the Virginia Tech IRB and received approval. An analysis was conducted to determine if older drivers drove through the same intersections as those in the 40 Teen dataset and to obtain a count of the number. Development of an algorithm for identifying left turns in naturalistic databases was specified, requested,

and begun. Development work is expected to be completed by the end of January 2010. Development of a new capability for applying the Mask (an automated capability for scoring the dataset to quantify head rotation during left turns) was requested, and a separate project was spawned. Development is not yet complete. Development was initiated in a very preliminary way on a protocol for scoring glances (to support the assessment of scanning breadth and level of activity).

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. The ORD is assessed based on the 60 seconds of video prior to a trigger event (or baseline epoch). Therefore, the 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 the 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 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 contained the definition and purpose of the 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 (CMV) 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 U.S. Department of Transportation (U.S. DOT). Forty-six trucks were instrumented with VTTI's data acquisition system (DAS), and 103 CMV drivers participated in this study, resulting in almost 46,000 driving-data hours covering 2.3 million miles traveled during 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 (n=807) and 29 percent of 1,530 randomly selected baseline driving epochs when using a threshold of PERCLOS>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.

This study was published in Traffic Injury Prevention in 2009:
Wiegand, D. M., Hanowski, R. J., & McDonald, S. E. (2009). Commercial drivers' health: A naturalistic study of body mass index, fatigue, and involvement in safety-critical events. Traffic Injury Prevention, 10(6), 573-579.

Commercial Driver Health and Well-Being, Phase II

The purpose of this project is to provide an outreach website for CMV drivers, providing them with information about maintaining a healthy lifestyle as a driver. Studies have indicated that a substantial portion of CMV drivers have an unhealthy body weight. The NSTSCE *Commercial Motor Vehicle Health and Fatigue* study (Wiegand, Hanowski, and McDonald, 2009) examined the BMI and driving performance of 103 CMV drivers. Results of this study found that 28 percent of CMV drivers were overweight, and 53 percent were obese. These drivers were found to have a significantly greater risk of driving while fatigued, not wearing a seatbelt, and being involved in a safety-critical event. However, many CMV drivers' jobs present barriers to maintaining a healthy body weight and overall good health. The NSTSCE Driver Health Tips Website will serve as a single-source information portal for CMV drivers, allowing them to gain information and the support needed for maintaining a healthy lifestyle as a CMV driver. This will serve as a critical outreach vehicle for the NSTSCE, partners, and potential stakeholders.
The NSTSCE Driver Health Tips Website project began in October 2009, and work progressed in several main areas. The VTTI research team has assembled a list of potential stakeholders and has started contacting them to gauge support for a CMV driver-oriented health outreach website and social networking

outreach website. The results of this process will help determine the best course of action as to providing information to CMV drivers and having the largest impact on CMV driver health.

The research team has also started collecting information supporting healthy CMV driver lifestyles. Particular focus is being paid to finding information that lends itself to distribution through social networking media. Examples of this information include video demonstrating exercise equipment that can easily be stored in a commercial vehicle's sleeper berth.

The research team has made progress on methods of delivering health outreach information through social networking media (e.g., Facebook). This is an important step, as the process of implementing a health outreach website through social networking media presents additional challenges in terms of providing stable information and maintaining control over key site elements.

Additionally, VTTI has begun preparing submissions to a Transportation Research Board (TRB)-sponsored, international scope conference focused on CMV driver health and wellness that will bring additional attention to the project.

Case Study on the Impact of Treating Sleep Apnea in Commercial Motor Vehicle Drivers

This project will assess the overall effectiveness of Schneider National's sleep apnea program as well as document two different sleep apnea programs being implemented by truck carriers (Schneider National, Inc. and J.B. Hunt). A sleep apnea implementation manual to include a set of best practices for a successful obstructive sleep apnea (OSA) treatment program will be developed, which may serve as a guide for trucking fleets wishing to implement a sleep apnea treatment program to improve the health of their drivers, reduce crashes and fatigue-related traffic incidents, and reduce health- and safety-related costs. The intent is to distribute this manual to other trucking fleets; VTTI has enlisted the assistance of several other agencies, including the National Institute for Occupational Safety and Health (NIOSH), the Federal Transit Administration (FTA), the National Sleep Foundation (NSF), the American Transportation Research Institute (ATRI), and the American Sleep Apnea Association (ASAA). We anticipate the manual produced in this study will be beneficial to other transportation modalities and industries. Specifically, VTTI will:

1. Evaluate the efficacy of OSA treatment, including automatic positive air pressure (APAP), while CMV drivers are on the job;

2. Assess the safety and health benefits in treating OSA (e.g., reduced crashes and improved health profile);

3. Evaluate the overall return-on-investment (in terms of reduced heath care premiums, lower crash rates, and increased driver retention compared to the costs of treatment);

4. Develop models to predict beneficial health and safety outcomes (i.e., compliance rates, age, gender, etc.); and

5. Develop a set of best practices for implementing and maintaining a successful OSA program for the trucking industry.

Focus group research will also be conducted with drivers and staff involved in the Schneider National, Inc. and J.B. Hunt programs. The purpose of the focus group research will be to assess participants' perceptions and opinions of the program and to gain insight firsthand from those who participated as to what worked, suggested improvements, etc. Findings from this study will provide recommendations as to why carriers should implement a sleep apnea program as well as how they can do so in an effective and efficient manner.

In 2009, the contract for the Case Study on the Impact of Treating Sleep Apnea in Commercial Motor Vehicle Drivers (OSA Case Study) was awarded on September 1 to VTTI. In Task 1 of the project, several institutions were identified by VTTI and the NSTSCE Stakeholders' Committee as potential collaborators in the OSA Case Study (the goal being to leverage the NSTSCE initiative with these partners). In Task 1, VTTI devised a plan for approaching these potential stakeholders and initiated contact and discussions with each organization. VTTI contacted each organization by sending an electronic letter to a point of contact at each organization as well as a follow-up telephone call. Many organizations expressed interest in the OSA Case Study by requesting project updates and agreeing to assist in disseminating the final report. Several organizations, including the FTA, ASAA, NIOSH, NSF, and ATRI expressed interest in NSTSCE and requested additional stakeholder information. Going forward, VTTI researchers will maintain contact with these organizations with project updates and involve them in disseminating the final sleep apnea manual. Task 1 was completed on September 30, 2009. Also in 2009, VTTI developed a work plan that provides the roadmap for conducting the project during Task 2. The work plan details procedures for collecting, organizing, and analyzing the existing data from Schneider National's OSA program. Moreover, the work plan details the methods for recruiting and conducting focus groups with drivers and personnel involved in the J.B. Hunt and Schneider National, Inc. OSA programs. Task 2 was completed on October 30, 2009.

During Task 3 of the project, interim Virginia Tech Institutional Review Board (IRB) approval was granted on September 3, 2009. VTTI prepared all the necessary paper materials needed to conduct the study. This included Virginia Tech IRB approval to conduct this study, informed consent forms for drivers and staff, questionnaires, and focus group procedures. Task 3 was completed on October 30, 2009.

In Task 4 of the project, VTTI will collect data previously gathered by Schneider National, Inc. and Precision Pulmonary Diagnostics (PPD) regarding their OSA program. VTTI obtained permission to collect the necessary data from Schneider National, Inc. and PPD; however, these data are not all in one location nor are they properly formatted. Based on discussion with Schneider National, Inc. and PPD personnel, it was determined that it will take some time for Schneider National, Inc. to provide the necessary identified data to VTTI. Due to the nature of the existing health and medical data, a Certificate of Confidentiality is needed prior to Schneider National, Inc. and PPD sending data to VTTI. This Certificate of Confidentiality has been applied for from the National Institutes of Health (NIH); VTTI is currently awaiting feedback on its status. In Task 6a of the project, drivers and staff involved in the Schneider National Inc.and J.B. Hunt OSA pilot programs will be eligible to participate in the questionnaire and focus group research. Both carriers agreed to allow VTTI to recruit drivers and staff involved in their respective OSA programs. Initial planning and discussions with both carriers regarding focus group recruitment are ongoing.

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