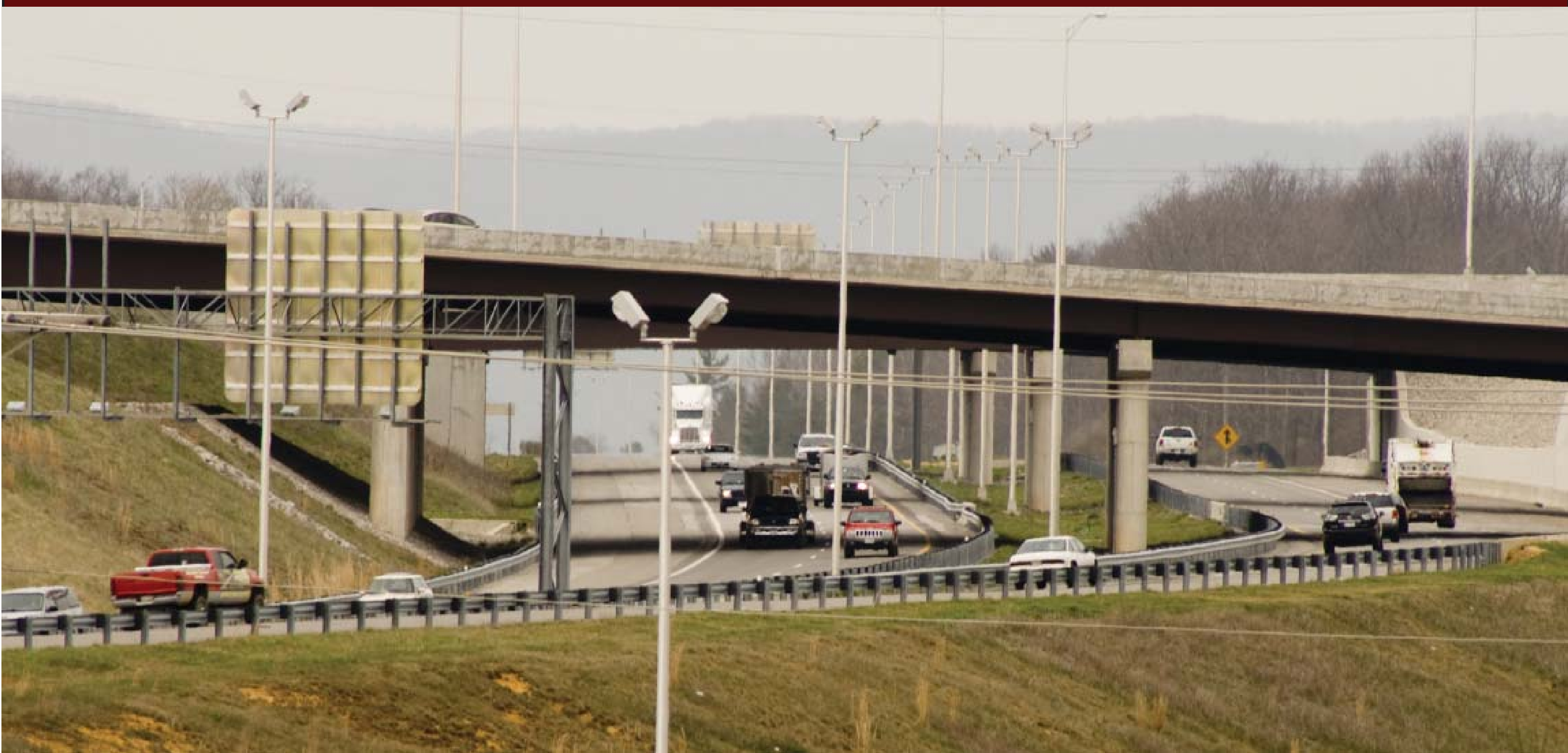

# National Surface Transportation Safety Center for Excellence

## Annual Report

July 2006 - December 2007

The National Surface Transportation Safety Center for Excellence

# Message From the Director

Dr. Tom Dingus

December 31, 2007, marks the conclusion of the first year of the National Surface Transportation Safety Center for Excellence at the Virginia Tech Transportation Institute. The Center was formally awarded to VTTI through the Federal Highway Administration (FHWA) in July 2006.

Senator Warner 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). We were indeed honored on August 30, 2006 to have the Honorable John Warner dedicate a newly constructed 22,000-square-foot building named the National Surface Transportation Safety Center for Excellence (NSTSCE).

On that day, as we embarked on the journey to create NSTSCE, I shared some harsh facts that highlight the magnitude of the transportation safety problem:

- Traffic deaths in the United States are at the highest level since 1990.
- The traffic fatality rate, as in the number of deaths per mile of travel, has increased for the first time in 20 years.
- The United States was for many years the safest place to drive in the world. We dropped to 2nd in 1995 and fell all the way to 9th in 2003.
- Because vehicular crashes do not discriminate by age, they constitute a leading killer based upon years of lost life. For example, newly licensed teen drivers, America's future, are three times as likely to be in a fatal crash than their older counterparts. They are also more likely to die in a car crash than all other sources of disease and accidental injury, combined.
- Drivers over 65 years of age are the second most likely group to die in car crashes. It is particularly important to consider this fact given that the number of drivers over 65 will more than double in the next 25 years.

As director of VTTI and NSTSCE, I also shared my vision to make NSTSCE truly a National Center for Excellence. We are bringing this vision to life by creating research partnerships that transcend bricks and mortar that enable important research and application of findings in new safety countermeasures and policy.

In NSTSCE's first year, we have been successful in utilizing the National Center to develop key stakeholders across the public and private sectors that will help us make unprecedented progress. With commitments of support for our Center from the Federal Highway Administration, the Virginia Department of Transportation, the Virginia Transportation Research Council, the General Motors Corporation and Virginia Tech, our resources have grown to more than $1 million per year. We have developed a sustainable funding model based on research stakeholders and partners that will enable NSTSCE to make a significant difference in transportation safety well into the future far beyond the life of the SAFETEA-LU designation. As you review this report you will see that we are making good progress in answering critical questions that will have a measureable impact on surface transportation safety.

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# Mission of the Center

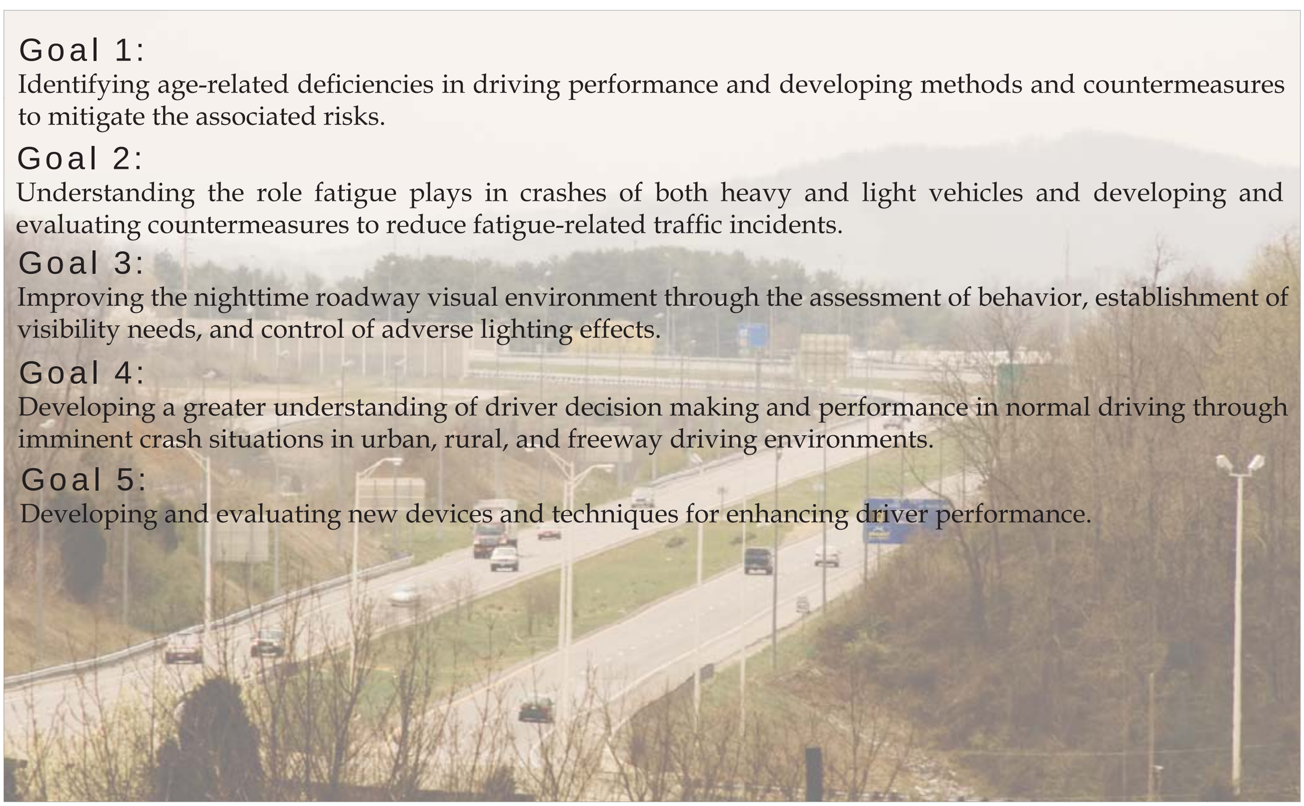
The mission of NSTSCE is defined as using state-of-the-art facilities, including the Virginia Smart Road, to develop and test transportation devices and techniques that enhance driver performance, examine advanced roadway delineation and lighting systems, address age-related driving issues, and address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

Using the strategic plan and the prioritized list of projects, VTTI will target representatives from parties that will derive direct benefit from research conducted through NSTSCE projects. VTTI will strive to obtain Stakeholders' Committee representation for the primary research areas as well as draw membership from a proportionate mix of industry and state and federal agencies. These stakeholder agencies will provide additional resources to maximize the impact of the research conducted under the auspices of NSTSCE.

VTTI markets NSTSCE stakeholder and partnering opportunities to industry groups at industry conferences and organizational meetings. Potential project lists developed during the strategic planning process from the primary research areas needs-analyses will describe opportunities for prospective stakeholders.

# 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 Accomplisments

•Dedicated the National Surface Transportation Safety Center for Excellence (NSTSCE) Building on August, 30, 2006. Senator John Warner delivered the keynote address to more than 500 state, federal, and industry representatives.

•Continued to market stakeholder membership and project directed partnerships to federal transportation agencies and industry.

•Developed NSTCE logo and website to disseminate NSTSCE strategic plan and NSTSCE research results.

•Explored additional opportunities to disseminate research results such as delivering a bi-annual human factors symposium and supporting research publication.

# Crash/Near-Crash Trigger Algorithm

| Invalid Triggers | | | Valid Triggers | | |
|---|---|---|---|---|---|
| Trigger Type | Trigger Frequency | Percent of Invalid Triggers | Trigger Type | Trigger Frequency | Percent of Valid Triggers |
| Forward TTC | 25,536 | 19.3 | Forward TTC | 5,371 | 46.63 |
| Lane abort | 1,206 | 0.9 | Lane abort | 2 | 0.02 |
| Lane solid | 1,209 | 0.9 | Lane solid | 8 | 0.07 |
| Lateral accel. | 3,269 | 2.47 | Lateral accel. | 88 | 0.76 |
| Lon. accel. | 7,937 | 6.00 | Lon. accel. | 3,675 | 31.91 |
| Rear TTC | 866 | 0.66 | Rear TTC | 440 | 3.81 |
| Side blind spot | 1,507 | 1.14 | Side blind spot | 4 | 0.03 |
| Side blinker | 3,845 | 2.91 | Side blinker | 3 | 0.03 |
| Side cutoff | 853 | 0.64 | Side cutoff | 261 | 2.27 |
| Side yaw | 1,396 | 1.06 | Side yaw | 15 | 0.13 |
| Yaw rate | 84,648 | 64.00 | Yaw rate | 1,651 | 14.33 |

One common problem in naturalistic driving research data is extracting all the crashes and near-crashes from a huge dataset without having a large number of false alarms. Typically, an algorithm is required to run through the data (thousands of hours) to look for cases when a driver is suspected to be involved in a crash or near-crash. These cases are then reviewed via video to determine if the driver was involved in crash/near-crash or if the case was incorrectly flagged as a potential crash/near-crash.

For example, during the 100-Car Study over 120,000 kinematic triggers, which were developed to identify potential cases of interest, were identified. Video analysts reviewed each of these triggers and identified approximately 10,000 events of interest. This review took several months to complete with the only value added being the identification of those events that needed to undergo extensive video analysis. 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.

As part of the original 100-Car Study, an attempt was made to use statistical methods to discriminate between valid and invalid kinematic triggers. Due to time and budgetary constraints, a limited group of models with simplistic summary measures were used. This limited group of models did demonstrate an improvement over the use of simple kinematic triggers alone. The objective of this project is to build on this effort and determine better statistical and analytical methods to extract crashes/near-crashes from large naturalistic datasets while keeping misses and false alarms as low as possible.

Table 1 provides a summary of the validated 100-Car kinematic triggers. It shows the trigger type (e.g., forward time-to-collision), trigger frequency, and the percent of triggers that were both valid and invalid. Of particular interest is the yaw rate trigger. Although this trigger accounted for 14 percent of all valid triggers it also accounted for 64 percent of all invalid triggers. As a result, video analysts reviewed over 84,000 erroneous triggers. Improvements in the discriminant ability of the yaw rate trigger could result in substantial resource savings. For example, if classification methods were able to reduce the number of invalid yaw rate triggers by 50 percent, over 40,000 triggers would be eliminated from video validation.

Classification efforts initially will focus primarily on the yaw rate trigger for this reason. Statistical methods have been developed to address the classification of rare events and to make use of continuously collected data – that is to classify curves or functions. Several statistical classification methods will be employed to classify potential cases based upon kinematic data. Case validity as determined by video review will be used to assess classification accuracy. This project is expected to provide the tools necessary to greatly reduce the number of invalid cases that will need to be reviewed to isolate the cases of interest.

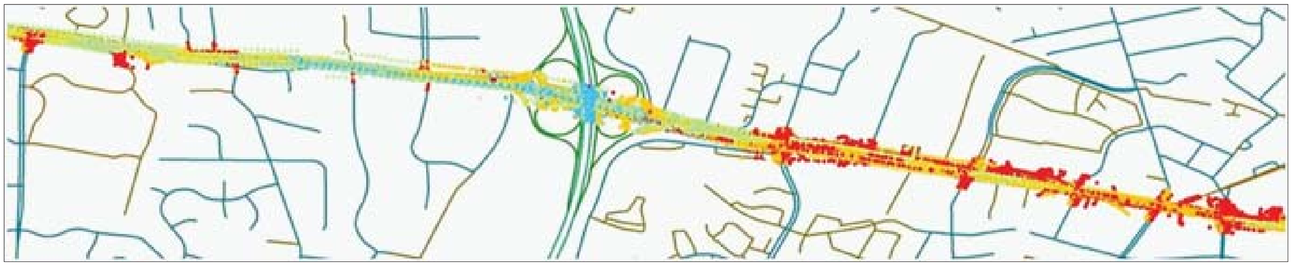
# 100-Car Study Reanalysis

The 100-Car Naturalistic Driving Study (released in 2006) was able to provide new levels of detail in naturalistic driving research with its 40-Terabyte-plus database. The data continues to be a wealth of information for transportation research, providing 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 on 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 is also allowing 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. To date, approximately 30 percent of the trip files have been reviewed (54,850 out of 187,350 readable data files). The initial focus was on the leased vehicles; and the last leased vehicle is currently in progress. In all, reviews have been completed for 24 vehicles.


From the data entered to date, the drivers are recorded as wearing a seatbelt in 81 percent of trip files. Time of day is Daytime for 70 percent of the trip files (includes dawn/dusk); the remaining 30 percent occur at night. Other secondary calculations that will be possible using these data include exposure and risk based on age/gender and miles/time driven. We expect to complete the remainder of this verification in 2008.

# Method for Extracting Rural Driving

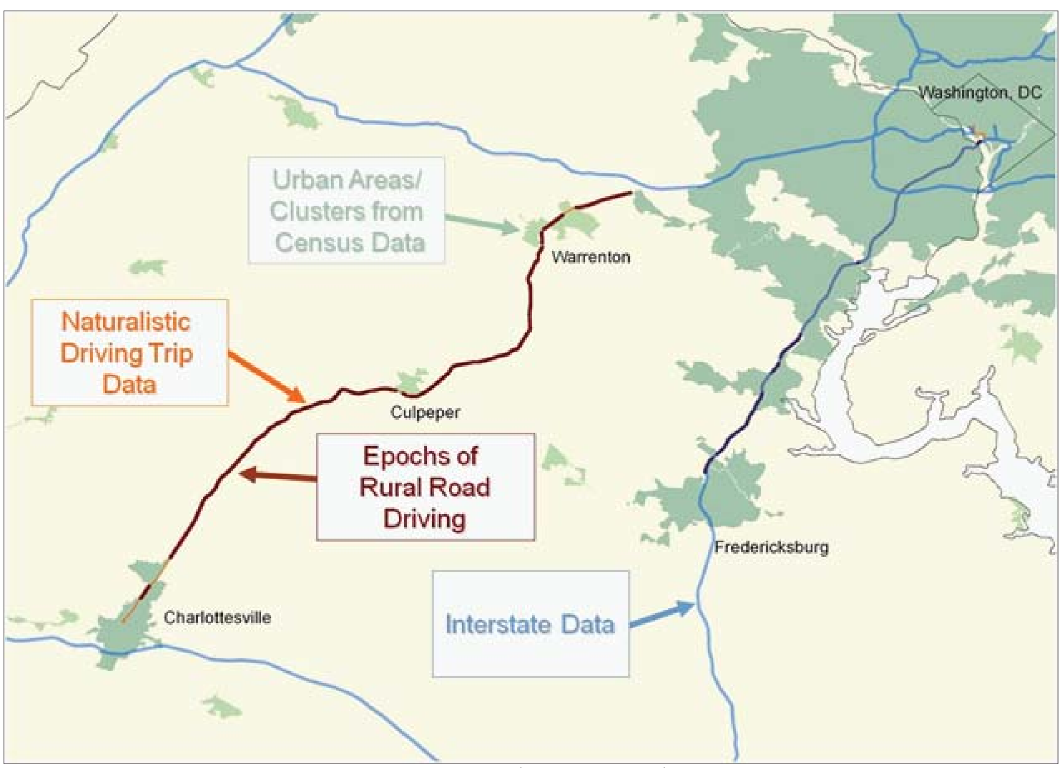


*Trips and vehicle speeds within an intersecting segment of interest*

Naturalistic driving research is able to acquire data from a participant's every day driving habits which can include a variety of environments, including urban, suburban, and rural roads. The ability to extract information from a dataset that pertains to only one type of driving environment can be valuable in conducting a variety of analyses.

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 GIS, database, and numerical processing tools to classify location-based data according to categorical variables of interest. In the present effort, this includes locating rural driving, urban driving, and interstate driving. In the figure below, the urban areas are shaded (green), while rural areas are unshaded. GPS traces for a trip from north of Warrenton, Virginia to Charlottesville, Virginia are illustrated as well as a trip along I-95 with an origin in Fredericksburg, VA. Where driver trips travel on interstates or within urban areas, they are flagged with different codes. The reader can look at the traces and see when the driver was in an urban area, on the intestate or in a rural area. For analysis purposes then the rural data could be extracted from the urban and interstate data for further analysis. 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.

For example, Route 236 is one of the roadways VDOT has indicated as high crash risk. In the figure above, data from many trips along Route 236 from the 100-Car Study are presented. In this depiction, they are coded with vehicle speed at the location by color with blue indicating fast speeds and red indicating slow or stopped. Other variables, such as distance from a lead vehicle or travel direction, could be used to investigate crashes and near-crashes. This data could then be laid over the location of actual crashes from crash data files. This tool is expected to produce a great deal of uses for our naturalistic data analysis.



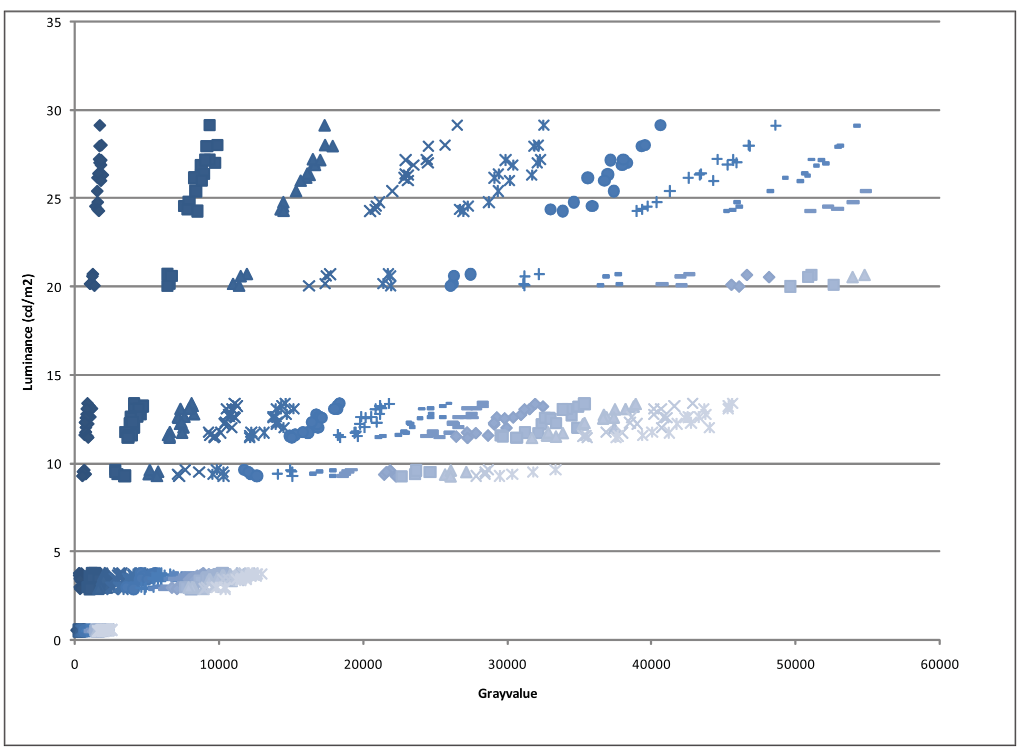

*Data sources and trip examples*

# Luminance Camera Development


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 we 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 the driver experienced. 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 is also in the process of testing a luminance calibration model that can be used to process the dynamic image information. A preliminary field test has been accomplished in an effort to gauge the video capture system and calibration model. A final validation field test and incorporation into the VTTI Data Acquisition System is expected soon.

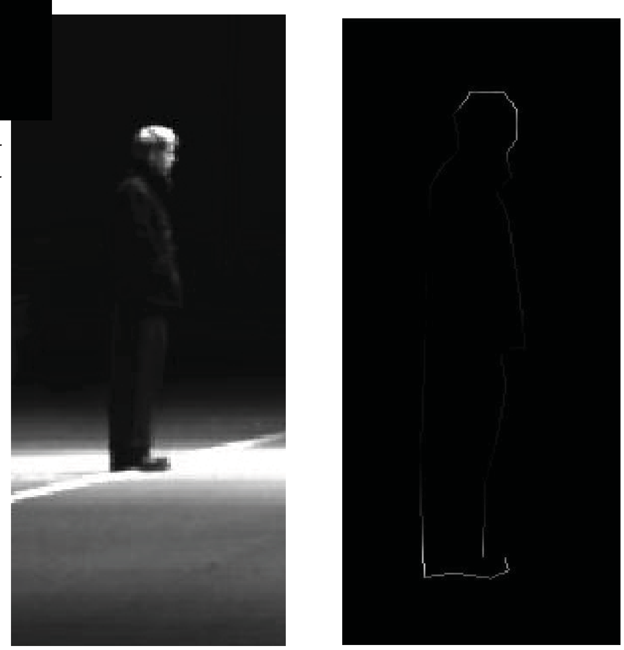



*Calibration Model Analysis*

# Luminance Metrics for Roadway Lighting

To be able to analyze images from both dynamic and still-collection methods, using metrics other than the simple contrast formula ((luminance of target – luminance of background)/ 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. The team has further improved these metrics through the use of Root Sum of Squares, Power Spectrum Signature, and Discrete Wavelet Transform methods in an effort to identify contrast information. These 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 final goal of the project is to incorporate these additional metrics and automation when analyzing the luminance camera data.



*Original and converted images using automated edge detection and Root Sum of Squares contrast analysis*

# Older Driver Data Collection

Because older drivers (75+) generally experience elevated crash and injury risks and the fact that they are an ever-growing portion of the driving population, transportation safety research with this population is becoming more important. The project is a driving study where 20 older drivers will have their private vehicles instrumented with an extensive yet unobtrusive data acquisition system (DAS) for one year each.

Continuous data for this study to be collected include: 4-channel video (synched together and with the other data, includes driver's face, instrument cluster [over the driver's shoulder], 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 will also be available, so when an incident occurs, the participant may press the button, located near the rear-view mirror, which briefly opens an auditory recording channel and places a marker in the data stream for future analysis. We estimate that this study will entail approximately 5000 hours and 130,000 miles of naturalistic driving, generating some 2.5 terabytes of raw video, driving behavior, vehicle kinematics, and crash 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, we are also attempting to implement highly capable accelerometer assemblies in a subset of 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.

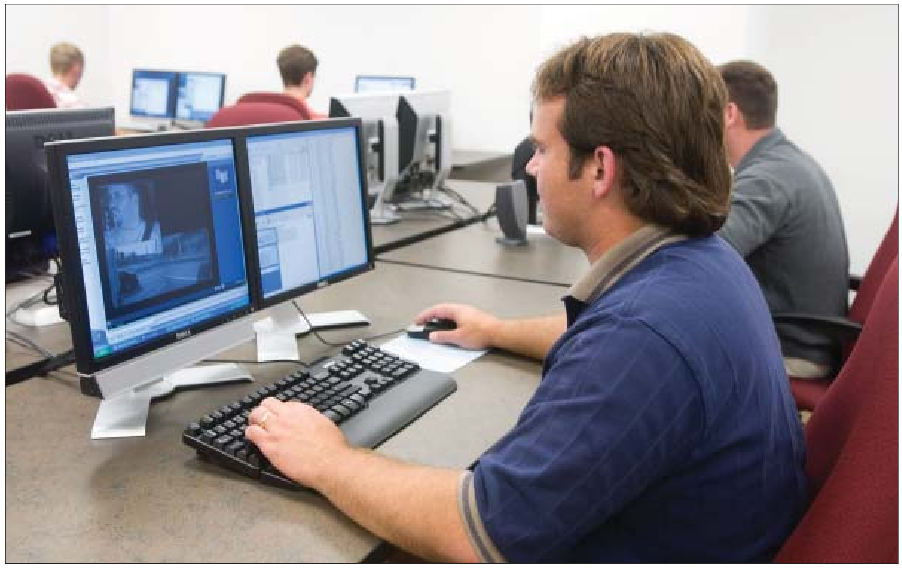
Data show that older drivers, as a group, are among the most safety conscious of all age groups. So why should their per-mile crash rates be elevated above that of middle aged drivers? A major part of the answer is that as people age, they tend to develop decrements in their physical and cognitive abilities. But each person ages individually, so when evaluating older drivers, it is also crucial to determine their unique impairment profiles across a variety of driving-relevant dimensions.

In this study, we are assessing the participants with the following dimesions: visual (including static and dynamic visual acuity, contrast sensitivity, color deficiency, depth perception, vertical and lateral phoria, glare sensitivity, and accomodation), visual-cognitive (including Field of View®, trail making, and visualizing missing information, psychomotor (upper and lower body reaction time, and physical (upper and lower body strength as well as head, neck, and torso flexibility). Also, as part of the study, we will correlate participant impairment profiles against the driving behavior and safety outcome data for relationships or patterns that may lead to improved interventions, training, or cessation protocols.

In addition to assessing drivers' impairment profiles, we also wanted to assess a cohort of 20 individuals who have recently given up driving due to age-related concerns. Our goal with this aspect of the research program is to compare the impairment profiles of the drivers to the non-drivers to learn more about why older individuals choose to give up driving. At this point, we have assessed or scheduled 17 of the 20 non-drivers, and we have installed DAS units (or have in-queue) 14 of the 20 drivers.

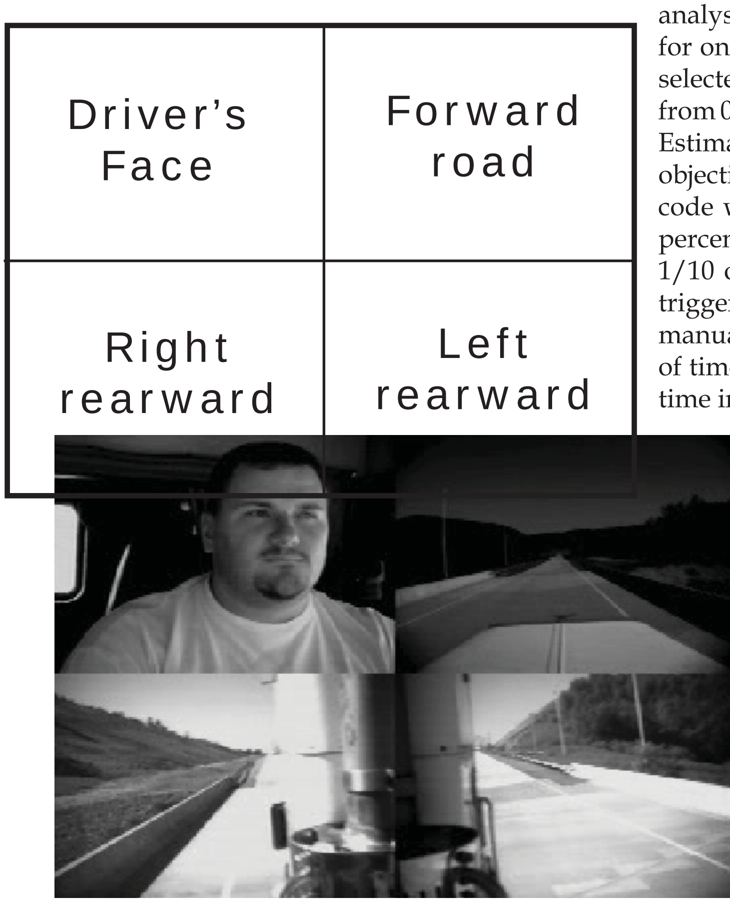
We hope to secure funding for an additional 20 drivers (and 20 non-drivers). Several NHTSA personnel have been approached about funding this study specifically as well as the possibility of joining the NSTSCE as a partner or stakeholder, but none has committed support at this point. Other potential partners are also being sought (e.g., NIH). Since we are in the early stages of data collection, especially for the drivers, we have little in the way of preliminary results at this point. However, we do have preliminary results regarding the reasons why the non-drivers indicated that they gave up driving.

# Drowsy Driver Warning System Field Operational Test Data Analysis



An existing naturalistic dataset from the Drowsy Driver Warning System Field Operational Test (DDWS FOT), conducted by researchers at VTTI, was expanded and analyzed to gain a greater understanding of 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 United States Department of Transportation. 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 (see figure for a screen shot of the video data views) 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 expected to be available on the NSTSCE website in Spring 2008.

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