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Interim Report

The 100 Car Naturalistic Driving Study

Phase I – Experimental Design

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16. Abstract

In developing crash countermeasures and the associated supporting models of driver behavior and performance, particularly those associated with response to threat or imminent crash situations, it is becoming increasingly apparent that data collection in a "naturalistic" setting is a preferred approach for obtaining necessary human factors data. Given the variability and complexity of driver behavior and performance, the random and rare nature of crashes, and the lack of adequate pre-crash data in today's crash record, it is especially important to collect real-world data that includes the crash experience and crash-relevant incidents in sufficient detail and depth. This elucidates the conditions and driver behaviors that precipitate crashes, and supports the development and refinement of crash countermeasures.

The "100 Car Naturalistic Driving Study" is a three-phased effort designed to accomplish three objectives: Phase I, Conduct Test Planning Activities; Phase II, Conduct a Field Test; and Phase III, Prepare for Large-Scale Field Data Collection Effort. This report documents the efforts of Phase I. Project sponsors are the National Highway Traffic Safety Administration (NHTSA) and the Virginia Department of Transportation (VDOT).

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EXECUTIVE SUMMARY

In developing crash countermeasures and the associated supporting models of driver behavior and performance, particularly those associated with response to threat or imminent crash situations, it is becoming increasingly apparent that data collection in a "naturalistic" setting is a preferred approach for obtaining necessary human factors data. Given the variability and complexity of driver behavior and performance, the random and rare nature of crashes, and the lack of adequate pre-crash data in today's crash record, it is especially important to collect real-world data that includes the crash experience and crash-relevant incidents in sufficient detail and depth. This elucidates the conditions and driver behaviors that precipitate crashes and supports the development and refinement of crash countermeasures.

The "100 Car Naturalistic Driving Study" is a three-phased effort designed to meet three objectives: Phase I, Conduct Test Planning Activities; Phase II, Conduct a Field Test; and Phase III, Prepare for Large-Scale Field Data Collection Effort. The large-scale field data collection effort is Phase IV, which is not being conducted under the current contract. The objectives of Phases I, II, and III are accomplished through 30 tasks spanning a 34-month period that began August 2001. This report documents the efforts of Phase I, which consisted of the tasks detailed below. Project sponsors are the National Highway Traffic Safety Administration (NHTSA) and the Virginia Department of Transportation (VDOT).

Task 1: Establish IVI Data Needs

The objective of Task 1 was to specify the details of the pre-crash and near-crash data that will be gathered during the data collection phase. As such, research questions were generated and refined by the NHTSA Task Order Manager (TOM), interested NHTSA researchers, and other stakeholders in this project. The general categories of research questions addressed driver behavior and performance, the distribution of collected driving events, and design of the Phase IV study. The research questions lead to a set of candidate measures derived through a variety of methods including a literature review, a review of database variables (e.g., police-report form variables), and consultations with the TOM.

Task 2: Develop Phase I Test Requirements

The Phase I test requirements were developed iteratively by VTTI with the cooperation of the TOM and stakeholders of this project. The primary Phase I test requirements addressed issues such as the number of cars to be instrumented, the number of camera views, the number of vehicle makes and models to be used, the rate at which data is collected, and so forth.

Task 3: Select Candidate Test Areas and Evaluate Crash Frequency Data

The objective of Task 3 was to determine the number of sites from which data could be collected, the rear-end crash frequency at various geographic locations, and the optimal location of the data collection site from the perspective of project resources. The decision was made to collect data in the Washington, DC/Northern Virginia metropolitan area.

Task 4: Determine Crash Sampling Requirements

A goal of this study was to collect naturalistic data on approximately 10 rear-end crashes. In assessing the utility of the data set, it was decided that continuous rather than triggered data would prove a greater value to the IVI program, other stakeholder organizations, and the development of the Phase IV protocol. From an operational and financial resource perspective, it was determined that 100 vehicles would be instrumented for continuous data collection. Although the number of crashes and other events to be captured cannot be predicted with certainty, it is expected that this number of vehicles, driven by high-exposure drivers, will provide sufficient numbers of crashes and other events (both general and of the rear-end type).

Task 5: Determine Driver/Vehicle Demographic Requirements

After a review of literature summarizing the driver factors that contribute to rear-end crashes, an ideal age and gender distribution was determined:

- Age 18-20 years: drivers = 18 males and 12 females
- Age 21-24 years: drivers = 18 males and 12 females
- Age 25-34 years: drivers = 6 males and 4 females
- Age 35-44 years: drivers = 6 males and 4 females
- Age 45-54 years: drivers = 6 males and 4 females
- Age 55-64 years: drivers = 6 males and 4 females

The above distribution will be sought in the subject selection; however, this distribution will be a goal rather than an essential requirement due to other recruiting factors, such as high-mileage drivers, roadway types traveled, and so forth. In addition, this task was conducted iteratively with Task 9, which provides further information for the selection criteria.

VTTI began determining the vehicle requirements by first establishing the primary criteria that should be considered in selecting vehicles. The ease and cost of data collection system installation is a factor for vehicle selection. Specific vehicle models will be limited to six to accommodate data systems installation requirements. This reduces the number of cable and connector sets, custom mounting brackets, and software configurations required for installation. Model years will be restricted to sequential sets in which the selected models have the fewest design revisions. In addition, using only three vehicle makes increase the commonality of each vehicle's onboard data network, thus requiring fewer software configurations. Recent year models will be selected to enhance the data retrieval available over the vehicle's onboard data network. Additional factors are the crash rate of various body types and the distribution of particular vehicles in the Washington, DC/Northern Virginia area. The vehicle types will be the Ford Taurus/Mercury Sable, Ford Explorer/Mercury Mountaineer (SUV), Toyota Corolla, Toyota Camry (all personal vehicles owned by subjects); and the Chevy Malibu and Chevy Cavalier (leased vehicles which will be loaned to the drivers). The task of choosing vehicle makes, model, and year numbers was conducted iteratively with Task 8, which provides further details of why the vehicles were chosen.

Task 6: Determine Near-Crash Statistical Power Requirements

In order to determine the near-crash statistical requirements, VTTI researchers reviewed four previous research studies that all used an instrumented vehicle in natural driving environments. The frequency counts for collisions, near-crashes, and driver errors are compared as well as the methods used to obtain these events and estimates for the number of collisions, near-crashes, and driver errors that could be potentially collected in this study are presented in the report.

Task 7: Conduct Trade Study – Research Design Parameters/ Sampling Rates/Formats Concept

There will be 20 leased vehicles and 80 privately-owned vehicles in the study. Issues that NHTSA would like to resolve by using two groups of vehicles are the length of time required for the driver to adapt to an unfamiliar vehicle and the feasibility of using leased vehicles in the Phase IV large-scale data collection effort. Also, it is critical to this study to collect pre-crash data for approximately 10 rear-end crashes. Given these constraints, the optimal experimental design is described in the report.

Task 8: Conduct Trade Study to Determine Vehicle Types

Several factors were considered when determining what vehicle types were most optimal. The most critical factors included vehicle type, vehicle demographics, vehicle location, data collection system installation issues, information obtainable from the in-vehicle network, and make and model requirements. These factors are interrelated and are discussed in the report.

With regard to the model year of the vehicles, a review of model year revisions for each of the four selected vehicles indicates the following:

- The Toyota Camry will be selected from the 1997 – 2001 model years. The Toyota Camry model design was static through 2001 with a new model in 2002.
- The Toyota Corolla will be selected within model years 1993 – 2002.
- The Ford Explorer will be chosen out of models years 1995 – 2000 and model year 2001, but only if manufactured by November 2, 2000.
- The Ford Taurus design was static over years 1996 – 1999, and a significantly different model has been on sale for the years 2000 – 2002. Population figures for the Taurus over these periods will be used to decide which sequence is optimum.

In addition, the Mercury Mountaineer is the made on the same assembly line and has the same body style as the Ford Explorer; therefore, the Mercury Mountaineer can be included in the study for the same model years as the Ford Explorer. Likewise, the Mercury Sable is the same body style as the Ford Taurus, and can be included in the list of potential vehicles.

Two additional makes and models will be added as part of the leased vehicle portion of the fleet. Twenty vehicles will be leased from the Virginia Tech Motor Pool: ten 2002 Chevy Malibus and ten 2002 Chevy Cavaliers. Obtaining the leased vehicles via the Motor Pool state contract will save money and significant logistical problems (licensing, leasing agreements, etc.). VTTI will be able to get each Malibu for $277/month and each Cavalier for $244/month.

Task 9: Develop Participant Recruiting Specification

When developing the specifications for subject recruitment, factors considered were: participant age, participant gender, vehicle types driven, the number of miles driven per year, and crash histories. Participant age, gender, annual mileage, and crash histories have important implications when considering the number of rear-end crashes that may occur during the data collection period. The type of vehicles that these participants drive will be very important for subjects recruited to drive their own vehicle, as each vehicle must either be a Toyota Camry or Corolla, Ford Taurus or Explorer. A hypothetical participant recruitment specification plan was developed based on the vehicle type, age group, and gender. Other issues addressed as part of this task were the example screening and classification questions and issues of informed consent.

Task 10: Develop Test Data Collection Plan

Task 10 was a report requirement that was a synthesis of Tasks 1 through 9. Comments were received from the contract sponsor and requested revisions are reflected in this document.

Task 11: Develop Test Reduction, Archiving, and Analysis Plan

The approach to data reduction for the Phase II study takes advantage of the critical incident/near-crash data reduction method as well as current database information. Continuous data will be collected and the critical incident/near-crash method will be applied to the data (meaning that events will be located in the data set via optimized triggers, to be determined through a sensitivity analysis). A data analysis plan was developed based upon the research questions.

The hardware aspects of data collection, back up, and archiving are explained in this report as well as the procedure for retrieving and organizing the data as it comes off the vehicles. Long term data storage is also explained.

Task 12: Development of Data Collection System Requirements

The results of Task 12 follow from the combined performance of Tasks 2 through 11. Additionally, Task 12 results were iterated and integrated with those of Tasks 13 and 15 to drive the Hardware/Software Design Specification. The data system requirements are categorized into four major areas:

1. Schedule Requirements
2. General Design Requirements
3. Performance Requirements
4. Test Vehicle Profile

The requirements under each of these major areas are explained in this report.

Task 13: Review/Test of Technology/Sensor Alternatives

Tasks 13 and 15 were conducted in parallel to determine the most suitable hardware and software alternatives for each subsystem component. The report lists each data collection subsystem and the related component that was analyzed under each subsystem. The data handling and software integration subsystems were addressed in Task 11. The remaining components are addressed in Tasks 13 and 15.

Task 14: Review/Test of Trigger Criteria Methods

Since it was decided early in the Phase I process that continuous data collection was desired, a triggered data set was not needed. Instead, critical incidents in the data set will be located post hoc with editable triggers, which will result in a comprehensive database that can be filtered, scanned, sampled, and so forth, according to researchers' needs. The sensitivity analysis to determine the post hoc trigger levels is explained in Task 11.

Task 15: Trade Study Analysis of Hardware/Software Alternatives

Task 13 determined the available technologies and the factors that were relevant based upon the data collection system requirements determined as part of Task 12. Task 15 completes that effort. This task lists the subsystem component options considered in trade study analysis (as determined in Task 13), the evaluation performed to evaluate the component, the evaluation results, and the decision made for final component selection. The sensors and instruments to measure specified variables are discussed.

It may be noted that several variables will not be collected through hardware. Driver classification and demographic variables will be collected with questionnaires. Detailed vehicle information will be collected prior to the study. In addition, information on crashes will be collected via police report forms.

Conclusion

This report summarizes the efforts of Phase I of the "The 100 Car Naturalistic Driving Study." Phase II of this effort was begun when approval to proceed was granted by the NHTSA TOM on February 22, 2002. Phase II and Phase III reports will be submitted to the sponsor in the summer of 2004.

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LIST OF ACRONYMS AND ABBREVIATIONS

ADVANCE	Advanced Driver and Vehicle Advisory Navigation Concept
CHMSL	Center High-Mounted Stop Lamp
DDDI	Dula Dangerous Driver Index
FARS	Fatality Analysis Reporting System
GES	General Estimate System
ICC	Intelligent Cruise Control
IRB	Institutional Research Board
IVI	Intelligent Vehicle Initiative
MVMT	Million Vehicle Miles Traveled
NAS	Network Attached Storage
NHTSA	National Highway Transportation Safety Administration
NIMH	National Institute of Mental Health
NoVA	Northern Virginia
RE	Rear-End
PAR	Police Accident Report
SUV	Sports Utility Vehicle
TOM	Task Order Manager
UMTRI	University of Michigan Transportation Research Institute
VDOT	Virginia Department of Transportation
VMT	Vehicle Miles Traveled
VNTSC	Volpe National Transportation Systems Center
VTTI	Virginia Tech Transportation Institute

INTRODUCTION

In developing crash countermeasures and the associated supporting models of driver behavior and performance, particularly those associated with response to threat or imminent crash situations, it is becoming increasingly apparent that data collection in a "naturalistic" setting is a preferred approach for obtaining necessary human factors data. Given the variability and complexity of driver behavior and performance, the random and rare nature of crashes, and the lack of adequate pre-crash data in today's crash record, it is especially important to collect real-world data that includes the crash experience and crash-relevant incidents in sufficient detail and depth. This elucidates the conditions and driver behaviors that precipitate crashes, and supports the development and refinement of crash countermeasures.

The *100 Car Naturalistic Driving Study* is a three-phased effort designed to accomplish the objectives listed in Table 1. The six objectives are accomplished through 30 tasks spanning a 34-month period (project start date August, 2001). As the Task 16 deliverable, this report documents all of Phase I, including Tasks 1 through 15. The time frame of Phase I is 15 months. Project sponsors are the National Highway Traffic Safety Administration (NHTSA) and the Virginia Department of Transportation (VDOT).

Table 1. Organization of the Naturalistic Driving study.

PHASES	TASKS	OBJECTIVES
PHASE I: CONDUCT TEST PLANNING ACTIVITIES	1-16	1. Establish Intelligent Vehicle Initiative (IVI) data needs to support rear-end and lane-change crash countermeasure development and benefits estimation. 2. Develop a methodology for data gathering, reduction, archiving, and analysis for field study data collection. 3. Develop and deploy a data collection system.
PHASE II: CONDUCT IVI FIELD TEST	17-27	4. Conduct a naturalistic driving study. 5. Develop a philosophical and mathematical relationship between rear-end crashes and rear-end near-crashes as well as lane-change crashes and lane-change near-crashes.
PHASE III: PREPARATION FOR THE LARGE-SCALE FIELD DATA COLLECTION EFFORT	28-30	6. Make recommendations to IVI for large-scale field study partnerships.

In the following sections, each task is reported in numerical order. Since the tasks were interdependent, each of the task descriptions may refer to other tasks.

TASK 1: ESTABLISH IVI DATA NEEDS

Research Questions

The objective of Task 1 was to specify the details of the pre-crash and near-crash data that will be gathered during the data collection phase. As such, a comprehensive list of research questions was generated and is provided in Appendix A. The NHTSA Task Order Manager (TOM), interested NHTSA researchers, and other stakeholders in this project each created a list of research questions that they felt should be answered by this study. These questions were ranked on two scales by Virginia Tech Transportation Institute (VTTI) researchers and organized into three topic areas. The first ranking put the research questions into priority order, with a '1' indicating that a question will be addressed in the final report, a '2' indicating it will be addressed if time permits, and a '3' indicating it will not be addressed in the final report (Appendix A).

The second ranking procedure indicated whether or not data would be available to answer the research question. A '1' indicates that the currently proposed data collection system will be collecting the necessary data to answer the particular question in an efficient manner. A '2' indicates the data are available; however, there is no simple method to obtain those data. A '3' indicates that the data required to answer the research question are not currently being collected by the proposed data collection system. Finally, a '4' indicates that the question would be better answered in Phase IV rather than Phase II of the current project (Appendix A).

NHTSA and VTTI researchers collaborated on the final ranking of priority and determined which questions would have adequate data to provide an answer. After an agreement had been reached, the research questions ranked a '3' for priority or ranked a '3' or '4' for the ease of data collection were removed from the list and the remaining questions were grouped into three topic areas: Driver Behavior and Performance, Distribution of Events, and Design of the Phase IV Study. The research questions were further grouped within subcategories under each top-level category as follows:

I. Driver behavior and performance
   a. Crash/near-crash/conflict driving scenarios
   b. Distraction issues
   c. Baseline driving and data collection issues
II. Distribution of Events
   a. Rear-end/near-crash/conflict driving scenarios
   b. Distraction issues
   c. Baseline driving and data collection issues
III. Design of the Phase IV Study
   a. Vehicle instrumentation
   b. Data reduction and analysis

A list of research objectives was then developed by consolidating the research questions into ten primary research goals (Table 2). The same general research categories and subcategories listed in the research question document are maintained in this table of research objectives. These 10 goals will provide the basis for the data analysis plan, which was presented to NHTSA and described under Task 11 of this report. Based upon the research questions, a list of measurement variables and an Event Coding Directory were also developed.

Table 2. List of research objectives organized by research category and subcategory.

General Research Category: Driver Behavior and Performance	
Subcategory: Crash/Near-Crash/Conflict Events	
Goal 1	Classify and quantify causal factors and dynamic scenarios involved in each crash type.
Goal 2	Operationally define a "near-crash" using quantitative measures.
Subcategory: Distraction Issues	
Goal 3	Characterize driver distraction as it relates to driver errors, critical incidents, near-crashes, and crash events.
Subcategory: Baseline Driving and Data Collection Issues	
Goal 4	Characterize the differences in driving behavior and/or driver performance between: 1) One week field data and one year of naturalistic driving data 2) One month in leased vehicle versus owned vehicle
General Research Category: Distribution of Events	
Subcategory: Rear-End Event Analysis	
Goal 5	Determine rear-end causal factors and dynamic conditions. For each of the four rear-end (RE) lead-vehicle conditions (stopped >2 seconds, decelerating, accelerating, and moving at a slower constant speed), determine the frequency distribution of the following: vehicle crash encounters, near-crash encounters, and critical incidents 1) Per vehicle mile traveled (VMT); 2) In relation to contributing factors; 3) in relation to corrective actions; and 4) in relation to transition events.
Goal 6	Determine RE dynamics and primary factors; specifically, determine the frequency distribution for the following variables: 1) Per VMT 2) Initial Dynamic Condition/Kinematic Condition 3) Primary contributing/causal factor Crossed with these variables: 1) Rear-end event (crash, near-crash, incident) 2) Rear-end event where lead vehicle changed lanes in front of subject vehicle 3) Rear-end event where subject vehicle changed lanes behind lead vehicle 4) Rear-end event where subject vehicle took corrective action
Subcategory: Distraction Issues	
Goal 7	Determine the distribution of distraction types for each RE lead-vehicle condition (stopped >2 seconds, decelerating, accelerating, and moving at a slower constant speed)
Subcategory: Baseline Driving and Data Collection Issues	
Goal 8	Characterize each of the four RE lead vehicle motion types in relation to Heinrich's triangle.
General Research Category: Design of Phase IV Study	
Subcategory: Vehicle Instrumentation	
Goal 9	Evaluate the performance of the hardware, sensors, and data collection system used in Phase II.
Subcategory: Data Reduction and Analysis	
Goal 10	Evaluate the performance of the data reduction plan, triggering methods, and data analysis.

Variable List

The Task 1 report consisted of a set of candidate measures derived through a variety of methods including a literature review, a review of database variables (e.g., police-report form variables), and consultations with the TOM. The variable list was further expanded in later tasks into an Event Coding Directory providing specific variables and elements. The Event Coding Directory is provided in Appendix B and is described in detail under Task 11.

TASK 2: DEVELOP PHASE I TEST REQUIREMENTS

The Phase I test requirements were developed iteratively by VTTI with the cooperation of the TOM and stakeholders of this project. The primary Phase I test requirements are summarized as follows:

- Upon review of the utility of the pilot test data set, it was decided that continuous, rather than triggered data, would prove a greater value to the IVI program, VDOT, and others interested in the data set. During data reduction, various trigger criteria will be applied to the continuous data stream to isolate near-crashes and incidents (driver errors). One advantage of a continuous data collection system is the opportunity to determine the "best" trigger criterion for each variable, both in the current study and in Phase IV. The data will be filtered for different trigger values to determine the best value for particular event severity levels (i.e., near-crashes, incidents).

- The requirement for continuous data collection affected the vehicle instrumentation, data transmission, and data storage needs of the study. It was determined that, from an operational and financial resource perspective, 100 vehicles could be instrumented for continuous data collection.

- Several considerations have been made with regard to whether privately-owned or leased vehicles should be included in the study. The final decision was to include 80 privately-owned vehicles and 20 leased vehicles. NHTSA is interested in a within-subject comparison of driver performance in privately-owned versus leased vehicles. In addition, the option of a leased vehicle will provide flexibility with regard to subject recruitment. Specifically, leased vehicles will be assigned to subjects who are highly desirable from the standpoint of various study criteria but who do not drive one of the selected vehicle models.

- The use of leased vehicles will also enable the study to gather data on driver adaptation to new vehicles. To further expand this type of data and to increase overall exposure (and thus the potential output of crash data) in the study, the 20 leased vehicles will be provided to 20 of the 80 own-vehicle subjects for an additional thirteenth month of data collection.

- A goal of the study is to collect detailed naturalistic and reconstructive information on approximately 10 rear-end crashes. This may include subject vehicle striking and subject vehicle struck crashes. The instrumentation suite and data collection methodology will be designed to provide sufficient data for both subject and vehicle role in rear-end crashes.

- An additional goal of the study is to evaluate lane change maneuvers. This requires that sensors be placed on each side of the vehicle to detect the presence of vehicles on each side of the subject vehicle. For this reason it was decided that additional sensors would be added to the leased vehicle fleet only. Resources will not permit the addition of side sensors to the privately-owned vehicles.

- A maximum of six (6) vehicle models will be employed in the study. The justification for this decision and the specific models in detail is under Task 8. Briefly, the makes and models will be:
  - Personal vehicles
    - 1996-2002 Ford Taurus
    - 1995-2001 Ford Explorer
    - 1993-2002 Toyota Corolla
    - 1997-2001 Toyota Camry

- Leased/Loaned vehicles
    - 2002 Chevy Malibu
    - 2002 Chevy Cavalier

  In addition, the Mercury Mountaineer is the made on the same assembly line and has the same body style as the Ford Explorer; therefore, the Mercury Mountaineer can be included in the study for the same model years as the Ford Explorer. Likewise, the Mercury Sable is the same body style as the Ford Taurus, and can be included in the list of potential vehicles.

- Several options were considered for the number and locations of cameras. To meet the study objective of reconstructing rear-end crashes (both striking and struck), both forward and rearward-facing camera views are essential. However, the National Institute of Mental Health (NIMH – to issue the Certificate of Confidentiality), the Office for Human Research Protections (as the Federal oversight organization), and the Virginia Tech Institutional Review Board (IRB) prohibited the use of camera views that would show vehicle occupants other than the driver, thus limiting camera use. To meet both requirements, an instrumentation suite with five cameras will be used. Two cameras will be mounted from the rear-view mirror: one looking forward, and the other facing to the left and rearward to capture the driver's face and the view out the left side/rear of the vehicle. A third camera will be mounted near the Center High-Mounted Stop Lamp (CHMSL) and will face rearward and to the left. A fourth camera will be mounted on the ceiling of the vehicle interior near the dome light, and will look over the driver's shoulder and show the driver's hands and feet. A fifth camera will be mounted on the passenger side A-pillar and record the right side of the vehicle. Figure 1 depicts these camera views. Since data reductionists will need to view all five video channels simultaneously, two quad-splitters will be used to fuse the video images into a single, compartmentalized image where each camera is represented in one of five locations (Figure 2). Capturing the five camera views is feasible within the video bandwidth limitations.

- Striking and struck rear-end crash data will be collected using both forward- and rear-facing Vorad radar sensors to collect range/range-rate information.

- The five camera views will be recorded at 30 Hz (Figure 1). Driving performance data will be collected at 10 Hz. The justification for these decisions is provided in Task 8.

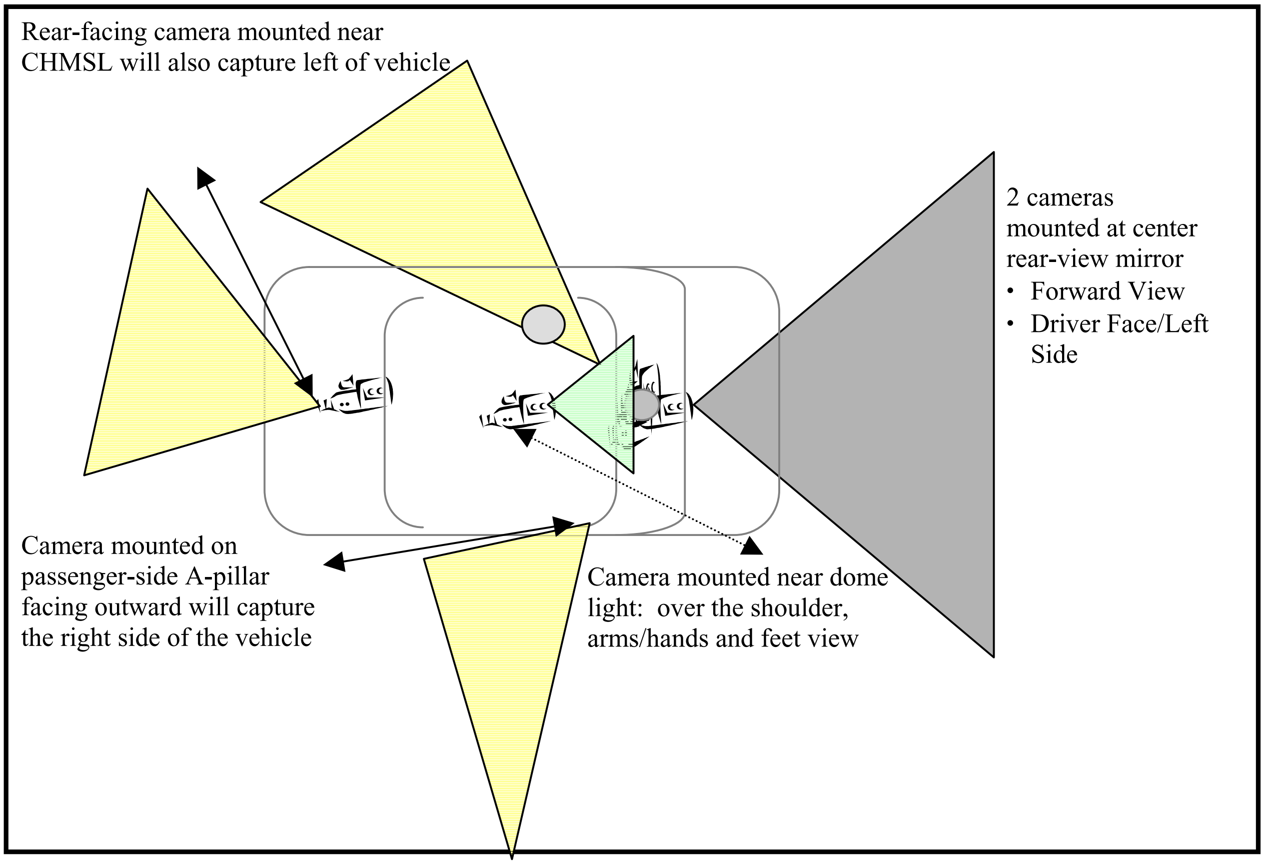

Figure 1. The five camera views to be recorded in the instrumented vehicle. (1) forward view, (2) driver face/left side of vehicle, (3) rear-facing view, angled to the left to capture left side activity, (4) over the driverís shoulder view capturing the steering wheel, instrument panel, and the driverís hands and feet, and (5) right side view.

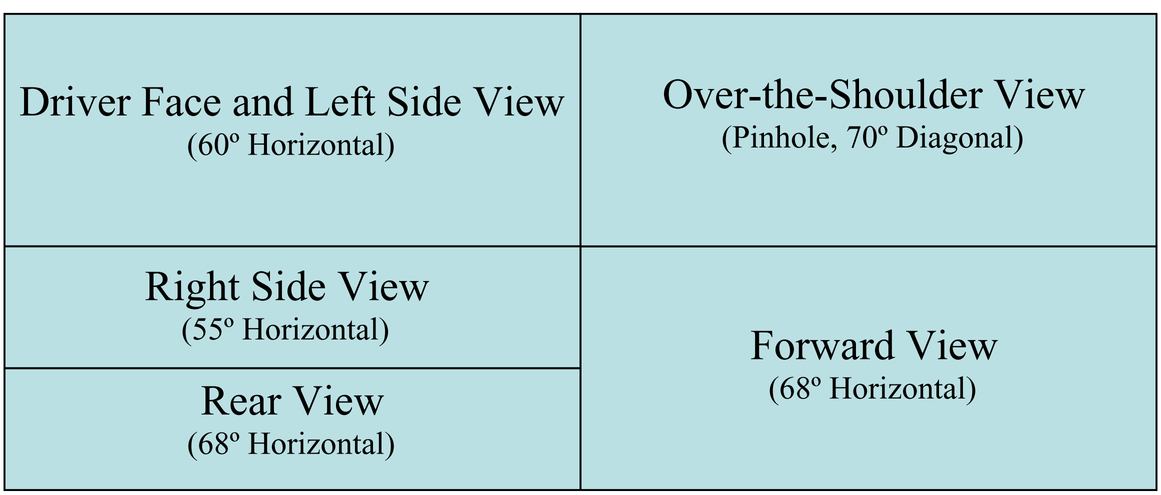

Figure 2. Diagram of simultaneous presentation of five camera views.

- Data will be transferred by wire cable from all subjects' vehicles to a roving 'base station' located in VTTI experimental vehicles. To make this feasible within the study budget, most of the vehicles must be parked in centralized locations for data downloading purposes. Thus, vehicle parking location (work and/or home) is an important consideration in subject selection. Data will be downloaded at least once per week. A "snippet" of driving data from each vehicle will be downloaded wirelessly via cellular telephone every two to three days to assure that the data collection system is performing to specification.

- An automatic incident notification system will be provided for each vehicle. The collision force criterion will be a sustained g-force of 2.5gs over 1.2 msec on any of three axes. G-forces meeting this criterion will activate a call to a VTTI researcher. Voice contact with the driver will be attempted and appropriate services and personnel will be contacted. This may include police/ambulance (911) and NHTSA crash investigation personnel (i.e., the NASS Go-Team, CIREN). While the driving participant may benefit from this service, there will be no guarantee of service in the event of a crash.

- VTTI programmers will develop a software program to obtain data for normalized lane position and Boolean lane departure information. The system will utilize machine vision using the forward camera view to detect lane edges through the combined use of fuzzy logic and statistical probabilities. Normalized lane position will be collected at 10 Hz with a resolution of +/- 2 inches.

- Research questions were generated in cooperation with the TOM, interested NHTSA researchers, and VTTI researchers. The data reduction plan is presented as Task 11 of this report.

- As discussed previously, a variable list and Event Coding Directory have been developed to describe all the measures that will be collected by the data collection system (Appendix B).

- Raw data, including video data, will be saved on DVDs and transferred to a server at Virginia Tech to be reduced by trained data reduction analysts. The post-video-reviewed, reduced electronic data will be saved on the server and backed up using DVDs (at least two copies). This data set will be used to analyze the primary study research questions and potentially many other important research questions. Both raw and reduced data will be saved and will be accessible to other interested researchers.

TASK 3: SELECT CANDIDATE TEST AREAS AND EVALUATE CRASH FREQUENCY DATA

Prior to the kick-off meeting (August 22, 2001), personnel at VTTI examined several issues regarding candidate test areas. A major issue was the number of test areas. Researchers were of the opinion that monitoring multiple sites would not be possible in light of the project timeline, logistics, and financial resources.

Another issue was the crash rate in the Washington, DC/Northern Virginia (NoVA) area. The study objective is to capture approximately 10 rear-end crashes and as many other crashes as possible. Preliminary estimates of the number of rear-end crashes that could be expected to have occurred in the Washington, DC area over the past six years is presented in Table 3. These data were derived by calculating the national urban (area population ≥ 50,000) rear-end crash rate per 100 million vehicle miles traveled (using the General Estimates System, GES, databases and the Highway Statistics manuals), then calculating the number of vehicle miles driven in the Washington, DC urban area (using the Highway Statistics manual). These numbers were then multiplied to provide an estimate of the number of rear-end crashes for the Washington, DC urban area for a given year.

Table 3. Expected number of rear-end crashes in the Washington, DC metropolitan area, 1994-1999.

	1994	1995	1996	1997	1998	1999
GES urban rear-end crash rate per 100 million VMT	59.4	56.9	57.5	55.7	53.1	63.2
Annual vehicle miles traveled, DC urban area, 100 millions	284.4	289.0	290.2	292.6	298.0	299.4
Rear-end crashes expected, DC urban area	16,893	16,454	16,690	16,294	15,838	18,929

The Washington, DC metropolitan area is considered ideal in terms of logistics. Virginia Tech has a satellite campus and facility in Falls Church, Virginia next to the Falls Church Metro station. A VTTI Senior Research Scientist is located in the area to oversee the efforts there. VTTI is establishing a support subcontract with a company specializing in auto electronics installation and management (e.g. an auto stereo or mobile radio installer). The installer subcontract will support the full duration of the study, including equipment de-installation at the completion of data collection. The 20 leased vehicles will be equipped in Blacksburg by VTTI technicians; the 80 subject-owned vehicles will be equipped by the installer subcontractor in Northern Virginia. Subjects will bring their vehicles to the installer's facility and the vehicles will be instrumented while the drivers are at work and then picked up at the end of the day.

TASK 4: DETERMINE CRASH SAMPLING REQUIREMENTS

A goal of this study is to collect naturalistic data on approximately 10 rear-end crashes. In assessing the utility of the data set, it was decided that continuous, rather than triggered data, would prove a greater value to the IVI program, other stakeholder organizations, and the development of the Phase IV protocol. From an operational and financial resource perspective, it was determined that 100 vehicles would be instrumented for continuous data collection. Although the number of crashes and other events to be captured cannot be predicted with certainty, it is expected that this number of vehicles, driven by high-exposure drivers, will provide sufficient numbers of crashes and other events (both general and of the rear-end type).

Several techniques were employed to ensure the presence of a reasonable number of crashes in the data set. First, as described in the previous section, using the metropolitan Washington, DC area as the data collection site increases the probability of encountering a rear-end crash in the vehicle fleet. The impact of this urban environment on the crash rate estimate is discussed in the next section. Second, instrumentation was added so that data could be obtained for both struck and striking vehicle crashes. This essentially doubles the number of rear-end crashes for which there will be usable data.

Third, it was decided that the subject sample could be systematically biased with regard to the number of vehicle miles traveled. It was agreed that a sample of drivers who average 27,000 miles of driving per year would be used. This increases the exposure of the vehicles to possible crashes.

Fourth, the sample will also be systematically biased by age. Younger drivers are over-represented in rear-end crashes and thus more of these younger drivers will be sampled relative to older drivers. *Traffic Safety Facts* (NHTSA, 1999) provides the crash rate per 100,000 drivers for crash types including fatal, injury, and property-damage only by age group (Table 4). As shown, the crash rate for all drivers in 1999 was 5,980 drivers per 100,000. However, younger drivers were greatly over-represented in crashes.

Table 4. Crash rates per 100,000 drivers (*Traffic Safety Facts*, NHTSA, 1999).

Driver Age	Crash rate per 100,000 drivers
All drivers:	5,980
16-20:	15,356
21-24:	9,057
25-34:	7,047
35-44:	5,408
45-54:	4,467
55-64:	3,697

Given the data in Table 4, the probability of crashes can be increased by recruiting more drivers in younger age groups. Specifically, if there are 30 drivers in the 18-20 and 21-24 age groups and 10 in each of the other categories, the estimate of crash rates increases as shown in Table 5 below.

Table 5. Calculation of crash rate for an age biased sample of drivers.

Driver Age	Number of Drivers	Rate Calculation
18-20	30	0.3 X (15,356/5980) = 0.7704
21-24	30	0.3 X (9,057/5980) = 0.4545
25-34:	10	0.1 X (7,047/5980) = 0.1784
35-44:	10	0.1 X (5,408/5980) = 0.0904
45-54:	10	0.1 X (4,467/5980) = 0.0747
55-64:	10	0.1 X (3,697/5980) = 0.0618
Total Rate Multiplier for Age Biased Sample		**1.6302**

The above calculations are based upon the number of drivers in the population independent of the vehicle miles traveled for each of the age groups shown. There are some differences in the average miles traveled for each age group, particularly for the older age group. However, it is believed that this calculation represents a reasonable overall estimate of the increase in crashes due to the biased sample. Thus, in the calculations presented in Task 4, an “age” multiplier of 1.63 was used as part of the calculation to estimate the crashes that will occur during the course of this study.

Calculations using several different references and data sources were used to estimate the number of police-reported rear-end crashes. These calculations are described in the following sections.

Crash Rate Calculation 1

The first crash rate calculation is based on the preliminary crash rate in the Washington, DC metro area for 1999 provided in Task 3, which is thought to be slightly conservative. An initial assumption is made that 100 vehicles will be on the road for 12 months.

- For 100 drivers who drive 27,000 average miles per year (high mileage biased sample), this will total 2.7 million miles of data collected.
- The GES rear-end urban crash rate reported in the Washington, DC metro area for 1999 was 63.2 per 100 million vehicle miles traveled (MVMT).
    - 63.2 x 0.027 = 1.71 police-reported rear-end crashes
- If the sample is biased toward younger drivers, the collision rate is multiplied by 1.63 (based on *Traffic Safety Facts* and data presented in Task 5).
    - 1.71 x 1.63 = 2.79
- If the 20 leased vehicles stay on the road for an additional month for experimental design reasons (see Task 7), the collision rate is multiplied by 1.016.
    - 2.79 x 1.016 = 2.83
- If vehicle exposure includes striking and struck, the collision rate is multiplied by 2.
    - 2.83 x 2 = <u>5.66</u>

This number is lower than the goal of approximately 10 rear-end crashes. However, Washington, DC crash rate estimates are considered conservatively calculated. More importantly, it does not include non-police-reported crashes, which are thought to be half, or more, of all rear-end crashes, and which will be captured by the present study. These factors make the goal of approximately 10 rear-end crashes (police-reported plus non-police-reported) very realistic.

Crash Rate Calculation 2

As a second calculation, data provided by Knipling, Wang, and Yin (1993) are used (Table 6). This data is derived from GES and provides the rate of striking and struck vehicle crashes for male and female drivers.

Table 6. Rate of striking and struck vehicle crashes for male and female drivers.*

Role of Vehicle	Male Drivers	Female Drivers
Striking Vehicle	61.4 per 100 million VMT	61.5 per 100 million VMT
Struck Vehicle	62.8 per 100 million VMT	86.9 per 100 million VMT

*Adapted from Knipling, Wang, and Yin (1993).

Using this crash rate information, an estimated crash probability can be calculated (Table 7). The estimate is based on 60 percent of the drivers being men, and 40 percent of the drivers being women. The estimate assumes that high mileage drivers (27,000 miles per year on average) will be recruited and that 20 leased vehicles will be kept on the road for an additional month. This example does not account for the bias that will be introduced into the sample by recruiting younger drivers.

Table 7. Rate of striking and struck vehicle crashes for male and female drivers in Phase II.

Role of Vehicle	Male Drivers	Female Drivers
Striking Vehicle	1.01	.68
Struck Vehicle	1.03	.95

From Table 7, one can see that the sum of the rates is 3.67:

- If the sample is biased toward younger drivers, the collision rate is multiplied by 1.63 (based on *Traffic Safety Facts* and data presented in Task 4).
  - 3.67 x 1.63 = 5.98
- To account for the higher rear-end crash rate in the Washington, DC/NoVA area, multiply by 1.03.
  - 5.98 x 1.03 = <u>6.16</u>.

Again, this number is lower than the goal of approximately 10 rear-end crashes; however, the inclusion of non-police-reported rear-end crashes should push the number to or above the goal.

Crash Rate Calculation 3

Crash rate calculations 1 and 2 are for 12 months of data collection for 100 vehicles plus an additional month for the 20 leased vehicles. An alternative that would increase the crash probability would be to keep 60 of the privately-owned vehicles on the road for another month as well.

VTTI will instrument the same 80 privately owned vehicles and 20 leased vehicles. At the end of 12 months, the drivers who had the 20 leased vehicles would return them to be used by 20 of the drivers who were previously driving privately-owned vehicles (see Task 7 for the experimental design justification for this procedure). Originally, it was supposed that the other 60 privately-owned vehicles would be de-instrumented. However, an alternative scenario that would add more miles of data collection to the study is that the other 60 privately-owned vehicles would also continue on the road for an additional month. Therefore, there would be 100 vehicles on the road for 12 months and 80 vehicles on the road for an additional month. This would result in 2.88 MVMT. With this change, the resulting rate of striking and struck vehicle crashes for male and female drivers in Phase II (Table 5) would increase to 3.86 (i.e., by summing the four cells and accounting for the additional mileage).

Thus, using the basic calculations from the previous approach again:

- If the sample is biased toward younger drivers, the collision rate is multiplied by 1.63 (based on *Traffic Safety Facts* and data presented in Task 5).
  - 3.86 x 1.63 = 6.29
- To account for the higher rear-end crash rate in the Washington, DC/NoVA area, multiply by 1.03.
  - 6.29 x 1.03 = <u>6.48</u>

As shown, the additional data collection for the study adds an increase in the probability crash rate without adding considerable cost. Therefore, it is proposed that the additional data be collected *if* significantly fewer than 10 rear-end crashes are present at the end of the 12 month data collection period. The option of collecting additional data is also described in the experimental design considerations discussed in Task 7. Data collection of 2.88 MVMT is also used in a fourth crash rate calculation.

Crash Rate Calculation 4

Another calculation of expected rear-end crashes is based upon data by Wang, Knipling, and Blincoe, 1999. Their analysis used GES and Highway Statistics data from 1989 to 1993. They found that striking vehicle crashes in which the lead vehicle was stopped accounted for 48.85 crashes per 100 MVMT. In addition, striking vehicle crashes in which the lead vehicle was moving accounted for 23.07 crashes per 100 MVMT. Assuming the same rate for struck vehicles, the total rate of these crashes is 143.84 per 100 MVMT.

- Assuming the same rate for struck as for striking vehicle crashes, multiply by 2.
  - 71.92 x 2 = 143.84
- Assuming that 2.88 MVMT will be collected.
  - 143.84 x .0288 = 4.14
- If the sample is biased toward younger drivers, the collision rate is multiplied by 1.63 (based on *Traffic Safety Facts* and data presented in Task 5).
  - 4.14 x 1.63 = 6.74
- To account for the higher rear-end crash rate in the Washington DC/NoVA area, multiply by 1.03.
  - 6.74 x 1.03 = <u>6.94</u>

With the addition of non-police-reported crashes, the above calculations further support the projection of approximately 10 rear-end crashes in the study.

TASK 5: DETERMINE DRIVER/VEHICLE DEMOGRAPHIC REQUIREMENTS

Driver Demographic Requirements

Age and Gender

As explained in the previous section, age has been shown to be a factor with regard to the likelihood of being struck or striking in a rear collision. Overall, Wiacek and Najm (1999) found that drivers less than 24 years of age are overly involved in rear-end collisions. They represent 21 percent of all drivers, but 30 percent of drivers involved in rear-end crashes. Conversely, drivers over age 64 are under-involved in rear-end collisions. They represent 13 percent of all licensed drivers, but account for 6 percent of all rear-end collision involvements. A review of the 1998 GES database by Najm (1999) found that the age groups with the highest probability of driving the striking vehicle in a rear-end crash is 18-24 years of age and 75 years and older. The 25-74 year age group is more likely to be in a struck vehicle. General figures for all crash types show that drivers aged 16 to 24 years represent roughly half of crash involvements, drivers aged 25 to 54 years represent roughly 25 percent of crash involvement, drivers 55 to 64 years represent 15 percent of crash involvement, and drivers aged 65 years and older represent roughly 10 percent of crash involvement *Traffic Safety Facts* (NHTSA, 1999).

With regard to gender, males are slightly over-represented in rear-end collisions (Figures 3 and 4). They constitute 53 percent of the driving population, yet constitute 60 percent of all involvements in rear-end crashes. In addition, Knipling, Wang, and Yin (1993) found that males are slightly more likely to be in the striking vehicle whereas females are much more likely to be in the struck vehicle (Table 8).

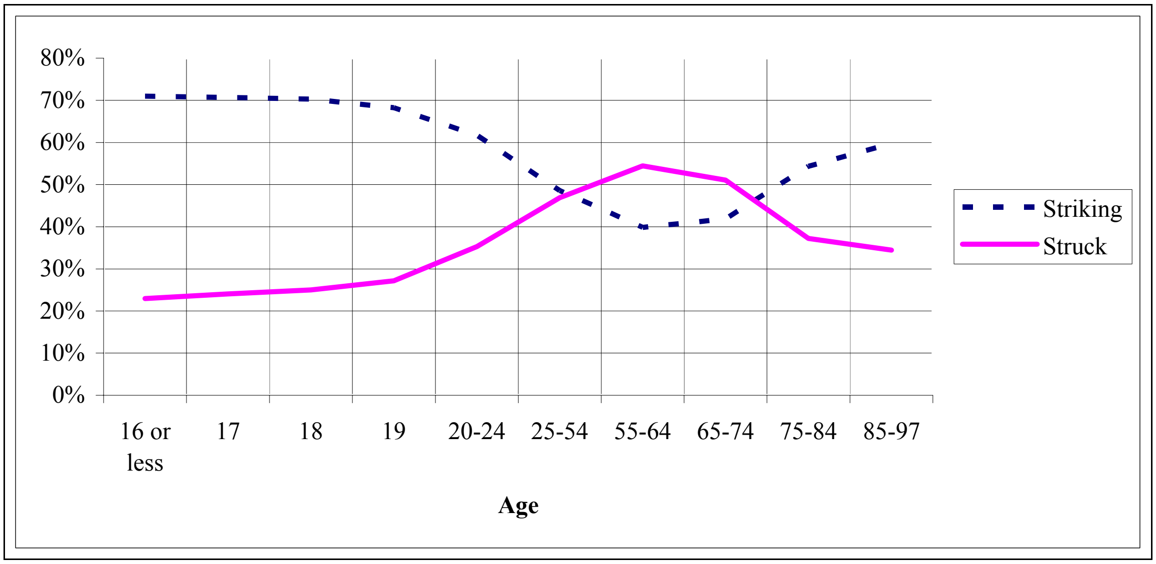

Figure 3. Males' role in rear-end crashes (Najm, 1999).

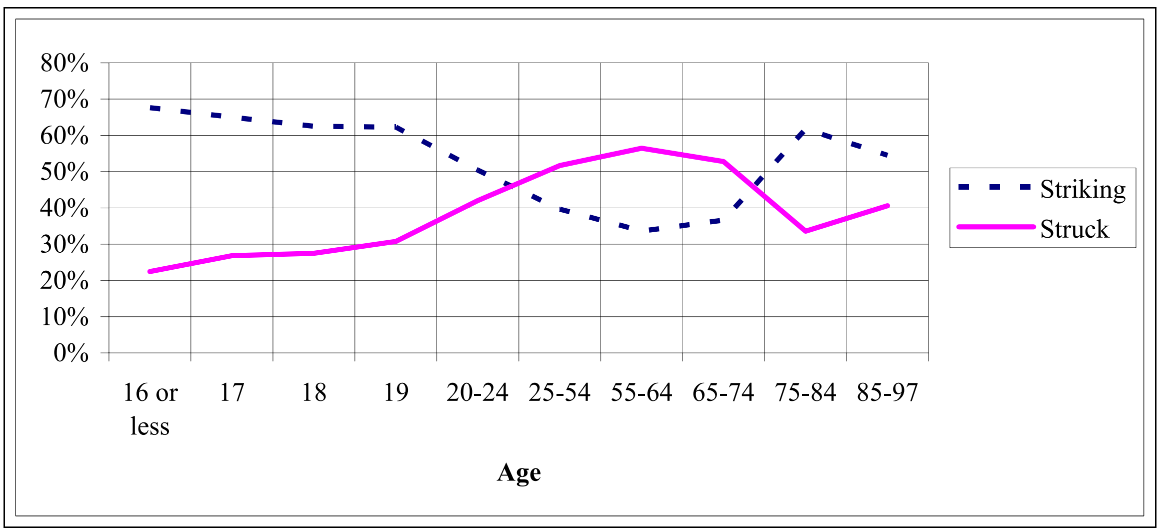

Figure 4. Females' role in rear-end crashes (Najm, 1999).

Table 8. Rate of striking and struck vehicle crashes for male and female drivers.*

Role of Vehicle	Male Drivers	Female Drivers
Striking Vehicle	61.4 per 100 million VMT	61.5 per 100 million VMT
Struck Vehicle	62.8 per 100 million VMT	86.9 per 100 million VMT

*Adapted from Knipling, Wang, and Yin (1993).

Considering the variables of age and gender presented, an ideal age and gender distribution for subjects in the study is as follows:

- Aged 18-20 years: drivers = 18 males and 12 females
- Aged 21-24 years: drivers = 18 males and 12 females
- Aged 25-34 years: drivers = 6 males and 4 females
- Aged 35-44 years: drivers = 6 males and 4 females
- Aged 45-54 years: drivers = 6 males and 4 females
- Aged 55-64 years: drivers = 6 males and 4 females

The above distribution will be sought in the subject selection. Of course, given the many other subject selection criteria and potential difficulties recruiting these subjects, the above should be considered as a goal rather than an essential requirement.

Driver's License
Drivers are required to have a current, valid license in order to participate in the study.

Driver's Health Status
There will be no health status requirements for participation in the study; however, health survey information will be obtained prior to participation (e.g., visual acuity, hearing ability, pregnancy status, eye-surgery status, general health status, and medications). Drivers with serious health issues (e.g., which might jeopardize their ability to complete one year of data collection) will not be included in the study.

Miles Traveled
Recruitment of drivers who are high mileage drivers (average of 27,000 miles per year) is a requirement. Related to this, project results will be more useful if each vehicle is operated entirely by the selected primary driver. Therefore, primary drivers expecting the least mileage usage by other drivers are preferred.

Occupation
Drivers who have occupations that require a high number of miles will be specifically recruited (e.g., real estate agent, sales persons). As an exception, commercial vehicle drivers or professional drivers with mostly intercity highway driving will be excluded from the study. However, some local couriers may be selected, such as pizza delivery persons. These drivers receive no special training or licensing, and likely are fairly typical of other drivers (of the same demographics) in their driving behaviors and safety risks.

Driving History/Record
Recruitment of drivers with a history of crash involvement is a requirement. Therefore, drivers will be asked about their prior crash involvement.

Travel Mix of Roadway Type
Recruitment of drivers who drive a mix of roadway types is a requirement. Emphasis will also be placed on recruiting urban commuters.

Driver Vehicle Type Requirements
Drivers will be recruited who drive the vehicle types specified in *Vehicle Requirements* as well as the makes and models specified in Task 8.

Vehicle Requirements

Primary Vehicle Selection Criteria
VTTI began determining the vehicle requirements by first establishing the primary criteria that should be considered in selecting vehicles. The ease and cost of data collection system installation is a factor for vehicle selection. Specific vehicle models will be limited to six to accommodate data systems installation requirements. This reduces the number of cable and connector sets, custom mounting brackets, and software configurations required for installations. Model years will be restricted to sequential sets in which the selected models have the fewest design revisions. In addition, holding the number of vehicle makes to three will increase the commonality of the vehicle's onboard data network, thus requiring fewer software configurations. Recent year models will be selected to enhance the data retrieval available over the vehicle's onboard data network. Additional factors are the crash rate of various body types and the distribution of particular vehicles in the Washington, DC/NoVA area.

Body Type Requirements
Rear crash statistics reported by Najm (1999) are shown in Table 9. These data, taken from the 1998 GES, indicate that the known body types that constitute the largest portion involved in a rear crash (36.5 percent) are 2-door and 4-door passenger vehicles. No other known single vehicle type contributes considerably to the number of crashes. Note that the definition of "light truck" (at the bottom of the chart) indicates that this is not a unique category but a compilation of utility, van, and pickup.

Data from the 1995 NPTS Summary of Travel Trends show that the top four vehicle body types represented in that nationwide survey were passenger cars (64.3 percent), pickups (17.7 percent), vans (7.8 percent), and SUVs (6.9 percent). Although these percentages are likely to have changed somewhat in the last few years, passenger cars are still likely to make up the highest percentage of vehicle body type on the road.

Table 9. 1998 GES rear-end crash statistics for each vehicle body type.

Body Type		% Crashes	% Striking	Striking*	Struck*	Both	Total	Code
Type	**Style**							
Passenger Car	all	66.3%	50%	1,133,000	956,000	201,000	2,290,000	
	convertible	0.2%	69%	5,000	2,000	1,000	8,000	1
	2-door	**11.6%**	**54%**	**216,000**	**148,000**	**37,000**	**401,000**	**2**
	4-door	**24.9%**	**48%**	**411,000**	**376,000**	**73,000**	**860,000**	**4**
	wagon	2.3%	48%	37,000	36,000	5,000	78,000	6
	hatchback	2.0%	50%	34,000	27,000	8,000	69,000	3,5,7
	unknown	25.3%	49%	430,000	367,000	77,000	874,000	9,10
Utility	all	7.5%	47%	122,000	119,000	18,000	259,000	
	small	3.9%	45%	61,000	64,000	11,000	136,000	14
	large	0.6%	53%	11,000	8,000	1,000	20,000	15
	utility wagon	0.7%	46%	11,000	11,000	2,000	24,000	16
	unknown	2.3%	49%	39,000	36,000	4,000	79,000	19
Van	all	7.5%	44%	114,000	124,000	20,000	258,000	
	minivan	2.8%	39%	38,000	50,000	10,000	98,000	20
	large	0.7%	40%	10,000	14,000	1,000	25,000	21
	unknown	3.9%	49%	66,000	60,000	9,000	135,000	22,29
Pickup	all	16.2%	50%	278,000	247,000	35,000	560,000	
	small	4.4%	48%	72,000	67,000	11,000	150,000	30
	large	4.3%	49%	74,000	68,000	8,000	150,000	31
	unknown	7.5%	51%	132,000	112,000	16,000	260,000	32,39
Light Truck	all**	33.7%	48%	560,000	525,000	80,000	1,165,000	
	unknown	2.6%	53%	46,000	35,000	7,000	88,000	40,41,48
All Types		100.0%	49%	1,693,000	1,481,000	281,000	3,455,000	

*Rounded to the nearest thousand

**Includes utility, van, pickup, and type unknown.

Since SUVs are usually derived from pickup truck frames, driving characteristics are expected to be similar between SUVs and pickups; more so than other body type combinations. Thus selecting a mix of cars plus SUVs/pickups covers about 89 percent of the vehicle population and represents a wide range of handling characteristics. Generally, pickups and vans are more difficult to instrument unobtrusively since they lack the concealment and shelter available in a car or SUV trunk. All of these factors point to using cars and SUVs for the test vehicles.

Another issue is the rate at which different vehicle body types are involved in crashes. Some crude estimates, using 1998 data from Table 4 and data from the 1995 NPTS Summary of Travel Trends, are shown in Table 10. These estimates show cars and SUVs to have the highest per mile crash involvement, although the differences are marginal.

Table 10. Crash Involvement

Body Type	Percentage
Passenger car	25.3
Van	24.3
SUV	27.3
Pickup	23.1

Based on the body type requirements, considerations for data system installation, population by body type, and the crash rate data, five car models and one SUV model will be chosen. As noted previously, these will be the Ford Taurus/Mercury Sable, Ford Explorer/Mercury Mountaineer (SUV), Toyota Corolla, Toyota Camry (all personal vehicles owned by subjects); and the Chevy Malibu and Chevy Cavalier (leased vehicles).

TASK 6: DETERMINE NEAR-CRASH STATISTICAL POWER REQUIREMENTS

In order to determine the near-crash statistical requirements, VTTI researchers reviewed four previous research studies that all used an instrumented vehicle in natural driving environments. The frequency counts for collisions, near-crashes, and driver errors are compared as well as the methods used to obtain these events and estimates for the number of collisions, near-crashes, and driver errors that could be potentially collected in this study are presented.

Previous Research

Dingus and Mollenhauer (1998) conducted a study where they compared the data collected in two field studies: the TravTek study (Dingus et al., 1995) and the ADVANCE (Advanced Driver and Vehicle Advisory Navigation Concept) evaluation studies (Mollenhauer, 1998). The primary purpose of the TravTek and ADVANCE studies were to evaluate driving performance while using an in-vehicle navigation device. The ADVANCE studies consisted of two data sets: the safety baseline data and the safety evaluation data, both of which used the same drivers. These three data sets used instrumented passenger vehicles in a variety of different road types and traffic densities. In all three studies, the hazard analysis technique was used where the driving performance and video data was used to categorize driving incidents as one of the following: 1) driver error, no hazard present; 2) driver error, hazard present; 3) near-crash; and 4) collision. There is some evidence in other safety applications that the number of near-crashes and errors are related to the number of accidents that will occur for a specified environment (Heinrich, 1980).

The frequencies of near-crashes and driver errors per million vehicle miles were extrapolated and compared across these two studies (Table 11). No collisions occurred during this field study; therefore, no values are reported in that column.

Table 11. Collision, near-crash, and driver error frequency in comparative studies.

Study	VMT	Collision per MVMT	Rate per VMT	Near-Crash per MVMT	Rate per VMT	Driver Error Hazard Present per MVMT	Rate per VMT
TravTek	2032	N/A	N/A	14763	0.015	129921	0.130
ADVANCE Safety Evaluation	2882	N/A	N/A	14226	0.014	143650	0.144
ADVANCE Baseline Data	487	N/A	N/A	6160	0.00616	110882	0.111
Local/Short Haul Study	27924	N/A	N/A	537	0.0005	7126	0.006
Long Haul Study	123422	16.2	0.000016	178	0.00018	19948	0.020
Intelligent Cruise Control Systems – Highway	31390	N/A	N/A	509	0.0005	69226	0.07
Intelligent Cruise Control Systems - Arterials	15695	N/A	N/A	765	0.0008	104810	0.1

In addition to these studies, research conducted with instrumented commercial vehicles was also reviewed. Hanowski, Wierwille, Garness, and Dingus (1996) conducted a study investigating fatigue and driving performance in local/short haul truck drivers. These drivers also drove a combination of highway and urban environments. Over 40 drivers participated in this study for a two week period, which resulted in approximately 28,000 vehicle miles traveled. Extrapolating to one million vehicle miles traveled, Hanowski et al. calculated a rate of 537 critical incidents and 7,126 driver errors per million vehicle miles traveled (Table 11).

A recently completed study by Dingus et al. (2001) investigated fatigue and driving performance with long-haul truck drivers. This data collection system did not use continuous data collection, but rather a triggered-event data collection system where data was saved only when a vehicle sensor value exceeded a set threshold. For example, if the driver made a hard braking maneuver and the longitudinal accelerometer exceeded 0.3 g, then the driving performance and video data for two minutes prior and one minute after the trigger point was saved. While the exact calculation of vehicle miles traveled (VMT) was not possible (given the data collection system only collected data during triggered events), it was estimated that approximately 123,000 miles of data was collected. Two collisions, 22 near-crashes, and 2,462 driver errors with hazard present were identified. Table 11 shows a breakdown of the number of crashes, near-crashes, and driver errors per million vehicle miles traveled that occurred for this study. Note that the percent VMT for near-crashes and driver errors is much smaller for these two studies than it was for the TravTek and ADVANCE studies.

A fourth study, conducted at UMTRI and evaluated by Volpe National Transportation Systems Center, investigated the safety of Intelligent Cruise Control systems in passenger vehicles (Koziol et al., 1999; Fancher et al., 1998). In this study, a technique similar to the hazard analysis was used in which a variety of driving events were identified and categorized as near-crash, hazard present, or no hazard present (no collisions occurred). The participants drove on a variety of road types, two of which were arterials and freeways. These two road types accounted for 75 percent of the miles traveled. The types of events that were used to identify near-crashes and driver errors included: time headway, velocity, acceleration, braking force, and response times. The results of this hazard analysis show that the percent frequency of driver errors and near-crashes are higher than the results found in the Local/Short Haul study and Long Haul Truck study.

Comparison of Methods

As the percentages per MVMT and VMT vary greatly among these studies, the differences in these studies must be noted. First, the TravTek and ADVANCE studies not only used driving performance variables as triggers for driver errors, but also counted driver eye glances greater than 2.5 seconds, more than two glances to the navigation device, high workload ratings, among somewhat liberal driving performance triggers. The two other studies did not use these dependent measures.

Naturalistic Driving Study Estimates

VTTI researchers predicted the frequency of near-crashes and driver errors based on the Local/Short Haul and Long Haul studies. Using the rates per VMT and extrapolating to the number of VMT for this study, these two studies suggest 520 near-crashes and 58,000 driver errors will be collected in this Naturalistic Driving Study if 2.88 MVMT is collected (as specified in Task 4 and Task 7). Rates per VMT from the Intelligent Cruise Control study would suggest 700 near-crashes and 100,800 driver errors on highways and 580 near-crashes and

72,000 driver errors on arterials. Note, however, that if the criteria used to identify driver errors will be more stringent for this study to reduce the presence of "false alarms." It is expected that the change in criteria will reduce the number of driver errors. However, it is expected that a minimum of 25,000 driver errors will be analyzed as part of this study.

It is also expected that 16 police-reported crashes including 6 police-reported rear-end crashes could be obtained based upon equations and collision rates developed from Wang, Knipling, and Blincoe (1999). Wang et al. stated that there are 556.15 police-reported crash involvements per 100 MVMT. This would yield 556.15 X 0.0288 = 16.02 police-reported crash involvements for this study. This estimate does not correct for urban driving or high-risk drivers. The equations used to calculate approximately 6 police-reported rear-end crashes, and therefore the likelihood of 10 or more total rear-end crashes, is reported in Task 4.

TASK 7: CONDUCT TRADE STUDY – RESEARCH DESIGN PARAMETERS/ SAMPLING RATES/FORMATS CONCEPT

Research Design Parameters

As stated, there will be 20 leased vehicles and 80 privately-owned vehicles in the study. Issues that NHTSA would like to resolve by using two groups of vehicles are the length of time required for the driver to adapt to an unfamiliar vehicle and the feasibility of using leased vehicles in the Phase IV large scale data collection effort. Also, it is critical to this study to collect pre-crash data for approximately 10 rear-end crashes. As previously discussed, there is a reasonable probability of meeting this goal. Given these constraints, the optimal experimental design is described.

Subjects

One hundred participants will be recruited from the Washington, DC metro area. Eighty of these subjects will drive their own vehicle and 20 will drive a leased vehicle from VTTI. Participants will be selected based upon an average mileage of approximately 27,000 miles per year, make/model of vehicle they drive, and gender. A higher percentage of younger drivers and male drivers will be recruited due to higher involvement in rear-end collisions (as discussed in Task 5). The number of males and females per age group that will be recruited is as follows:

- Aged 18-20 years: drivers = 18 males and 12 females
- Aged 21-24 years: drivers = 18 males and 12 females
- Aged 25-34 years: drivers = 6 males and 4 females
- Aged 35-44 years: drivers = 6 males and 4 females
- Aged 45-54 years: drivers = 6 males and 4 females
- Aged 55-64 years: drivers = 6 males and 4 females

Procedures

The optimal experimental design option would be a mixed-subject design where 100 subjects are recruited to participate in the study. VTTI will instrument 80 privately-owned vehicles and 20 leased vehicles. At the end of 12 months, the drivers who drove the 20 leased vehicles will return them to be used by 20 of the drivers who were previously driving privately-owned vehicles for an additional month of data collection. The other 60 drivers of privately-owned vehicles would continue to drive for an additional month (Table 12) if more crash data is needed.

Table 12. Number of vehicles on the road for thirteen months.

Time Frame	Privately-Owned Vehicles	Leased Vehicles
Month 1 – 12	80	20
Month 13	60	20

The benefit of the mixed-subject design is that it provides a full year of data on driving differences for both private and leased vehicles. Additionally, there would be one month of data for 20 subjects where one could compare the first month of driving their own instrumented vehicle versus one month of driving a leased instrumented vehicle. The one month of driving a leased instrumented vehicle could also be compared to the sixth and twelfth months of driving a privately-owned instrumented vehicle to determine whether there are any differences in the first month of driving for a driving study. This design will allow for the collection of 2.88 MVMT in 13 months, which is within the scope of this project.

The disadvantages of the mixed-subject design is that if adaptation to an experimental vehicle requires longer than one month, then this experimental design will not be adequate. Given past experience, VTTI researchers do not believe that adaptation to the leased vehicle will take longer than one month (or over 2000 miles of driving, in this case) to become familiar with the leased vehicle. Therefore, VTTI researchers are confident that this experimental design will adequately capture the behavioral characteristics of vehicle adaptation with this experimental design.

Sampling Rates

The amount of raw sensor and video data that must be stored and transferred from the vehicles is a critical constraint for this project. Driving performance data has been sampled at 10 Hz for the past several studies at VTTI and has proven to be an effective sampling rate. Even though considerably more data will be collected in this study when compared to other VTTI studies, this sampling rate is still feasible. The text files created will be relatively small.

The files created by the video data are an order of magnitude larger than the driving performance data files. The tradeoff is that data must be sampled at a high enough rate so that eye glance data reduction can be performed using the digital video, yet small enough to transfer files from the data collection system in a reasonable amount of time. In addition, data storage and backup of a large amount of digitized video is a concern.

To save hard disk space, it was first suggested that the face camera and the forward view camera should be sampled at 30 Hz and the other three cameras should be sampled at 10 Hz. This technique was attempted by the VTTI hardware and software engineers; however, there were serious problems with sampling different cameras at different rates and then attempting to splice them together in a quad-split video image. The option selected by VTTI is to use a sampling rate of 30 Hz for all five cameras and save the video in a format that would compress efficiently and economically. The compression technique is discussed in the following section.

Data Format

As stated previously, the amount of raw data that must be stored and transferred from the vehicles is a critical constraint for this project. While this is not critical for the driving performance data, which will be a text file, it is very critical for the digital video data. One five-minute segment of video with five camera views quad-split into once screen and sampled at 30

Hz is equal to 2,500 megabytes saved in an uncompressed format. Digital video compression techniques are still somewhat new and newer technologies are being introduced every month. VTTI software engineers tested many video compression programs and the results of their tests are listed in the Table 13. Given the results of their research, the MPEG 1 compression format provides the smallest file size while producing the cleanest video output.

Table 13. Comparison of eleven video compression techniques.

Digital Video Compression Technique	File Size
5 Minute Uncompressed (24 bit color)	2500 MB
MJPEG	205 MB
MPEG 4.0	26 MB
DIVX MPEG 4 (Fast Motion)	10 MB
DIVX MPEG 4 (Low Motion)	10 MB
DIVX 4.0	37 MB
Cinepak	120 MB
Microsoft RLE	393 MB
Microsoft Video 1	86 MB
Sorenson Quicktime	33 MB
Wavelet (hardware comp.)	150 MB
MPEG 1 or 2 (hardware comp.)	**9.7 MB**

TASK 8: CONDUCT TRADE STUDY TO DETERMINE VEHICLE TYPES

Several factors were considered when determining what vehicle types were most optimal. The most critical factors included vehicle type, vehicle demographics, vehicle location, data collection system installation issues, information obtainable from the in-vehicle network, and make and model requirements. These factors are interrelated and are discussed below.

Vehicle Type

As presented in Task 5, factors considered in selected vehicle types included data system installation, population by body type, and crash rate data. In regard to vehicle type, a sample consisting of cars and SUVs was considered optimal.

Vehicle Demographics

Given these vehicle type criteria, VTTI sent two teams of experimenters to Washington, DC area parking garages and lots to determine what vehicle types are most common. These teams surveyed nine facilities consisting of two Park-N-Ride lots on the I-66 corridor approximately 30 miles and 10 miles outside of the district, three parking garages near the Dupont Circle metro stop, and four parking garages near Union Station. The teams counted Ford, GM, and Toyota products (members of CAMP) primarily. Their results, shown in Figure 5, suggest that Toyota products are popular in the DC area, Ford products are moderately popular, and GM products are under-represented. One may note four spikes in Figure 5 for the Ford Explorer, Ford Taurus, Toyota Corolla, and the Toyota Camry.

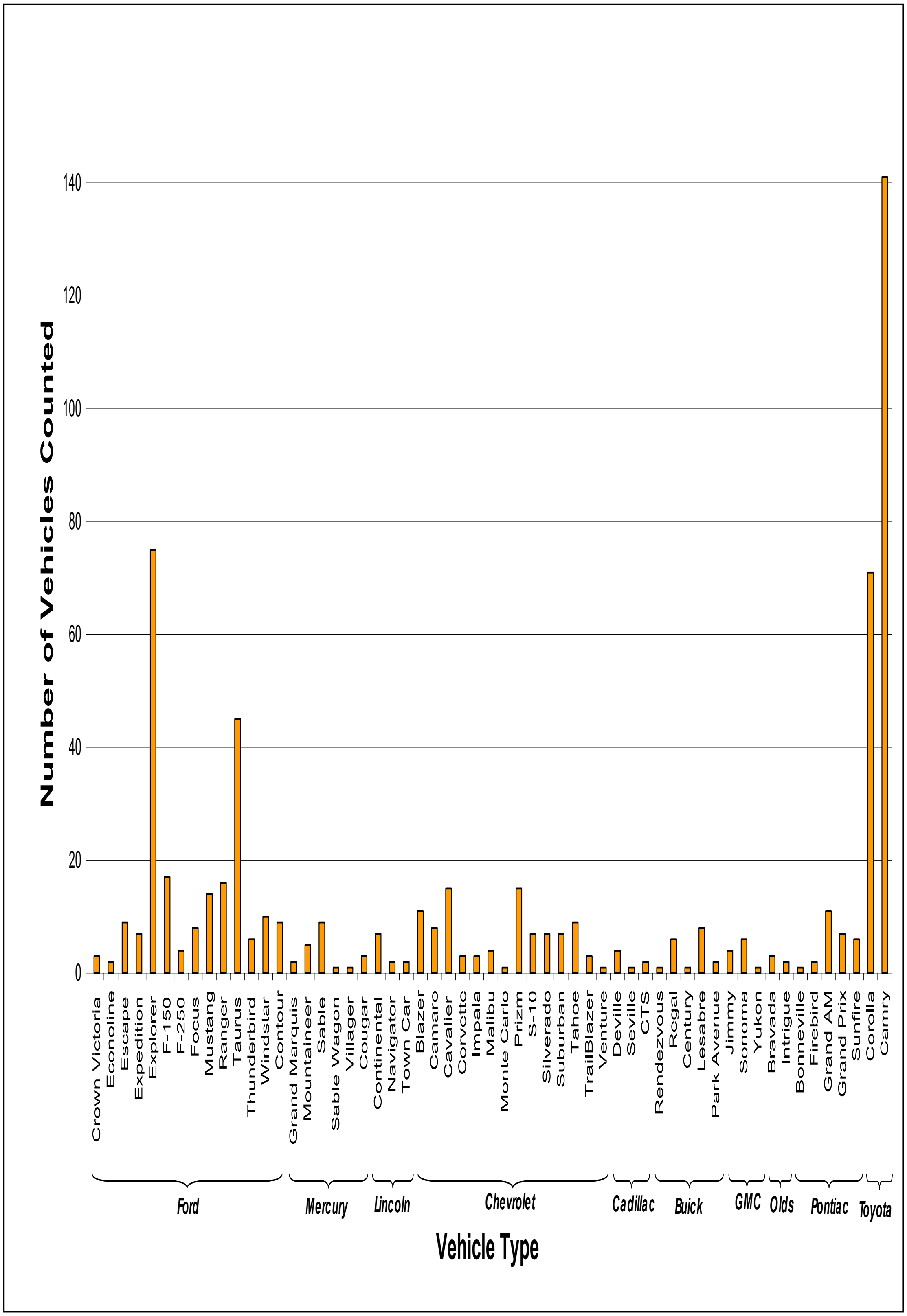

Figure 5. Frequency count of a variety of vehicle makes/models as found in Washington, DC area parking garages and parking lots.

Vehicle Locations

All of the vehicles must be parked for at least 2-3 hours every day in a limited number of centralized locations for data downloading purposes, as described in Task 2. Various parking garage company representatives in the Washington, DC and Northern Virginia area were approached to determine the feasibility of recruiting subjects from parking garages. Six parking garage companies, four government office buildings with underground parking, three representatives from different universities, and several townhouse communities were contacted. One parking garage company showed considerable interest in assisting in data collection. The other five parking garage companies demonstrated varied levels of interest. A representative from George Washington University was very helpful and showed great interest, as did a representative from Georgetown University. Several of the townhouse communities were also interested and provided new ideas for driver recruitment. One issue that caused some problems, especially in the federal buildings, was security. Specifically, there was some concern about a VTTI vehicle gaining access to the underground parking. This issue will be resolved as subjects are recruited, beginning in areas closest to the VT Northern Virginia Center, or at large parking lots within a practical driving distance from the Center.

Data Collection System Installation and Placement Requirements

The issue of data collection system installation and placement constrains the number of different vehicle types chosen as well as what types of vehicles can be chosen. The systems will be installed over a 4-5 month period beginning in July 2002. Systems must be custom built with the appropriate bracketry and fixtures to instrument each vehicle in less than four hours, so that at least two vehicles can be instrumented in a day. Therefore, the number of vehicle types has been limited to six different models.

In-Vehicle Network Information

Information available on the in-vehicle network is also a primary constraint as information on airbag deployment, for example, is most efficiently collected via the vehicle network chip. Several methods were used to obtain the information available on the network for Ford, GM, and Toyota products. The first method used was to contact respective companies and request this information. No information was ever obtained by contacting companies directly. Next, a VTTI engineer went to a dealership in Christiansburg, VA that sells Ford, GM, and Toyota products. This engineer, working with the dealership mechanic, accessed the vehicle network and determined the information available. The table in Appendix C shows the results of this in-vehicle network scan.

Make and Model Requirements

The two manufacturers with the highest recent sales of passenger car and SUV models are Toyota and Ford, respectively. Given the results of the vehicle demographics frequency count, the Year 2000 sales figures placed the Toyota Camry first in sales, the Corolla seventh in sales, and the Ford Taurus third in the passenger car line-up. Similarly for SUVs, the Ford Explorer is first in sales. Although other automotive manufacturers have high sales, the restriction to two manufacturers dictates a choice of these four models.

Within the selected models, it will be necessary to choose specific vehicles in good working order that are well maintained such that data collection time is not lost while a vehicle is under repair. Specific model style variations and vehicles with after-market equipment or body additions may be precluded from the study to accommodate data systems installation requirements.

Final Selection

Given the above constraints, the following four vehicle makes and models have been chosen for the privately-owned vehicles in the study:

- Toyota Camry
- Toyota Corolla
- Ford Taurus
- Ford Explorer

With regard to the model year of the vehicles, a review of model year revisions for each of the four selected vehicles indicates the following:

- The Toyota Camry will be selected from the 1997 – 2001 model years. The Toyota Camry model design was static through 2001 with a new model in 2002.
- The Toyota Corolla will be selected within model years 1993 – 2002
- The Ford Explorer will be chosen out of models years 1995 – 2000 and model year 2001, but only if manufactured by November 2, 2000.
- The Ford Taurus design was static over years 1996 – 1999, and a significantly different model has been on sale for the years 2000 – 2002. Population figures for the Taurus over these periods will be used to decide which sequence is optimum.

In addition, the Mercury Mountaineer is the made on the same assembly line and has the same body style as the Ford Explorer; therefore, the Mercury Mountaineer can be included in the study for the same model years as the Ford Explorer. Likewise, the Mercury Sable is the same body style as the Ford Taurus, and can be included in the list of potential vehicles.

Two additional makes and models will be added as part of the leased vehicle portion of the fleet. Twenty vehicles will be leased from the Virginia Tech Motor Pool: ten 2002 Chevy Malibus and ten 2002 Chevy Cavaliers. Obtaining the leased vehicles via the Motor Pool state contract will save money and significant logistical problems (licensing, leasing agreements, etc.). VTTI will be able to get each Malibu for $277/month and each Cavalier for $244/month.

TASK 9: DEVELOP PARTICIPANT RECRUITING SPECIFICATION

When developing the specifications for subject recruitment, the following factors were considered: participant age, participant gender, vehicle types driven, the number of miles driven per year, and crash histories. Participant age, gender, annual mileage, and crash histories have important implications when considering the number of rear-end crashes that may occur during the data collection period. The type of vehicles that these participants drive will be very important for subjects recruited to drive their own vehicle, as each vehicle must either be a Toyota Camry or Corolla, Ford Taurus or Explorer, as specified in Task 8. Table 14 shows a hypothetical participant recruitment specification plan based on the vehicle type, age group, and gender. This hypothetical specification plan results in the needed number of male and female drivers in each age category as specified in Task 5, and may be considered a target distribution for subject recruiting.

One may note that Table 14 is biased toward more drivers using Corolla and Camry models, based upon the frequency count of vehicle makes and models discussed in Task 8 and shown in Figure 5. Leased vehicles are distributed fairly evenly across the age groups but, in practice, it may be necessary to assign leased vehicles primarily to younger drivers to comply with the need to recruit additional younger drivers.

Table 14. Hypothetical number of participants for each level of vehicle, age, and gender.

	Vehicle Demographics											
	Corolla		Camry		Taurus Sable		Explorer Mountaineer		Cavalier (leased)		Malibu (leased)	
Driver	M	F	M	F	M	F	M	F	M	F	M	F
18-20	4	3	4	3	4	2	4	2	1	1	1	1
21-24	4	3	4	3	4	2	4	2	1	1	1	1
25-34	1	-	1	1	1	1	1	1	1	1	1	-
35-44	1	1	1	1	1	-	1	1	1	-	1	1
45-54	1	1	1	-	1	1	1	1	1	1	1	-
55-64	1	1	1	1	1	1	1	-	1	-	1	1

To gain some understanding of the public's interest in participating in this study, consenting to have their vehicle instrumented, and being videotaped while driving, VTTI placed an advertisement in the Classified Advertisement section of the Washington Post that was published in the Thursday, Friday, and Saturday newspapers on October 30, 31, and Nov 1, 2001 (Appendix D). VTTI received 73 responses to this advertisement, including many prospective subjects with newer vehicles, suggesting that the public is interested and willing to participate in this type of study.

The subject recruitment plan for this study will focus on soliciting businesses with high mileage drivers such as realtors, sales, or possibly couriers; soliciting apartment complexes with private parking lots/garages; and soliciting public garages. VTTI will likely also advertise in newspapers, which has already proven to be productive. As stated previously, several parking garage companies have been contacted. Representatives of three universities in the DC area as well as nine townhouse/condominium developments were contacted to determine whether employees/residents who park in particular lots could be recruited to participate in this study. All three universities were interested and helpful in providing information on subject recruitment. The housing developments also proved to be interested and helpful, and some even suggested running a notice in their community newsletters.

Example Screening and Classification Questions

While age, gender, and type of vehicle will be controlled variables by which drivers will be recruited, other driver information will be collected that will be used for screening and classification of drivers. Information will be collected on driver demographics, the driver's vehicle information, driver well-being, and driver characteristics. The driver demographics and vehicle information variables will be collected over the telephone as part of an initial screening (Appendix E). If data for these variables do not meet participation criteria, no further data will be collected. Note that the telephone screening form will include personal identifiers and contact information. This information will be collected for subject recruitment purposes only and will not be turned over to the contract sponsor or any other agency in order to comply with confidentiality requirements.

Classification information will be collected upon first meeting with the driver. They will provide a wealth of information on driver medical and psychological characteristics that can later be correlated to driving performance data. VTTI will calculate odds ratios and other measures of the association of these driver characteristics to driving performance. The first general category of driver classification is the health assessment. Subjects will be given vision and hearing tests, and asked questions regarding their general health status such as medical problems and current medications. Typical questions include those shown in Appendix F.

Driver aggressiveness will also be assessed. Appendix G shows an example assessment tool to measure the propensity for angry driving (Dula and Ballard, in press). The Dula Dangerous Driving Index (DDDI) was created to measure drivers' self-reported likelihood to drive dangerously. Each DDDI scale (i.e., DDDI Total, Aggressive Driving, Negative Emotional Driving, and Risky Driving scales) has been shown to have strong internal reliability. Application of this assessment tool for the Naturalistic Driving Study would allow researchers to examine the relationship between the stated propensity for angry driving and the rate and types of driving errors, near-crashes, and crashes.

Driver sleep hygiene information will also be collected. An example assessment tool can be found in Appendix H. The categories of questions are as follows:

- General Sleep Habits and Preferences
- Sleep Symptoms Related to General Sleep Habits
    - "Initial insomnia"
    - "Middle insomnia"
    - "Terminal insomnia"
    - "Excessive daytime sleepiness"
- Substance-Related Sleep Problems
    - Sleeping pills
    - Caffeine
    - Other stimulants
    - Alcohol
    - Other substances
    - Nicotine
- Primary Sleep Disorders
    - Psychophysiological Insomnia
    - Sleep Disordered Breathing
    - Narcolepsy
    - Parasomnias
    - Periodic Limb Movement and Restless Leg Syndrome
- Sleep Disorders Related to Other Medical Problems
- Sleep Disorders Related to Psychiatric Disorders
    - Depression
    - Mania/hypomania
    - Anxiety disorders
    - Psychological stressors

Since the driver sleep hygiene questionnaire is rather lengthy, it will be necessary to reduce the number of items collected for the study. With regard to the final format of the driver assessment questionnaires, note that the example classification and screening questions in Appendices E, F, G, and H are not finalized. While final approval has been obtained from the Virginia Tech IRB, the information included is subject to change contingent upon obtaining final approval from the NIMH (which provides the Certificate of Confidentiality), and the NHTSA Human Use Review Panel. Moreover, the screening and classification data collection protocols need to be checked for time requirements and other aspects of the administration protocols. Nonetheless, the example questions do provide a foundation for questionnaires that will be refined prior to data collection.

TASK 10: DEVELOP TEST DATA COLLECTION PLAN

The Task 10 report was a synthesis of Tasks 1 through 9, and was delivered on January 21, 2002. Comments were received from the TOM on February 14, 2002 and were discussed at a briefing on February 22, 2002. Where applicable, revisions have been made to Tasks 1 through 9 in this report based on these discussions.

TASK 11: DEVELOP TEST REDUCTION, ARCHIVING, AND ANALYSIS PLAN

Data collection will begin as vehicles are instrumented. Data will be collected by transferring the data from the hard drive of the subject vehicle to a hard drive on a "chase" vehicle. This will be a "wire" transfer in that the chase vehicle will have a cable that will plug into a concealed wire on the subject vehicle. The data will then be copied to a DVD, and the DVD will be duplicated. One DVD will then be sent to VTTI and the other will be kept in Northern Virginia. As the data arrives at VTTI, it will be downloaded to the network attached storage and saved. Only after this data is safely copied to the networked attached storage at VTTI and quality checks are performed will the data be remotely deleted from the subject vehicle hard drive. Once the data is put onto the VTTI network, data reduction will begin.

The test data reduction, archiving, and analysis plan is based on VTTI's experience in reducing naturalistic driving data for large-scale field studies (e.g. Fatigue in Local/Short Haul and Fatigue in Long Haul Operations studies). Data reduction software has been developed in-house for previous studies and will only require modifications for use in the current study. The data archiving plan was developed in-house with technical assistance from a consultant. The data analysis plan is based on the research questions that were generated by NHTSA scientists and other interested parties. The research questions have been organized under ten broad research objectives. The measures and the statistical tests used in the analysis will be discussed for each research objective.

Data Reduction Approach

The approach to data reduction for the Phase II study takes advantage of the critical incident/near-crash method as well as current database information. This process is depicted in Figure 6. As shown, continuous data will be collected. The critical incident/near-crash method will be applied to the data, meaning that events will be located in the data set via optimized triggers, to be determined through a sensitivity analysis.

The traditional variables that are obtained through the critical incident/near-crash process will be expanded upon with variables from the NHTSA General Estimates System (GES) and the Virginia State Police Accident Report (PAR). This complimentary variable set has been merged to create the data reduction framework and, finally, the 95 coded variables of the event coding directory. The event coding directory will be the most comprehensive database of driver behavior information to date. The GES and PAR variables will be made more informative with pre-crash information on driver eye glance behavior, hands-on-wheel analysis, fatigue assessment, distraction assessment, as well as several other driver behavior variables that are detailed in Appendix B. The following sections detail this process.

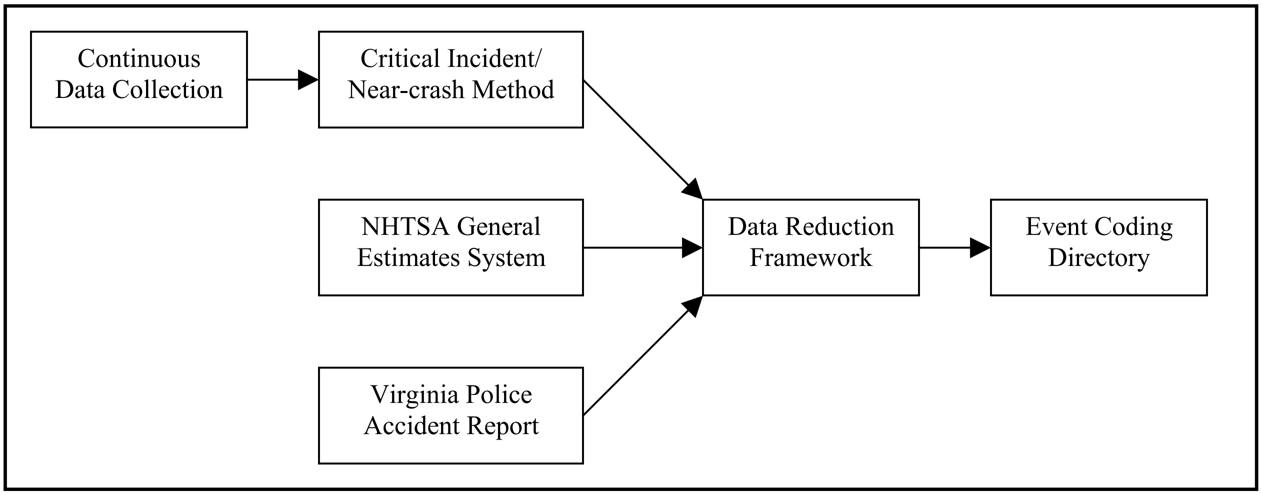

Figure 6. Data reduction approach for the Naturalistic Driving Study.

Critical Incident/Near-crash Trigger Sensitivity Analysis
The critical incident/near-crash method together with continuous data collection provides the opportunity to optimize the trigger criteria values for Phase II and refine them for Phase IV. As such, a sensitivity analysis will be conducted. As shown in Figure 7, the raw data from the vehicles will be saved on the networked attached storage at VTTI until 10 percent of the data is saved. At this time, preliminary trigger criteria will be set and a sensitivity analysis will be conducted.

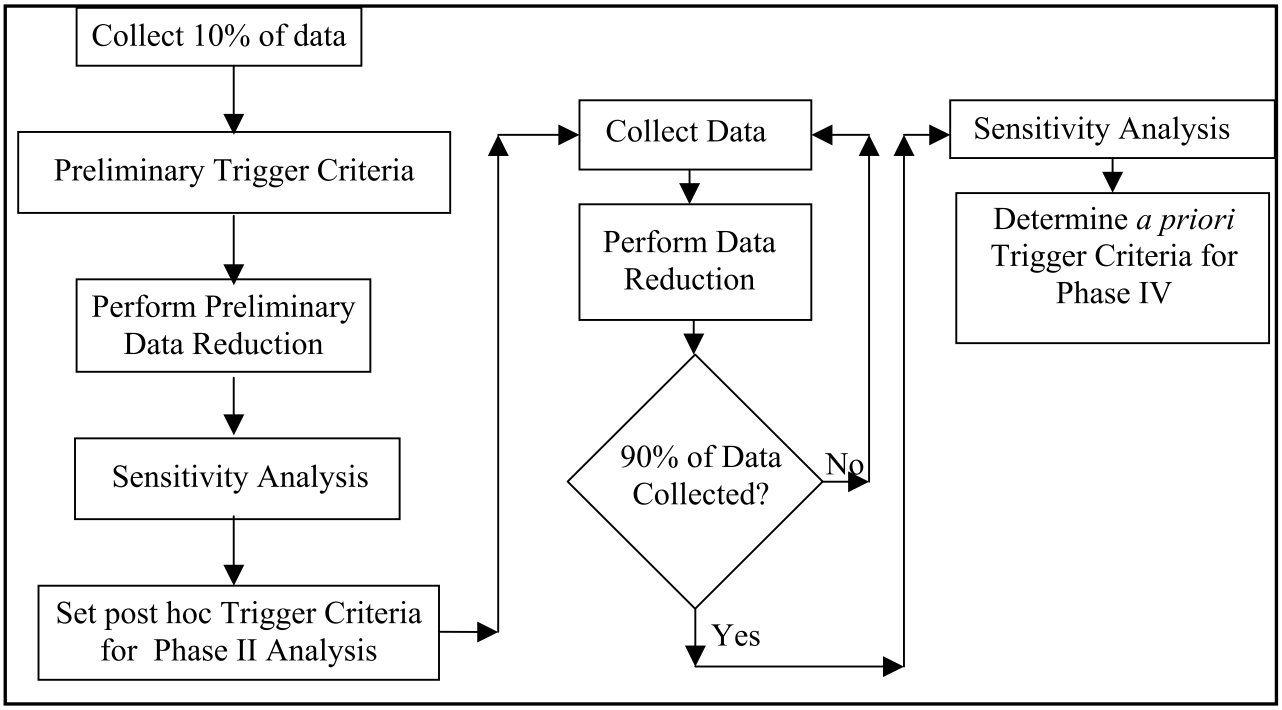

Figure 7. Flow chart of the data reduction process.

The sensitivity analysis will be conducted to ensure the identification of a large percentage of valid triggers while minimizing the presence of invalid triggers. This sensitivity analysis will be conducted by making iterative adjustments to the trigger values to ensure that most of the valid critical incidents are identified, with a few invalid incidents also being identified. The list of measurement variables used as incident triggers is presented in Table 15. Note that these are instantaneous triggers collected at 10Hz.

Table 15. Measurement variables used as critical incident triggers. The "X" values will be determined with the sensitivity analysis.

Trigger Type	Description
1. Lateral Acceleration	Lateral motion equal or greater than 0.X g
2. Longitudinal Acceleration	Acceleration or deceleration equal or greater than 0.X g
3. Critical Incident Button	Activated by the driver upon pressing a button located on the dashboard when an incident occurred that he/she deemed critical.
4. Lane Deviation	Activated if the driver crosses the solid line border (Boolean occurrence).
5. Normalized Lane Position	Activated if the driver's path deviates by X.X% of centerline.
6. Forward Time-to-Collision (TTC)	Activated if the driver followed the preceding vehicle with a TTC (range/range rate) of less than X seconds.
7. Rear Time-to-Collision	Activated if the driver following the experimental vehicle has a TTC (range/range rate) of less than X seconds.
8. Yaw Rate	Activated if the lateral motion of the vehicle is 0.X radians per second.
9. ABS Brake Status	Activated if the ABS brakes are active. Note: this will only be applicable to those vehicles that have ABS brakes.
10. Airbag Status	Activated if the airbag is deployed.
11. RF Sensor	Activated if the driver is using a cell phone or a PDA when the vehicle is on.

Specific values for each of these dependent measures will be used to determine when a possible critical incident occurred. These specific values will be called trigger criteria for the remainder of this report. A sensitivity analysis will be performed by setting the trigger criteria to a liberal level to reduce the chance of a missed valid incident while allowing a high number of invalid incidents (false alarms). A graphical depiction of this is shown in Figure 8. Data reductionists will then view all of the incidents produced from the liberal trigger criteria and classify each incident as valid or invalid. The number of valid incidents and invalid incidents that result from each trigger criterion setting will be recorded.

The trigger criteria will then be set to a slightly more conservative level, and the resulting number of valid and invalid incidents will be counted and compared to the first frequency count. The trigger criteria will continue to be made more and more conservative, and the number of valid and invalid triggers will be counted and compared until the optimum trigger criteria values that result in a minimal amount of valid incidents lost and a reasonable amount of invalid incidents identified can be determined. Note that the values for the individual triggers will vary independent from the other triggers; however, one sensitivity test (using all triggered incidents) will be performed. It should also be noted that many incidents will be identified by more than one trigger, which will decrease the number of valid events missed.

Based on past studies, it has been hypothesized 520 to 700 near-crashes and 58,000 to 100,000 incidents may be collected. However, as explained, the criteria used to identify driver errors will be more stringent for this study to reduce the presence of "false alarms." It is expected that a minimum of 25,000 driver errors will be analyzed as part of this study.

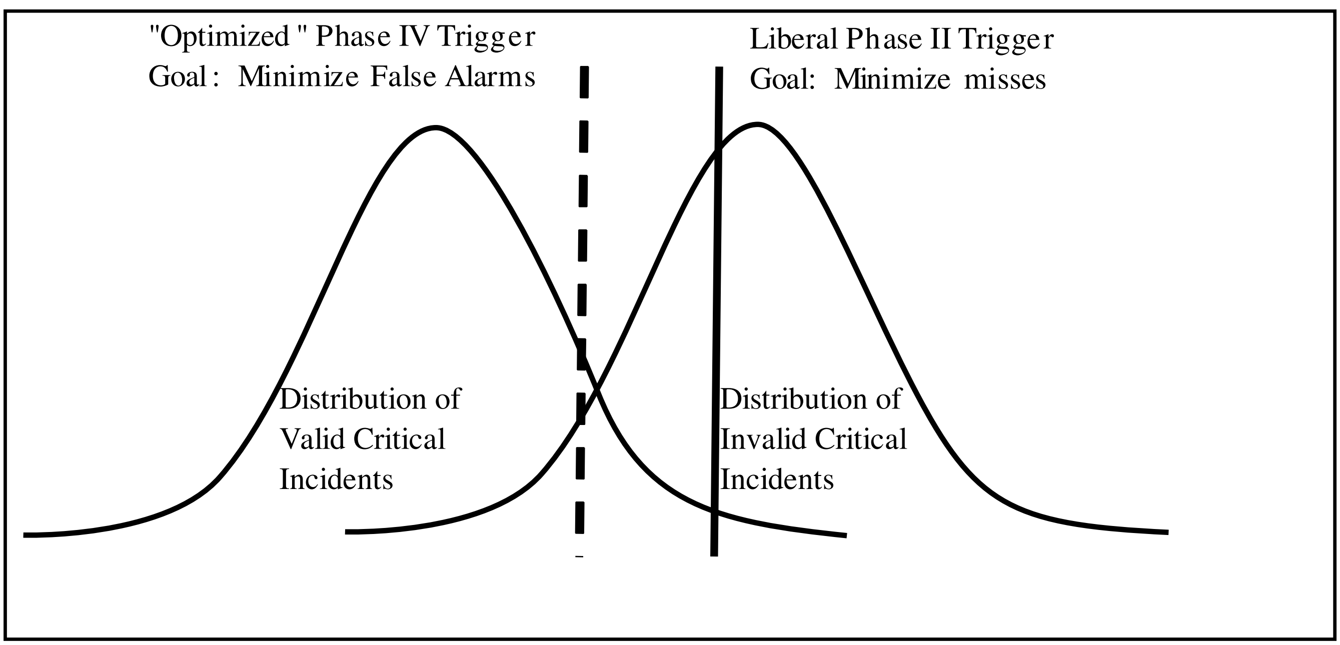

Figure 8. Graphical depiction of where the trigger criteria will be set for Phase II and Phase IV studies using the distribution of valid critical incidents.
Note that this distribution and criterion placement will be unique for each trigger type.

The optimal triggers for Phase IV will also be calculated using a similar sensitivity analysis, which will be conducted when approximately 90 percent of the data has been collected (after approximately 11 months of data collection). Given that Phase IV will result in a much larger data set than the current study, that sensitivity analysis will reduce the false alarms (invalid incidents) rather than minimize misses (valid incidents). Therefore, the trigger criteria will be much more conservative than the trigger criteria used for this pilot study.

Recruiting and Training Data Reductionists

Based upon past experience, it is estimated that reductionists will be able to reduce an average of four incidents per hour. Assuming one full year of data reduction, the task of reducing 25,000 incidents will require three full-time or six part-time data reductionists.

Six data reductionists will be recruited by posting notices to graduate student list serves on the Virginia Tech campus. A VTTI researcher will interview, hire, and train all of the data reductionists. The training procedure will include how to access the data from the server, how to operate the data reduction software, and how to complete all relevant operational and administrative procedures (approximately four hours of training). Each data reductionist will be presented with a data reduction manual to guide them in learning the software and reduction procedures. Secondly, all reductionist trainees will practice data reduction procedures with a trained analyst prior to reducing data independently. Once comfortable with the procedures, the trainees will work alone. The VTTI researcher will conduct spot checks on all data reduced, which will be used as a learning tool during weekly meetings to discuss issues that arise in data reduction.

Data Reduction Framework

As stated, the data reduction framework is a synthesis of the critical incident/near-crash method and variables taken from GES and PAR databases. For each post hoc triggered event in the data stream, video data will be marked and downloaded for one minute prior to the event and 30 seconds after the event. Of that video event data, reductionists will review the entire 90 seconds for context of the driving event, but will only reduce data for 30 seconds prior to the event and 10 seconds afterward.

Data reductionists will view four types of driving incidents: baseline epoch, critical incident, near-crash, and crash. Varying levels of detail will be recorded for each type of driving incident. Baseline incidents will have the least amount of information recorded, and near-crashes and crashes will have the most information recorded. A total of thirteen areas of data reduction may be recorded for each incident type. Table 16 defines each area of data reduction, lists the corresponding driving event that the reductionists will record, and provides examples.

Note that the presentation of the data reduction framework is based upon the critical incident/near-crash method. This is due to the fact that this data reduction perspective is conducive to the data reduction process. In addition, this process specifies the severity of the event (baseline, B; incident, I; near-crash, N; crash, C), which is then used to specify the level of detail for subsequent reduction of the event as specified in the following sections. The specific variables that will be recorded under each area of data reduction will be discussed in the section, Event Coding Directory.

Table 16. List of the areas of data reduction, definition of the area, the corresponding driving events, and examples.

Area of Data Reduction	Definition	Event Type	Example
Nature of Incident/ Crash type	Description of type of crash that occurred, may have occurred, or the incident that could have led to a crash.	C, N, I	Crash type: Run-off road crash. Near-crash: rear-end striking near-crash. Critical incident: following too closely.
Pre-Incident Maneuver	Description of the driving maneuver that was attempted prior to the critical incident, near-crash, or crash.	C, N, I	Slowing to make a left turn/ Maintaining a straight course with constant velocity.
Precipitating Factors	Description of any factor that directly contributed to the critical incident, near-crash, or crash.	C, N, I	Driver was distracted by passengers/Roadway was slippery.
Corrective Action/Evasive Maneuver	Description of any vehicular maneuver that driver attempted or performed to either avoid, alleviate impact, or lessen injury in a critical incident, near-crash, or crash.	C, N, I	Braked hard, swerved right.
Causal/Contributing Factors	Description of any one or several factors that may have contributed to the critical incident, near-crash, or crash.	C, N, I	Fatigue, distraction, weather.
State Variables	General description of the immediate environment, driver's state, and any other vehicle at the moment of the incident, near-crash, or crash. Any of these variables may or may not have contributed to the incident, near-crash or crash.	C, N, I, B	
Roadway/Traffic Variables	Description of the conditions of the road, type of road, and traffic density.	C, N, I, B	Dry pavement, rural two-lane road separated by a median, LOS A.
Other Person/Vehicle Type	Description of any other vehicle, driver, or pedestrian that interacts with the subject.	C, N, I, B	Class 8 heavy vehicle/Any information gleaned from PAR.
Driver's General State	Description of the driver's physical/mental state, drowsiness rating (if applicable), vision obstruction, distraction	C, N, I, B	Fatigue, alcohol, vision obstructed by fog, etc.
Weather/Lighting Conditions	Description of the weather and the lighting conditions at the time of the incident.	C, N, I, B	Clear and dry, nighttime on lighted roadway.
Narrative	Written description of the entire incident.	C, N, I, B	
Dynamic Reconstruction	Creation of an animated depiction of the event.	C, N	
Eye glance Reconstruction	Analysis of where the driver was looking for 30 seconds prior and through the duration of the incident. Also a description of what percentage of time drivers eyes were closed or were off the forward roadway.	C, N	

The baseline epoch will be the simplest and least intensive data reduction (Figure 9). Baseline epochs will be chosen randomly and in sufficient numbers as needed to answer any particular research question. All incidents will be analyzed by recording only the general state variables. Eye glance analyses or incident reconstruction will not be performed on the baseline data.

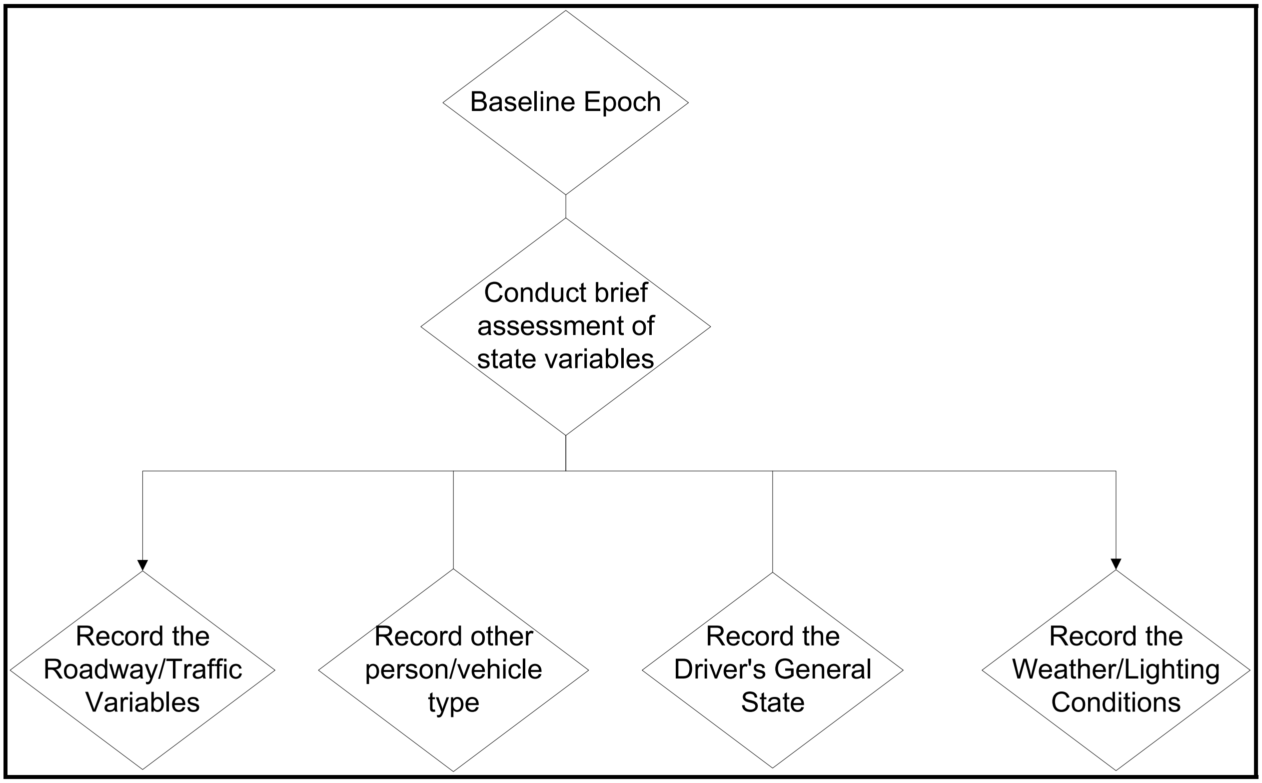

Figure 9. Flow chart for the baseline epoch data reduction.

The critical incident analysis (driver errors without a crash or near-crash event) will be more intensive than the baseline epoch data (Figure 10). Data will be reduced for all areas, except eye glance and accident reconstruction, for 30 seconds prior and 10 seconds after the event. This type of data will be the most common type of incident reduced and will consist of approximately 25,000 incidents.

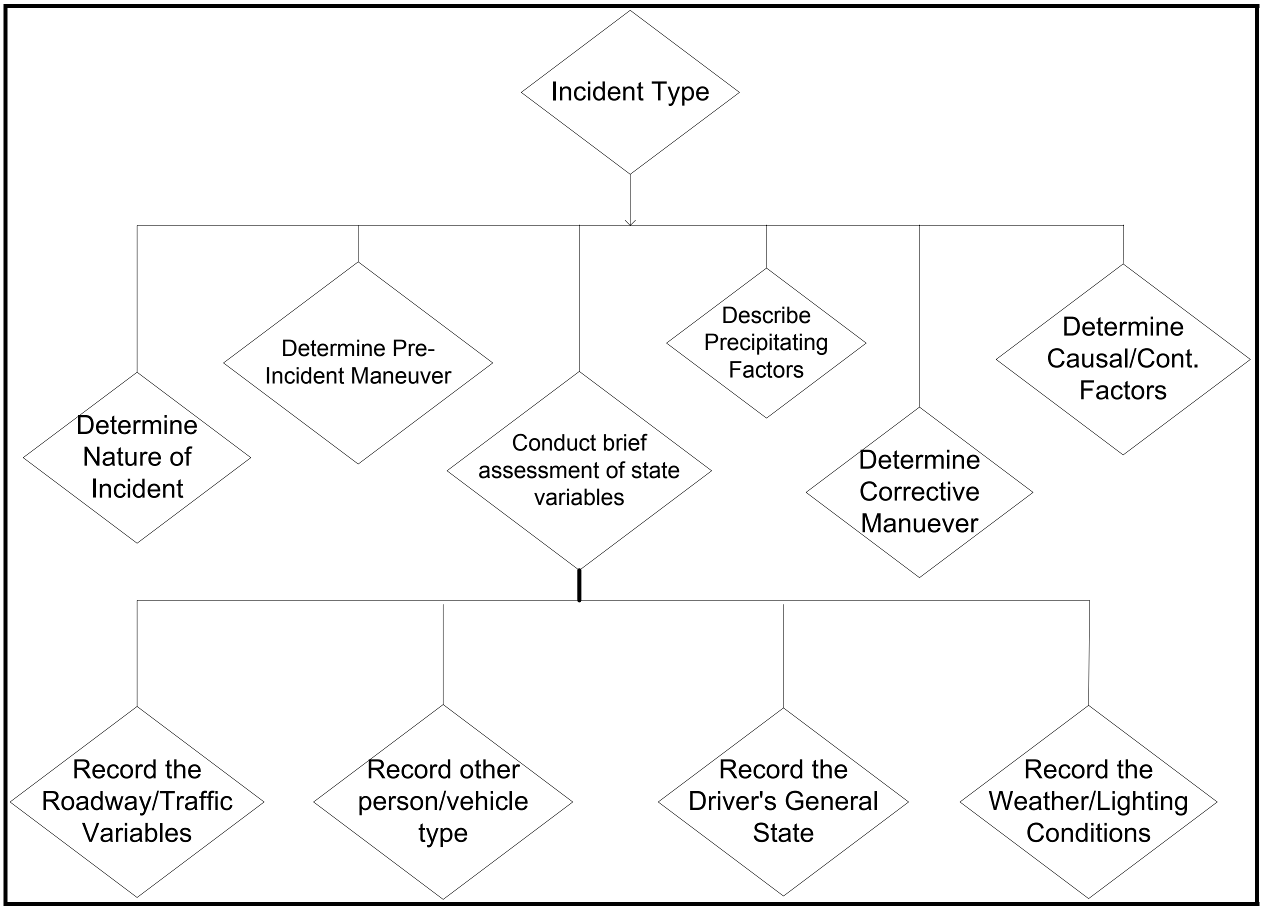

Figure 10. Data reduction framework for critical incident event.

The near-crash analysis will be more detailed than the critical incident analysis (Figure 11). Reconstruction software will be used to create an animated diagram of the near-crash. Eye glance analyses will be performed on these events to determine the location of the driver's eye glance, the percent of time the driver's eyes were closed (when applicable), and the percent of time the driver's eyes were off the forward roadway prior to the incident and during the entire event. The type of crash that nearly occurred will also be recorded as well as all other types of data reduction information. A secondary type of classification will also be conducted, which is to determine whether the near-crash was kinematically simple or complex. This classification will be conducted to develop an objective definition of kinematically simple near-crashes. One expert data reductionist will perform the reduction of near-crash events.

In addition to the analysis of coded data relevant to rear-end crashes, there will be a dynamic reconstruction and representation of rear-end crashes and near-crashes. In addition to data being reduced 30 seconds prior to the event and 10 seconds after the event, an accident reconstruction of the event will span the period from 10 seconds prior to impact (or successful crash avoidance) to 2 seconds after impact/avoidance. A scenario timeline will be obtained that captures vehicle pre-event actions, speeds, range, range rate, braking (timing and force), steering (if applicable), and trajectories. In addition to documenting the actions of the subject vehicle and principal other vehicle, the reconstruction will document the roles of other involved vehicles when the radar and/or video data support such documentation.

Driver behaviors and actions will be recorded by videos and other in-vehicle recorders, and will be indicated as part of the event timeline. These data will be recorded as a time-based multi-event scenario, and represented visually through the replaying of videos and animation of vehicle motion. The animation will simultaneously show vehicle motion, dynamic time and distance relationships (in particular, the dynamic relation between the two vehicles), and key events such as the initiation and cessation of braking, turn signal activation, and, of course, crash impacts.

Each video reconstruction will include a narrative preview of the overall event and its critical features, and a running narration describing key actions and events. The full set of rear-end dynamic reconstructions will be delivered to NHTSA on DVDs suitable for presentation, duplication, and distribution. The scenarios will be organized by major rear-end crash scenario type. The DVD will include a capability for slow motion replay. The dynamic reconstructions will be valuable as presentation tools, and can also be used analytically for modeling the effects of various safety interventions on the scenario. For example, one could model the likely effects of warnings provided to drivers at various range/range rates between vehicles or at other threshold levels of crash risk.

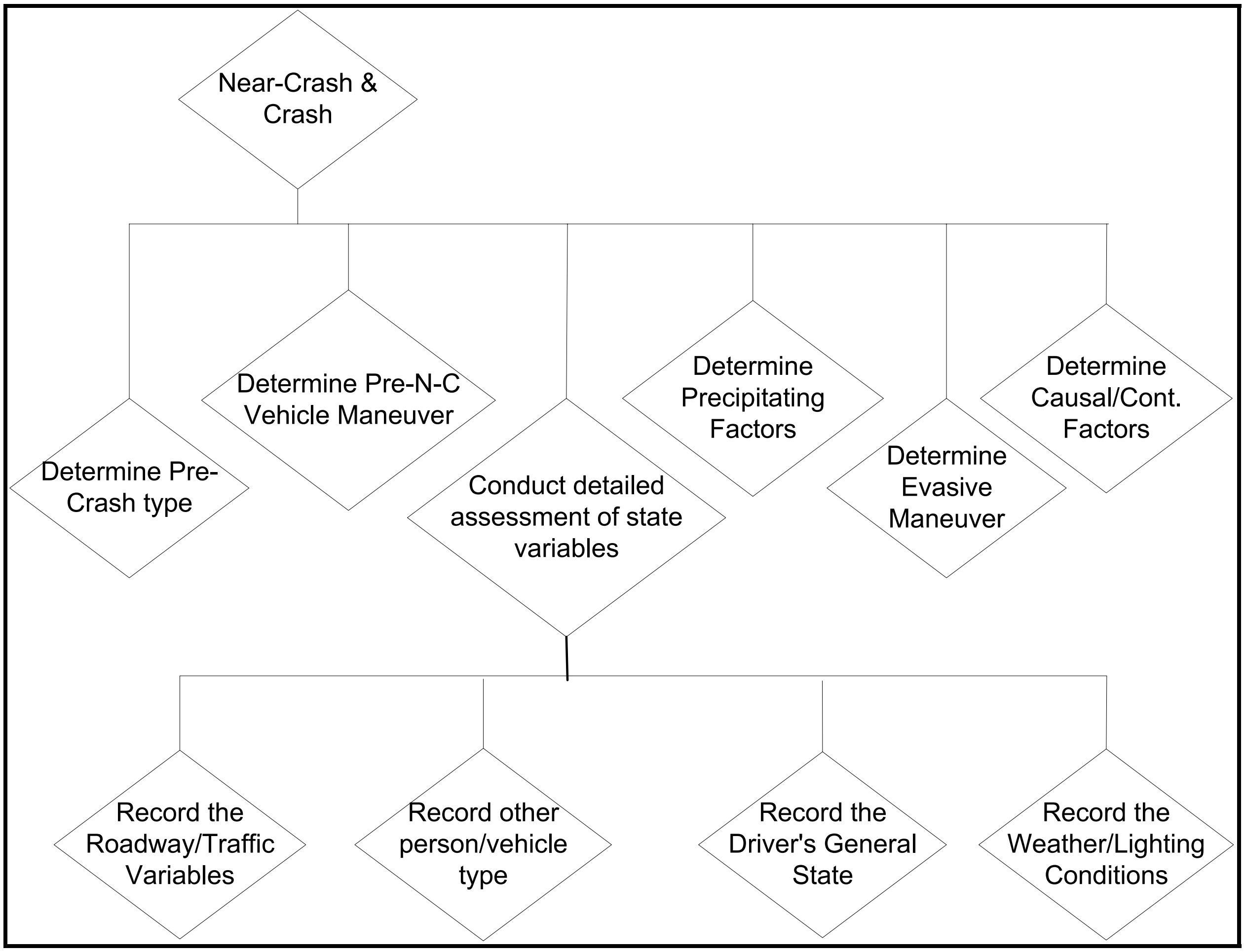

Figure 11. The flow chart for both near-crash and crash data reduction.

The crash analysis will be very similar to the near-crash analysis. The only difference will be the addition of any information gleaned from a police accident report. Again, for consistency, one expert data reductionist will reduce all crash events.

After the data reductionists completely reduce a driving event, the information they have recorded will be saved in a database format that will be usable in SAS or other data analysis programs. As will be outlined in the following section, this database will maintain variable names that currently exist in the GES, Fatality Analysis Reporting System (FARS), and Virginia State Police Accident Report forms. For example, all of the crash types that may be selected by the data reductionists are similar to the crash types listed in the GES database. The codes that correspond to these crash types in the GES database will also be used in this study's database. Using GES, FARS, and the Virginia State Police Accident Report coding schemes will allow direct comparisons between the information gathered in this study and these other databases.

Event Coding Directory

Each type of driving event will be identified and the five areas of data reduction will be recorded. The specific information coded within each area of data reduction is outlined and organized as listed in the Event Coding Directory provided in Appendix B. The Event Coding Directory contains 100 coding variables in three main categories:

1. "Event" variables, analogous to "Accident-Level" variables in data files like GES and FARS, are characteristics of the entire situation or event, such as time, weather, and general type of collision.

2. "Driver/Vehicle" variables apply to one of the involved parties in the event. No distinction is made between driver and vehicle variables; instead, there is a "Driver/Vehicle 1" file applying to the subject driver and vehicle, and a smaller "Driver/Vehicle 2" file applying to the principal other driver and vehicle.

3. "Occupant" variables apply to vehicle occupants as passengers (e.g., to document injuries in crashes). In accordance with Virginia Tech IRB guidance, no video or other data will be collected regarding occupants other than the driver of subject vehicles. Therefore, the only source of information on occupants is traditional crash investigation data from accident reports. Thus, occupant variables are applicable only to crashes.

To the greatest extent possible, variables and elements have been selected to be compatible with Virginia State PAR variables and NHTSA GES variables. The use of Virginia State PAR variables will permit direct comparisons between naturalistic driving events and police-reported crashes for the Northern Virginia area (i.e., Arlington and Fairfax). Selected GES variables have been adopted because they provide more information than those on the Virginia State PAR. Finally, additional variables have been compiled from a combination of sources to permit a more complete and detailed characterization of the event.

Most variables in the Event Coding Directory are accompanied by two types of information. First, the area of data reduction is listed where each variable can be found. Second, the "Source/comment" annotation is listed, which includes the VA or GES variable number, type of information it is coded under (e.g. state variables, incident type/crash type, etc), and any additional information needed to explain the purpose and rationale for the variable. Within a variable, data elements shown in *italics* are elements that have been added or revised from the original source variable. Elements that are boxed are elements that are omitted from the original VA PAR or GES variable.

Documentation of Crashes

The study will gather PAR type data on all subject vehicle crashes, both police-reported and non-police-reported. The inclusion of non-police-reported crashes is essential for two reasons. First, these crashes represent one-half or more of all motor vehicle crashes. These crashes are needed to obtain sufficient rear-end and other crashes in order to support project goals and reliable statistics on crashes. Secondly, non-police-reported crashes are an important "level" of Heinrich's Triangle. Documenting them will help to elucidate the Heinrich Triangle concept for rear-end crashes, and for crashes in general. The discussion of project Objective 8 under Task 11 addresses this.

The data variables collected for non-police-reported crashes will be identical to that of police-reported crashes, and no distinction is made between these two categories in the project data reduction framework and data directories. VTTI researchers will be notified immediately of all crashes, whether they are police-reported or non-police-reported. Automatic incident notification triggering will initiate a call to VTTI researchers based on the crash criterion of a sustained g-force of 2.5 gs over 1.2msec on any of the 3 axes. Voice contact with the driver will be attempted and appropriate emergency services contacted. Subjects will be instructed to immediately notify VTTI researchers of any crash, regardless of severity. If they fail to do so, as they may for some minor crashes, the event will still be captured post hoc via the triggering criteria of the data reduction.

When possible, VTTI researchers will immediately respond to crash notification. If this is not possible, they will meet with subjects as soon as possible to gather data on the crash. For police-reported crashes, a copy of the PAR will be obtained from the subject driver. NHTSA has also indicated that special crash investigation teams under contract to NHTSA (i.e., the "Go Team") will be able to participate in these investigations and reconstructions. In any event, the data collected on NPR crashes will be identical to that collected for PR crashes (e.g., the variables ordinarily coded on scene by police), and will provide information for coding as many crash data variables as possible. During the final data reduction, reductionists will review and evaluate both the paper-based and electronic data (especially videos) to ensure accurate crash coding.

Data Archiving Plan

There will be five sources of data collected for this project:

1. Driving performance data
2. Video data
3. General information/identification data
4. Subject classification data (questionnaires)
5. Police accident reports

For the driving performance and video data, it is estimated that the continuous data collection system will collect data for one year at 2 MB per minute for approximately two hours per day on 100 test vehicles for 12 months. If an additional thirteenth month is necessary for data collection of the approximate ten rear-end crashes, 80 vehicles will similarly be driven for an additional month. Therefore:

(2 MB/min * 120 min/vehicle/day * 100 vehicles * 365 days) + (2 MB/min * 120 min/vehicle/day * 80 vehicles * 30 days) = 9,336,000 MB
= ~9 TB of dynamic vehicle and video data

For the general information/identification data, baseline data for 100 individual vehicles has to be documented for model and year, style, engine, transmission, airbag configurations, VIN, manufacturer optional equipment, after market equipment additions, variables available from the onboard data network, vehicle condition, etc.

In the case of the subject classification data, all subjects will complete questionnaires on their general demographics, current health, driver aggressiveness, and habitual sleep hygiene. All subjects will also have their vision and hearing tested.

Detailed police accident report data files will be collected for all police-reported accidents that occur. The information gathered as part of the PAR will be used for data reduction purposes, to obtain specific information about the scene of the accident, the driver, and any other driver or pedestrian that may have been involved.

Data Analysis

Table 17 (Table 2 earlier in the report) lists 10 major project analytic objectives organized by research category and subcategory. The section below again lists these objectives and summarizes the planned analytic approach to each. The project objectives are organized by general research categories and subcategories.

Table 17. List of research objectives organized by research category and subcategory.

General Research Category: Driver Behavior and Performance	
Subcategory: Crash/Near-Crash/Conflict Events	
Goal 1	Classify and quantify causal factors and dynamic scenarios involved in each crash type.
Goal 2	Operationally define a "near-crash" using quantitative measures.
Subcategory: Distraction Issues	
Goal 3	Characterize driver distraction as it relates to driver errors, critical incidents, near-crashes, and crash events.
Subcategory: Baseline Driving and Data Collection Issues	
Goal 4	Characterize the differences in driving behavior and/or driver performance between: 3) One week field data and one year of naturalistic driving data 4) One month in leased vehicle versus owned vehicle
General Research Category: Distribution of Events	
Subcategory: Rear-End Event Analysis	
Goal 5	Determine rear-end causal factors and dynamic conditions. For each of the four rear-end (RE) lead-vehicle conditions (stopped >2 seconds, decelerating, accelerating, and moving at a slower constant speed), determine the frequency distribution of the following: vehicle crash encounters, near-crash encounters, and critical incidents 1) Per vehicle mile traveled (VMT); 2) In relation to contributing factors; 3) in relation to corrective actions; and 4) in relation to transition events.
Goal 6	Determine RE dynamics and primary factors; specifically, determine the frequency distribution for the following variables: 4) Per VMT 5) Initial Dynamic Condition/Kinematic Condition 6) Primary contributing/causal factor Crossed with these variables: 5) Rear-end event (crash, near-crash, incident) 6) Rear-end event where lead vehicle changed lanes in front of subject vehicle 7) Rear-end event where subject vehicle changed lanes behind lead vehicle 8) Rear-end event where subject vehicle took corrective action
Subcategory: Distraction Issues	
Goal 7	Determine the distribution of distraction types for each RE lead-vehicle condition (stopped >2 seconds, decelerating, accelerating, and moving at a slower constant speed)
Subcategory: Baseline Driving and Data Collection Issues	
Goal 8	Characterize each of the four RE lead vehicle motion types in relation to Heinrich's triangle.
General Research Category: Design of Phase IV Study	
Subcategory: Vehicle Instrumentation	
Goal 9	Evaluate the performance of the hardware, sensors, and data collection system used in Phase II.
Subcategory: Data Reduction and Analysis	
Goal 10	Evaluate the performance of the data reduction plan, triggering methods, and data analysis.

Driver Behavior and Performance; Rear-End Crash/Near-Crash/Conflict Events

Objective 1: Classify causal factors and dynamic scenarios involving in each crash type.

Approach: Conceptually, there will be a multi-dimensional analytic matrix (Figure 12) composed of any of the following dimensions: event (crash and sub-crash) type, severity, pre-crash/incident maneuvers, causal factors, precipitating factors, evasive maneuvers, and any/all state variables (Table 17, information type). Frequency data for crashes and other events will be analyzed per these multiple factors and dimensions. These frequency data can be expressed as rates by combining them with exposure measures such as VMT or vehicle-driver years.

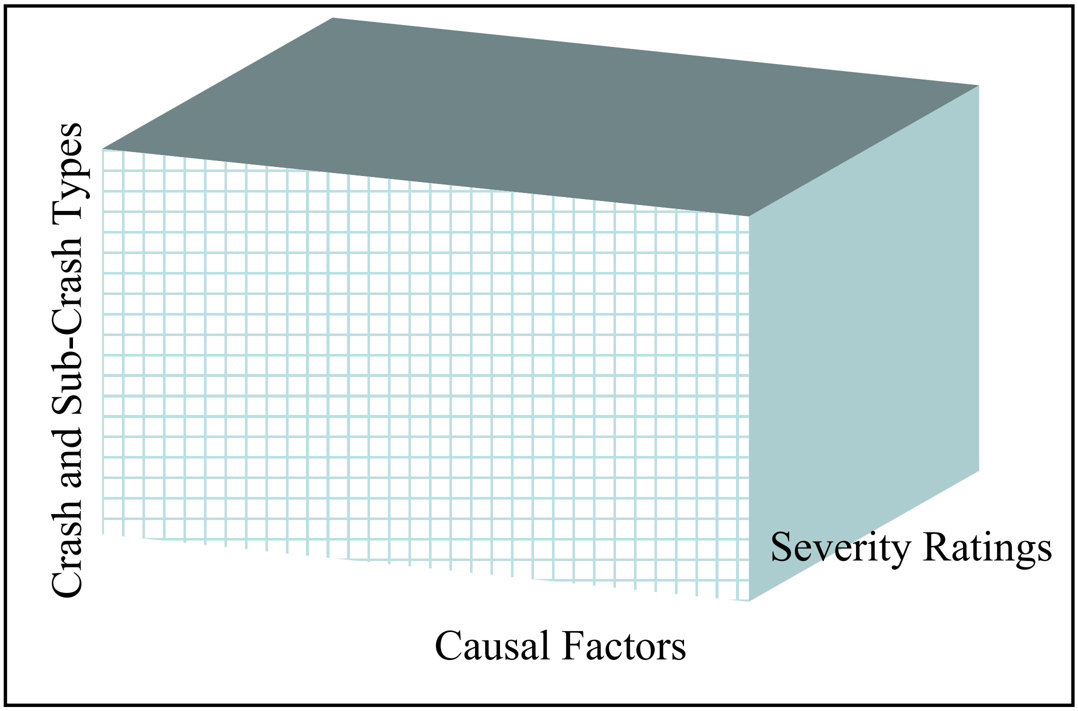

Figure 12. Multi-dimensional analytic matrix to be used in multi-factor data analyses.

Objective 2: Operationally define a near-crash using quantitative measures.

Approach: Currently, near-crashes are qualitatively defined as rapid, evasive maneuvers (i.e., very hard braking or violent swerving) performed in a controlled or uncontrolled manner to narrowly avoid a crash. Trained video reductionists view the video of critical events and classify each event as either a crash, a near-crash, or a critical incident based on this subjective definition.

To operationally define a near-crash in an objective manner, trained reductionists will continue to classify events by their severity using the above subjective definition. Then, each near-crash event will be viewed by an expert video reductionist and further classified as either a kinematically-complex near-crash or a kinematically simple near-crash. A kinematically-complex near-crash is defined as an event where the kinematic data is either incomplete, unclear, or unimportant in the classification of the event. A kinematically simple near-crash is one where the kinematic data is complete and clear. For example, a kinematically complex near-crash would be an event where the driver is making a lane change in stop-and-go traffic. No kinematic data will be collected on the side of the vehicle and forward and rear range-range/rate values will tend to be very small. A kinematically simple near-crash would be a rear-end striking incident where the range-range/rate information and video is present for the duration of the incident.

The kinematically simple near-crash incidents will then be used to develop multi-dimensional matrices where multi-factor statistical analyses can be performed to determine what relationships exist between the near-crash incidents. This information will be used to develop a quantitative definition of a near-crash event. The kinematically complex near-crashes will not be used in the development of a quantitative definition.

Driver Behavior and Performance; Distraction Issues

Objective 3: Characterize driver distraction as it relates to driver errors, critical incidents, near-crashes, and crash events.

Approach: Data variable DV1-18 is "Driver Distracted By" and is similar to GES Variable D7, and will be coded for all events (crashes, near-crashes, incidents, and baseline epochs). Data reductionists will classify all distraction events and determine whether distraction was a causal factor in the incident. Analysts will determine the frequency of events where distraction is a causal factor, and compare distracted and non-distracted driver performance for both severity of event and performance of corrective actions. The occurrence of distraction from various sources as indicated by DV1-18 (e.g., other occupants, talking on mobile phone, dialing phone, radio, CD) can be compared to all the other coded variables to elucidate the types of driving safety threats posed by each. Distracted driving and its various sources can be correlated with other driver characteristics (e.g., speeding, aggressiveness, hard braking) to further characterize the distracted driver. In addition, for crashes and near-crashes there will be a driver eye glance reconstruction for the 60 seconds prior to impact (or near-impact). This will be especially useful in documenting the distracting effects of in-vehicle devices or other distraction sources evoking multiple driver eye glances in the time period preceding the incident.

Driver Behavior and Performance; Baseline Driving and Data Collection Methods

Objective 4: Characterize the differences in driving behavior and/or driver performance between: one week FOT data and one year of naturalistic driving data, and one month in leased vehicle versus owned vehicle.

Approach: For the first 12 months of the study, 80 subjects will be driving their own vehicles and 20 will be driving leased vehicles. In the thirteenth month, 20 subjects of the original 80 will drive leased vehicles for this additional month. The data stream from the vehicles will automatically calculate the time subjects have participated in the study as well as their time driving each experimental vehicle. Analysts will:

- Determine the rate of vehicle adaptation in an unfamiliar vehicle with the data collection system.
- Determine the rate of vehicle adaptation in a familiar vehicle with the data collection system.
- Determine if any measurable differences exist between subjects in their own vehicles versus the same subject in leased vehicles.

Dependent measures most relevant to this determination include the rate of driving errors and specific variables such as “Driver Distracted By” and the driver eye glance reconstruction.

Distribution of Events; Rear-End Event Analysis

Objective 5: Determine rear-end causal factors and dynamic conditions. For each of the four RE lead-vehicle conditions (stopped >2 seconds, decelerating, accelerating, and moving at a slower constant speed), determine the frequency distribution of the following: vehicle crash encounters, near-crash encounters, and critical incidents:

- Per VMT
- In relation to contributing factors
- In relation to corrective actions.

Approach: For crashes and near-crashes, data variables such as DV1-5 (Vehicle 1 Maneuver) and DV1-8 (Critical/Precipitating Event for Vehicle 1) will enable the classification of RE events into the four lead-vehicle conditions. It will not be possible to classify incidents to this level of detail, but they will be classified as potential RE striking or RE struck scenarios in Variable DV1-7 (V1 Incident Type). The incidence of each of the RE scenarios per VMT (or other measures of exposure) will be determined. They will be characterized and compared using multiple scenario reconstruction and contributing factors variables, including the following.

- Scenario Reconstruction Variables:
  - Vehicle Maneuver
  - Vehicle Accident (or Near-Accident) Type
  - Vehicle Incident Type
  - Critical/Precipitating Event
  - Corrective Action Attempted
  - Deceleration During Braking
  - Steering Response
  - Driver Actions/Factors Relating to Crash/Incident
  - Driver’s Action [reason for avoiding, swerving, sliding]
- Contributing Factors Variables:
  - Driver Physical/Mental Impairment (if known)
  - Drowsiness Rating
  - Driver Time-On-Task
  - Eye Glance Reconstruction
  - Driver Alcohol Use (if known)
  - Driver Vision Obscured by (if known)
  - Driver Distracted By
  - Driver Actions/Factors Relating to Crash/Incident
  - Vehicle Contributing Factors
  - Driver’s Action [reason for avoiding, swerving, sliding].

Objective 6: Determine RE dynamics and primary factors; specifically, determine the frequency distribution for the following variables:

- Per VMT
- Initial Dynamic Condition/Kinematic Condition

- Primary contributing/causal factor

Crossed with these variables:
- RE event (crash, near-crash, incident)
- RE event where lead vehicle changed lanes in front of subject vehicle
- RE event where subject vehicle changed lanes behind lead vehicle
- RE event where subject vehicle took corrective action.

Approach: The four RE subtypes based on lead vehicle motion will be crossed with these specific scenarios. Variable DV1-8 (Critical/Precipitating Event for Vehicle 1) has been expanded from the GES version to identify the above scenarios. The incidence of each scenario will be determined in relation to VMT and other measures of driver exposure, and they will be characterized and compared using multiple scenario reconstruction and contributing factors variables, as listed above under Objective 5. The dynamic reconstruction of RE crashes and near-crashes will also capture and document these types of scenarios as well as other "transition" events as described by the Volpe National Transportation Systems Center (VNTSC) in their evaluation of the Intelligent Cruise Control (ICC) Field Operational Test. The descriptions of such transitions will include dynamic conditions such as distance between vehicles at the time of the lane change, level of braking by the lead-vehicle (when derivable from radar data), and vehicle speeds. Related situational variables such as type of roadway, weather, road surface condition, and traffic density will be analyzed.

Distribution of Events; Distraction Issues

Objective 7: Determine the distribution of distraction types for each RE lead-vehicle condition (stopped >2 seconds, decelerating, accelerating, and moving at a slower constant speed).

Approach: For crashes and near-crashes, the four RE subtypes based on lead vehicle motion will be crossed with data on driver distraction, and related variables. It will not be possible to classify incidents to this level of detail, but they will be classified as potential RE striking or RE struck scenarios. Driver distraction-related variables include the following:
- Drowsiness Rating
- Driver Time-On-Task
- Driver Eye Glance Reconstruction
- Driver Vision Obscured By
- Driver Physical/Mental Impairment
- Driver Distracted By
- Driver Actions/Factors Relating to Crash/Incident

In addition, the dynamic reconstruction of RE events (described previously) will include narrative comments on driver distractions and their role in the RE event.

Distribution of Events; Baseline Driving and Data Collection Methods

Objective 8: Characterize each of the four RE lead vehicle motion types in relation to Heinrich's triangle.

Approach: The four RE crash/near-crash subtypes and the two RE incident types (RE striking and struck) will be crossed with measures of event severity, and these event type/severity categories will be characterized in terms of their incidence (rate per VMT), associated confidence intervals, comparisons with GES and Virginia State statistics, and comparisons across vertical levels (i.e., C vs. N vs. I). Critical event severity-increasing factors will be identified. Altogether, eight levels of event severity will be identifiable based on the combination of Variables E-3 (Event Classification) and E-4 (Most Severe Injury in Crash). These eight identifiable levels are:

- Fatal Crash
- Injury Crash (A, B, and C)
- Tow-away Police-Reported Crash (No Injury)
- Non-Tow-away Police-Reported Crash (No Injury)
- Non-Police-Reported Crash
- Near-Crash
- Incident (Driver Error)
- Baseline Driving Epoch

The most important implication of Heinrich's Triangle for safety is the supposition that reducing unsafe acts will reduce crashes. The number of events at various levels of severity will be important, but more important will the qualitative relation; i.e., the degree to which events at different levels are similar or different in nature. Comparisons among different levels of event severity within each of the dynamic RE categories will provide detailed answers to these questions.

Design of Phase IV Study; Vehicle Instrumentation

Objective 9: Evaluate the performance of the hardware, sensors, and data collection system used in Phase II.

Approach: A major objective of Phase II is to gain lessons learned on all aspects of the naturalistic driving approach and methodology, and incorporate these lessons into the planning for Phase IV, the large-scale field data collection effort. Vehicle instrumentation is a major element of the naturalistic driving methodology and, accordingly, will be a major area of planning for Phase IV. VTTI will systematically evaluate sensor performance, including hardware/software reliability, data acquisition rates, and how well the instrumentation supports the acquisition of study data variables. VTTI will assess all data acquisition system components from the standpoint of cost (original purchase price plus installation and maintenance costs) and benefit (i.e., contributions to the meeting project objectives). VTTI will also review the trigger criteria used to capture incidents to determine whether vehicle instrumentation changes would improve incident capturing. There also will be lessons learned in the areas of equipment installation, de-installation, data storage in subject vehicles, and data downloading. All of these lessons learned will be incorporated into the Phase II final report as well as the Phase III planning for the Phase IV full-scale data collection.

Design of Phase IV Study; Data Reduction and Analysis

Objective 10: Evaluate the performance of the data reduction plan, triggering methods, and data analysis.

Approach: As noted above under Objective 9, a major objective of Phase II is to gain lessons learned on all aspects of the naturalistic driving approach and methodology, and incorporate these lessons into the planning for Phase IV, the large-scale field data collection effort. VTTI will critically assess all aspects of project data handling, reduction, and analysis to identify areas for improvement and recommended procedures for the Phase IV full-scale field data collection. This will include data handling, archiving, and display hardware, software, and procedures. Data reduction protocols will be reviewed, in particular the specific variables and elements of the Data Directory. Data variables will be assessed in regard to their support for study objectives, comparisons with Virginia State PAR and GES data on comparable variables, and coding reliability. Variable unknown rates will be a major source of evaluative information, both of the overall naturalistic driving methodology in relation to conventional crash investigation, and for further refining the naturalistic driving methodology. This project will include several "dynamic" data reduction approaches, including drowsiness ratings and PERCLOS measurement, driver eye glance reconstruction, and dynamic reconstruction and video "playback" of RE crash scenarios. The success of these methods will be assessed in the Phase II final report, and specific recommendations will be made in the Phase III report regarding Phase IV plans.

Hardware Configuration for Data Collection, Backup, and Archiving

A data acquisition system will reside on board each test vehicle and will continuously store measured variable data and video streams from five cameras during driving sessions. The internal hard drive is sized to store at least four weeks of six hour driving days, although VTTI researchers intend to download the data once per week. The large storage size allows for possible extended trips out of the DC area.

VTTI researchers will have communication capabilities with each of the test vehicles via cell phone. Each vehicle will have a cell phone account to enable the download of video and vehicle data "snippets" to verify proper systems operation, query the data system for GPS location information, and delete archived data from the vehicle hard drive. A wire system, as described previously, will be used to download the driving performance and video data to a nearby chase vehicle as well as upload software revisions from the chase vehicle to the test vehicle.

Each chase vehicle will be outfitted with a DVD-R drive to record data from daily test vehicle downloads. Each chase vehicle will recover data from an average of four to six vehicles and download approximately 6 GB per day.

For the data reduction hardware, a gigabit Ethernet network will interconnect all data reduction and administrative PCs to all data backup, archival, and retrieval hardware. This will be a stand-alone network with user ID and password logins, as well as priority and privilege assignments to protect data and software access (Figure 13).

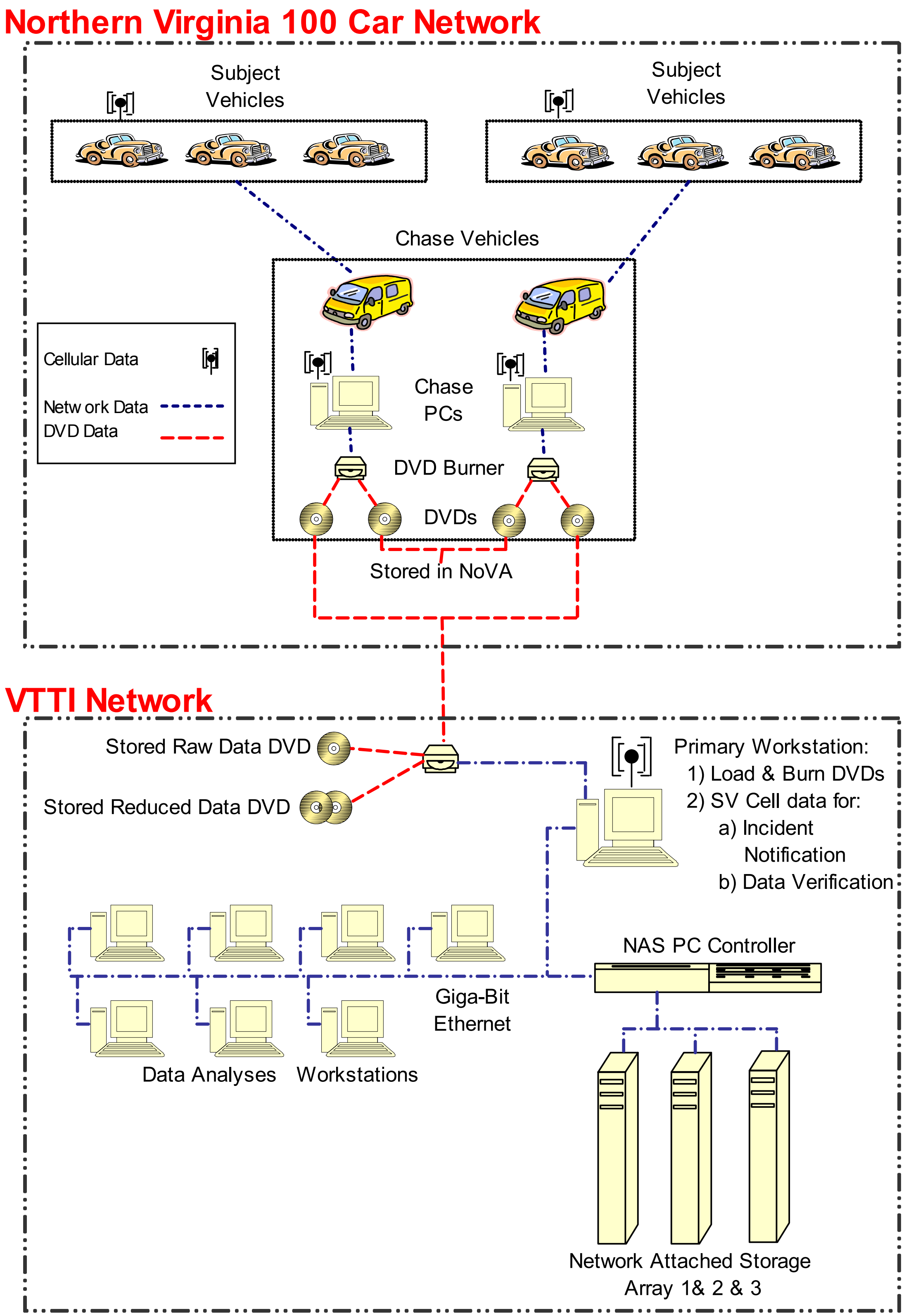

Figure 13. The data reduction hardware network.

An array of fast SCSI hard drives will provide a minimum 2 TB of network attached storage (NAS). The NAS is sized to store at least 80 days of raw driving data from 100 test vehicles. Initially, approximately 36 to 55 contiguous days of data will be used to optimize the post hoc trigger configurations for epoch scans. Once the server storage exceeds approximately 90 percent of capacity, the older data files will be scrolled off as new driving performance and video data are loaded. The removed data files will be copies of the original video and driving performance data files that are already backed up twice onto DVD disks.

Eight to 10 PCs will reside on the network. Two or three PCs will be used to write the original driving session DVD files to the NAS and catalog all resulting files in a database to track data files and data reduction progress. One or two PCs will be used to perform administrative, software support, backup, archival, and data retrieval roles. Five or six PCs will be used to analyze and reduce the data. Each data reduction PC will be equipped with at least a DVD/CD-ROM drive while the administrative or technical support PC will have a DVD-R/CD-RW drive.

Steps in the data backup and archival process are described below:

- Each test vehicle will have an onboard data collection system that will be downloaded to a chase vehicle. The onboard hard drives will maintain the recorded data files until the downloaded data has been backed up and is resident on the project server at VTTI. Thus, the vehicle data collection systems perform as temporary first level data backup systems.

- Downloaded data will be sequentially written to single-sided DVDs, each capable of storing 4.7 GB. Once a DVD is full, it will be backed up in the chase vehicle prior to being shipped to VTTI for data reduction. All of the original DVDs will be safely stored at one location in Northern Virginia. Presently, duplicating a single-sided DVD requires about 30 minutes, so an average of two and one-half hours daily will be devoted to duplicating the original data disks. The workload for this software-automated procedure will be negligible, requiring only a single disk swap-out per DVD duplication.

- Typically, five or six full DVDs will be shipped to VTTI where they will be uploaded to the server. At the end of the project, the original downloads and their duplicate sets (located in DC) will account for about 3,800 DVDs.

- At VTTI, the driving session files for each day will be written to the project server in their original form as well as the extracted non-video components, and catalogued to a separate file that accumulates day-by-day on that server. This file will contain all information required to effectively manage the data reduction, evaluation, backup, and eventual archival of all data, analysis, and results files. This file will also be immediately updated/backed-up to a DVD written on the PC used to administer data reduction, backup, and archival. Since the catalogue file will not include any video data and will be similar to a spreadsheet or database file, it will be a very small file that can be updated to a single CD or DVD throughout the project.

- During the first two to two and a half months, several post hoc trigger optimization scans will be performed across all of the non-video data extracted from the original data files accumulating on the project server. Each scan will result in epochs of time-streamed data straddling the time at which a trigger criterion was exceeded, indicating that an incident, near-crash, or crash may have occurred at the triggered time. Until the trigger optimization process is complete, the scanned, non-video epoch data will only be temporarily saved on the server for evaluation. Once the trigger optimization process is finalized, only the triggered incidents, including the associated video data, will be saved on the project server as well as on a DVD written on the PC used for data administration and backup. It is expected to average 500 MB per day in epoch data, or about 2 percent of the daily total, which can be backed-up to a blank CD daily. Weekly, a blank DVD will be used to accumulate and backup the previous seven days of epoch data on one disk.

- It is expected that no more than 80 days of original data files will be required to optimize and finalize trigger settings. This procedure will require a 2 TB server. Once 80 days of data are stored, or about 90 percent of server capacity is reached, older raw data will have to be purged from the server. Since these data will already be on 2 DVD backup sets, further archival will not be required. The crucial epoch data, including the associated video, will remain resident on the server as well as backed-up to both CDs (daily epochs) and DVDs (weekly epoch sets).

- If, at a later date, a tighter optimization of the current trigger-scanning process is achieved and a re-scan of the original data is required, it will be necessary only to re-scan the non-video individual epoch files which are stored on the project server.

- If, instead, a more loosely configured trigger scan is required, or if a different type of event is being scanned that occurs under a unique trigger configuration, then rescanning all of the original data will be necessary and will result in epochs outside the original set. Performing this type of re-scan over the entire original data set will require that the original files be reloaded. After the sequential reloads and re-scans are complete, all epoch subsets can be combined into one file. This process would be very time consuming; re-scanning all the original data collected would require 1,900 DVDs to be loaded back on the server in 1.5 Tb segments.

- At project completion, all project data, analysis, and results files will be stored:
    - As original data files on two duplicate sets of DVDs with about 1,900 disks per set. A subset 1.5 TB of these files will also be resident on the project server.
    - All epoch data files, including the associated video, on about 60 DVDs and duplicated also on DVD, as well as stored on the project server. The DVD set may be replaced with a second set of DVDs.
    - The catalogue files maintained on the server and two duplicate DVD disks.

TASK 12: DEVELOPMENT OF DATA COLLECTION SYSTEM REQUIREMENTS

The results of Task 12 follow from the combined performance of Tasks 2 through 11. Additionally, Task 12 results were iterated and integrated with those of Tasks 13 and 15 to drive the Hardware/Software Design Specification.

The data system requirements are categorized into four major areas:

1. Schedule Requirements
2. General Design Requirements
3. Performance Requirements
4. Test Vehicle Profile

The requirements under each of these major areas are listed in Table 18 below.

Table 18. Data collection system requirements.

Number	Requirement
1.0	**Schedule Requirements**
1.1	Engineering time less than 9 months
1.2	Manufacturing time less than 3 months
1.2.1	Two months at VTTI
1.2.2	One month with a subcontractor
1.3	Installation time less than 5 hours for each vehicle
2.0	**General Design Requirements**
2.1	Unobtrusive
2.1.1	Designed to avoid driver distraction
2.1.2	Must not limit the driver's field of view to the roadway and vehicle perimeter
2.1.3	Must not be salient, but an invisible installation is not required
2.2	Non-invasive
2.2.1	Installation cannot make permanent modifications to any part of the vehicle or vehicle systems.
2.2.2	Must be compact to minimize encroachment on vehicle cargo capacity
2.2.3	Must be adaptable to the chosen six test vehicle models (4 personal and 2 fleet models)
2.3	No experimenter present
2.3.1	Must have automated start-up and continuous operation during vehicle use
2.3.2	No subject performed calibration required
2.3.3	Must automate data and software transfer between test vehicle and assigned chase vehicle
2.3.3.1	Must automate downloading data to a nearby chase vehicle
2.3.3.2	Software revisions must be received by wire to automatically update software without the loss of data
2.3.3.3	Must allow chase vehicle operator to initiate purging of select data files that are double-backed up
2.3.3.4	Must be able to monitor hard drive space in real time to determine if data storage is nearing capacity
2.4	System must address power and internal communication needs
2.4.1	Designed to not deplete a standard automotive battery that is in good working condition under any circumstances
2.4.2	Serial network approach for low power needs and network flexibility
2.5	Cost no more than $8,500 for each of the 100 vehicles (exclusive of installation costs)
3.0	**Performance Requirements**
3.1	Reliable
3.1.1	Less than 10% data loss
3.1.2	Must be able to automatically detect and isolate hardware/software failure to line replaceable unit level
3.2	Continuous data collection
3.2.1	Incident data determined post hoc with editable triggers
3.2.2	Resulting comprehensive database can be filtered, scanned, sampled, etc. according to researchers' needs
3.3	Crash Survivability
3.3.1	Must function throughout and following a ±50g acceleration covering 50 ms
3.3.1.1	Assumes no fire conditions after crash
3.3.1.2	Must have internal battery to maintain power if main battery connection severed
3.4	Camera performance
3.4.1	Capture driver eye glance and driver manual operations including the instrument panel
3.4.2	Support observer rating of drowsiness analysis
3.4.3	Capture forward view, TCD presence/status, brake light status of lead vehicle, validity/severity/cause of incident
3.4.4	Capture adjacent vehicle presence on both left and right sides of vehicle
3.4.5	Capture rear view to assess vehicle-dynamic-related (not driver behavior-related) causes of struck vehicle crashes

Number	Requirement
3.4.6	Obtain limited information about traffic in vicinity
3.4.7	Conform to IRB and Certificate of Confidentiality requirements, including no passengers in video view
3.4.8	Must conform to IRB regulations
3.5	Driver performance events that must be detected
3.5.1	Determine if lane boundary is exceeded
3.5.2	Determine the presence of a lateral or longitudinal evasive maneuver for incidents, near-crashes, and crashes
3.5.3	Determine contributing factors and time history of driver response
3.5.4	Observe overt driver behavior that would indicate driver distraction as causal or contributing factor
3.5.5	Determine use of cellular telephones, PDA's and other wireless devices
3.5.6	Determine use of instrument panel and other in-vehicle devices for incidents detected via the above events
3.5.7	Allow driver to capture an incident and give verbal description
3.5.8	Determine speed of vehicle prior to incident
3.5.9	Determine when crash has occurred in order to notify 911, NASS Go-Team, etc.
3.5.10	Determine location of vehicle for system maintenance, emergencies, and environmental contributing factors
3.5.11	Obtain "baseline" performance data on demand to learn about the driving habits of the subject population
4.0	**Test Vehicle Profile**
4.1	Model years with common vehicle structural design and components
4.2	Model years with common set of in-network variables
4.3	Makes and models that are a large part of the DC/Northern Virginia fleet
4.4	Can access onboard vehicle data network

TASK 13: REVIEW/TEST OF TECHNOLOGY/SENSOR ALTERNATIVES

Tasks 13 and 15 were conducted in parallel to determine the most suitable hardware and software alternatives for each subsystem component. Table 19 lists each data collection subsystem and the related component that was analyzed under each subsystem. The data handling and software integration subsystems were addressed in Task 11. The remaining components are addressed in Tasks 13 and 15.

Table 19. Data collection subsystems and related components.

Data Collection Subsystems	Components
Data Acquisition	▪ Forward and Rear Range/Range Rate ▪ Lane tracking ▪ Side sensing ▪ In-vehicle network ▪ All other sensors
Video Acquisition	▪ Cameras ▪ Views ▪ Compression
Data Storage	▪ Temporary buffer ▪ Longer term storage
Data Communications	▪ Data transfer to VTTI chase vehicle by wire system ▪ Data snippet download system check by wireless system ▪ Software revisions ▪ Data deletion notification ▪ Locating test vehicle ▪ Automated collision notification
Power Management	▪ Hardware & software
Data Handling	▪ Data replication in chase vehicles ▪ Storage of DVDs at DC & VTTI ▪ Workstation PCs ▪ Temporary server storage ▪ Archive to DVDs
Software Integration	▪ Video and non-video integration ▪ Sensor signal interpretation ▪ E.U. conversions ▪ Data storage

The purpose of Task 13 was to review the alternatives for each subsystem component. Table 20 shows the available technologies and the factors that were relevant based upon the data collection system requirements determined as part of Task 12.

Table 20. Technology and sensor alternatives for subsystem components.

Component	Available Technologies	Factors

1. Forward and Rear Range Measurement	• Laser (single and multi-beam geometries)
	• Radar
		• Signal reliability
		  • Data Accuracy
		  • Signal Differentiation for Acceleration
		• Calibration/Maintenance Requirements
		  • Position sensitivity
		  • Susceptibility to road dirt, dust film build-up, etc.
		• Performance in rain/weather
		• Obtrusiveness for "other" drivers
		• Cost

2. Lane Tracking	• Hardware based measurement
	• Software and video camera integrated solutions
	  • Off-the-shelf purchase
	  • In-house creation
		• Reliability
		• Accuracy
		• Real-time processing
		• Costs and manpower requirements

3. Side Sensing	• Laser (single and multi-beam geometries)
	• Radar
		• Signal reliability
		  • Data Accuracy
		  • Signal Differentiation for Acceleration
		• Calibration/Maintenance Requirements
		  • Position sensitivity
		  • Susceptibility to road dirt, dust film build-up, etc.
		• Performance in rain/weather
		• Obtrusiveness for "other" drivers
		• Cost

4. In-Vehicle Network Issues	• In-vehicle network
	  • Must obtain or derive network variable access codes
	• Determine if minimal set of variables across all test vehicle models can satisfy requirements of project variables
	  • If not, add additional sensors, instruments, software, and so forth
	    • Hardware, manpower, and time impacts
		• Access codes availability
		• Costs and time requirements to make possible the measurement of variables not available on the in-vehicle network

5. Video Acquisition	• Analog video
	• Digital video on USB or Firewire networks
	  • Using software compression
	  • Using real-time hardware compression
		• Signal reliability
		• Picture quality
		• Sample/frame rate
		• Hardware
		  • Size
		  • Network requirements
		  • Transmission speed/bandwidth
		  • Multi-device handling capabilities
		  • Trade-off number of cameras versus picture resolution

6. Camera Views	• Trade studies performed for views
	• Trade studies performed for views as stored and presented to the data reductionist
	  • Under non-crash conditions
	  • During crash conditions
		• Meet the requirements to measure project variables
		  • Number of cameras/views necessary
		    • Maintain data rate < 2 MB/min
		    • Cost to meet the max data rate criterion versus additional archival storage cost
		  • Record exterior views on either side of test vehicle
		  • Record driver's face with sufficient resolution to measure eye glance data
		  • Record driver arms, hands and feet movements to measure driver commanded variables
		  • Record forward and rear views to determine the performance of the rear struck and striking vehicles prior to and following a crash, near-crash, or driving incident

Component	Available Technologies	Factors

		• Must not record passengers
		• Unobtrusiveness
		  • Does not interfere with test vehicle driver performance for each of the selected test vehicle models
		  • Should be hidden from driver to the greatest extent practical
		  • Must not provoke extended eye glance diversion by other drivers
		• How views are to be presented to data reductionist
		  • Manpower and time-implementation costs for video presentation alternatives
		  • Required image resolution to accurately assess driver actions, alertness, and eye glance diversion

7. Video Compression	• Uncompressed video (24 bit color)
	• MJPEG
	• MPEG 4.0
	• DIVX MPEG 4 (under two conditions- Fast Motion and Low Motion)
	• DIVX 4.0
	• Cinepak
	• Microsoft RLE
	• Microsoft Video 1
	• Sorenson Quicktime
	• Wavelet (hardware compression)
	• MPEG 1 or 2 (hardware compression)
		• Resulting data rate must be < 2 MB per minute
		• Hardware versus software based compression
		  • Hardware based compression
		    • No load on main CPU
		    • Additional monetary costs
		  • Software based compression at real-time speeds
		    • Increased processor speed requirements
		    • Manpower and time implementation costs
		• Picture quality sensitivity to picture change rate or object motion in frame
		  • High rate of change/motion
		  • Low rate of change/motion
		  • Sample frequency (frame-grab rate for digitized video)

8. Data Storage (Including Video)	• Tape (analog and digital formats)
	• Computer hard drive
	• Removable drive/cartridge
	• DVD disks (writeable)
	• Non-volatile memory
		• Temporary storage buffer for the pre- and post-accident period. At a minimum, must encompass the pre- and post-accident period
		  • Capacity sufficient for 2 minute data record
		  • Capacity to temporarily store several hours of driving data
		    • Allows the final storage device to be at rest
		    • System power requirements reduced
		    • May improve crash survivability of the final storage device
		  • Reliability
		    • Must maintain memory without electrical power
		    • Crash survivable
		• Final storage within the data collection system
		  • Reliable
		  • Capacity
		    • Sized to accommodate the maximum expected data volume between downloads to VTTI chase vehicles
		    • Data rate target is 2 MB per minute
		    • Average driving times per day are expected to be two hours
		    • Data sampling rates to be determined in trade studies
		• Costs
		  • Hardware
		  • Software implementation
		• Physical size
		  • Limited for non-intrusive installation

9. Data Transfer from Test Vehicles	• Cell Phone • Ricochet • Satellite • Wireless LAN • Long Range Wireless LAN	• Range and/or coverage areas • Data transmission rate: Download time • Total costs per year

For each of the alternatives described in the table, a trade study analysis was performed. The results of these analyses are given in Task 15.

TASK 14: REVIEW/TEST OF TRIGGER CRITERIA METHODS

As discussed previously in the report, it was decided soon after the contract award that continuous data collection was desired. As such, a triggered data set was not needed. Instead, critical incidents in the data set will be located post hoc with editable triggers, which will result in a comprehensive database that can be filtered, scanned, sampled, and so forth, according to researchers' needs. The sensitivity analysis to determine the post hoc trigger levels is explained in Task 11.

TASK 15: TRADE STUDY ANALYSIS OF HARDWARE/SOFTWARE ALTERNATIVES

Task 13 determined the available technologies and the factors that were relevant based upon the data collection system requirements determined as part of Task 12. Task 15 completes that effort. Table 21 lists the subsystem component options considered in trade study analysis (as determined in Task 13), the evaluation performed to evaluate the component, the evaluation results, and the decision made for final component selection. Note that there are references in Table 21 to Figures 14 and 15, which follow the table. In addition to the process information which is listed in Table 21, Appendix I provides the sensor and instrument to measure specified variables.

Note that several variables will not be collected through hardware. Driver classification and demographic variables will be collected with questionnaires. Detailed vehicle information will be collected prior to the study. In addition, information on crashes will be collected via police report forms.

Table 21. Subsystem components considered in trade study analysis, the evaluation performed, the evaluation results, and the decision made for component selection.

1. Forward and Rear Range Measurement

- Evaluation Performed
  - Simultaneous range measurements by all candidate instruments with all technologies represented. Compare measurements for accuracy, reliability, and stability in dry and wet road conditions. Rainfall was simulated using a snow and rain generation tower from the Smart Road at VTTI.
- Evaluation Results
  - See Figure 14 "Range Measurement Comparison". Radar technology exhibited high accuracy and stability (very few dropouts) plus immunity to rainfall and dirt/dust effects. Alignment was not as critical for this unit and did not require a precise alignment calibration with a target screen as with the laser devices. Concealment of the radar device is excellent as the unit chosen can be concealed entirely behind the vehicle license plate. The laser units had to be more conspicuously mounted on the dashboard or just within, or in front of the front grill.
- Decision
  - Radar was selected for both front and rear range measurements. Since radar cannot "see" through metal, VTTI has obtained permission from VDOT to replace the metal license plates with plastic replicas on the test vehicles.

2. Lane Tracking

- Evaluation Performed by-
  - Once the VTTI software-based solution has been constructed, tested, and debugged the resulting accuracy and reliability measures will be compared with those obtained in prior VTTI projects using hardware based methods of lane tracking. Any other lane trackers with competitive costs will be obtained for evaluation at the same time.
- Evaluation Results
  - Costs are prohibitive on the lane tracking devices we are currently aware of. VTTI hopes to successfully provide a reasonable costing, software-based solution. VTTI expects this work to be completed in the next few weeks.
- Decision
  - To be determined.

3. Side Sensing

- Evaluation Performed
  - Simultaneous range measurements by all candidate instruments with all technologies represented. Compare measurements for accuracy, reliability, and stability in dry and wet road conditions. Rainfall was simulated using a snow and rain generation tower from the Smart Road at VTTI.
- Evaluation Results
  - Radar technology exhibited high accuracy and stability (very few dropouts) plus immunity to rainfall and dirt/dust effects. Alignment was not as critical for this unit and did not require a precise alignment calibration with a target screen as with the laser devices. Concealment of the radar device is excellent as the unit chosen can be concealed entirely behind the rear quarter panels. The laser units had to be more conspicuously mounted on the side rear view mirrors.
- Decision
  - Radar was selected for side range measurements.

4. In-Vehicle Network Issues

- Evaluation Performed by-
  - Querying the networks on the test vehicle models selected for the variable of interest in this study.
- Evaluation Results-
  - Some common variables are available on all selected test vehicles. These variable pass codes are generally common throughout a manufacturer car line.
  - Most of the variables of interest are not available on the networks of the selected test vehicle models.
- Decision
  - Extract a minimal variable subset from all test vehicles and acquire additional data when available on individual test vehicles. The minimal subset variables are noted in Appendix I, "Sensors and Instruments to Measure Listed Variables."

5. Video Acquisition

- Evaluation Performed
  - Individually testing camera system technologies for their ability to handle multiple cameras at the required sample rates and reliably produce quality video streams.
- Evaluation Results
  - The demands of three or more digital cameras could not be handled by either USB or Firewire networks. Firewire cameras do not incorporate compression but the Firewire standard provides a sufficient bandwidth to handle five cameras, but the actual implementation of multiple cameras on a Firewire network does not allow for bandwidth sharing which results in one or two cameras overwhelming the network. Similarly, the much lower speeds of the USB protocol bottlenecked operation of more than two cameras; even though the USB cameras had built-in compression. Analog camera images are not transmitted over a network and all of the camera images are merged into one video signal by a quad splitter. This one video stream is all that is digitized and that task is handled by hardware, leaving the CPU untouched.
- Decision
  - Analog video cameras were selected for their small size, low cost, reliability for multiple camera presentations, and the associated hardware compression does not load up the main data collection system CPU. The US accepted NTSC standard for analog video in the U.S. sets the frame rate (sampling rate) at 30 Hz. Under-sampling, down to 10 Hz as for the non-video data, would not be worth the expected additional manpower and software implementation costs and reduced reliability.

6. Camera Views

- Evaluation Performed
  - Views from within vehicles were assessed by sitting and recording video from multiple camera installation configurations. The scenes were judged for their ability to best portray vehicles and conditions to the front, rear, and sides of the test vehicle as well as the subject driver actions and awareness.
  - To evaluate the presentation of the camera views to data reductionists, the camera views were passed through a quad-splitter and then digitized and presented at several resolutions. The best camera view to determine driver eye glance data was determined by comparing several different facial framings (zoom lens settings) and image resolutions.
- Evaluation Results
  - It was found that five cameras could provide the images to measure the required project variables without violating the imposed restriction to not record any vehicle occupants other than the driver.
  - The five cameras can be mounted to provide coverage of the driver's face, hands and feet, the front and rear of the test vehicle, and the left corner and right side. A total image resolution of 320 by 240 pixels provided sufficient detail to measure the required driver performance variables while meeting the data rate criteria of < 2 MB per minute.
- Decision
  - The selected camera configuration and resulting views are shown in Figure 15.

7. Video Compression

- Evaluation Performed by-
  - Recording 5 minutes of video on a busy highway
  - Captured video streams from 5 black and white NTSC cameras spliced into a quad image, then digitized and compressed into a 320 X 240 pixels resolution image. Compression ratios for each evaluated technology were set to avoid noticeable picture quality effects.
  - Compressing the raw data file using a number of software and hardware compression technologies. Note: hardware compression frees the main CPU of any video processing
- Evaluation Results

Compression Technology	Resulting File Size
Uncompressed (24 bit color)	2500 MB
MJPEG	205 MB
MPEG 4.0	26 MB
DIVX MPEG 4 (Fast Motion)	10 MB
DIVX MPEG 4 (Low Motion)	10 MB
DIVX 4.0	37 MB
Cinepak	120 MB
Microsoft RLE	393 MB
Microsoft Video 1	86 MB
Sorenson Quicktime	33 MB
Wavelet (hardware-based; cost ~$450)	150 MB
MPEG 1 or 2 (hardware-based; cost ~$400)	9.7 MB

- Decision
  - MPEG 1compression was selected because of its superior compression level with no CPU loading. Use of the next best solution, software-based DIVX MPEG 4, would have taxed the processor beyond its capabilities to maintain a real-time video stream and required an expensive addition of a second PC104 standard (rugged) CPU to handle all other data streams.

8. Data Storage (Including Video)

- Evaluation Performed
  - Each technology was evaluated for either serving as a temporary data buffer or the final data storage device for the data collection system. The data buffer storage device had to be extremely reliable and have high crash survivability, requiring a rugged design that would maintain its memory without power. The final storage device needed a large capacity to handle many days of driving data and also be able to survive most crashes.
- Evaluation Results
  - Compact Flash cards were judged to be the best value in the non-volatile memory devices. They can withstand a 2,000 g acceleration without harm and can be purchased up to a 500 MB capacity at a reasonable cost (less than $1 per MB). Laptop hard drives are more costly than desktop units, but are made more rugged to sustain the higher impact loads expected with portability. Still, their cost per MB is on the order of 1% of that for non-volatile memory cards. Tape drives are not rugged enough, without great expense, to survive a severe crash and data capacity for compact units is insufficient. DVDs only hold 4.7 GB on a single-sided disk and writing to a re-writeable DVD disk is much too slow and unreliable with current technology.
- Decision
  - All data will be buffered to a solid-state module; in this case a 500 MB Compact flash card. A 40 GB laptop hard drive was chosen as the final storage device.

9. Data Transfer from Test Vehicles

- Evaluation performed by-
  - Comparing available technologies and associated service providers for-
  - Range and/or coverage areas
  - Data transmission rate
  - Total costs per year
- Evaluation Results-

Type	Range/ Coverage Area	Data RateTotal	Costs
Cell Phone	Nationwide	192Kbits/s	~$350K
Ricochet	DC Area	280 Kbits/s	~$275K
Satellite	Nationwide	96 Kbits/s	~$250K
Wireless LAN	100 ft	5 Mbits/s	~$33K
Long Range-	1-2 miles	11 Mbits/s	~$440K

- Decision
  - Cell phone service (provider TBD) will be used for remote access to test vehicle data snippets, small software updates, location information, automated incident notification, and so forth. It was determined that for downloading subject data, it was more time and cost efficient to use a wire system as opposed to a wireless system.

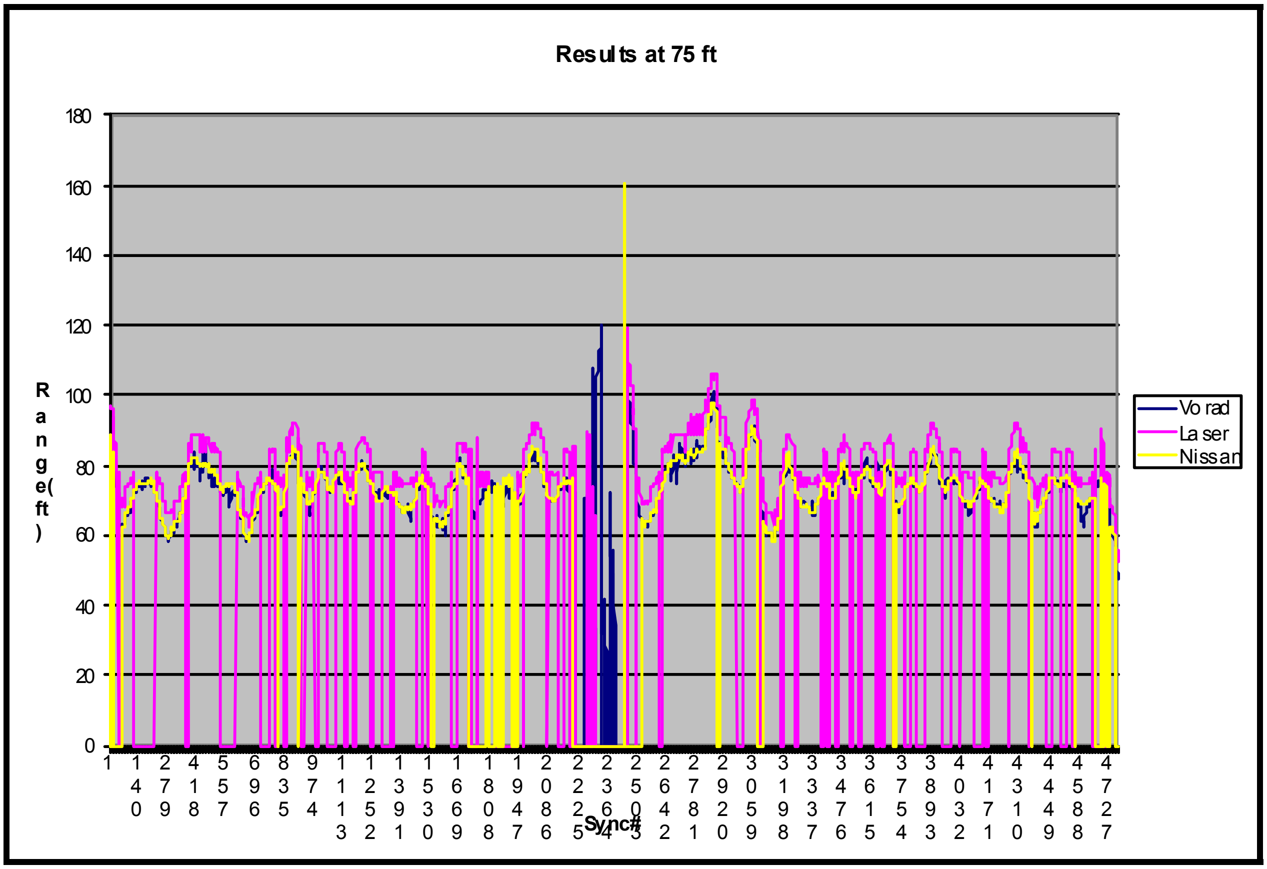

Figure 14. Range measurement comparison for radar and laser devices.

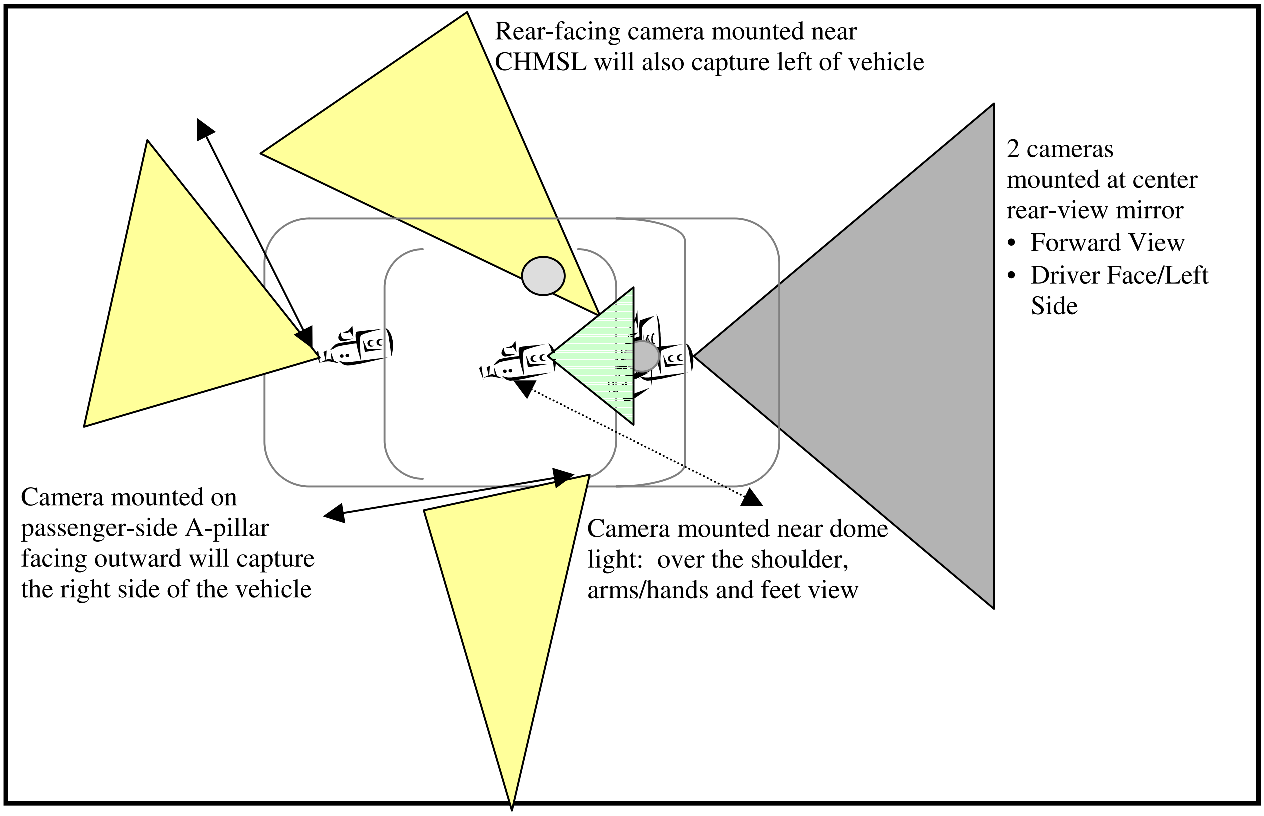

Figure 15. Graphical depiction of the camera views.

TASK 16: SUMMARY OF PROTOTYPE HARDWARE/SOFTWARE DESIGN SPECIFICATION AND HURP SUBMITTAL PREPARATION

The contract calls for submittal of draft HURP materials as part of the Task 16 Final Phase I report. The Virginia Tech IRB granted approval to conduct the study on March 12, 2002. The Informed Consent Forms submitted as part of this process, one for the drivers of privately-owned vehicles and one for the drivers of leased vehicles, are shown in Appendices J and K. An application will be filed for a Certificate of Confidentiality from NIMH. Once this if obtained, HURP materials will be submitted for approval.

This report summarizes the efforts of Phase I of the "Naturalistic Driving Study." Phase II of this effort was begun when approval to proceed was granted by the NHTSA TOM on February 22, 2002.

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APPENDIX A: RESEARCH QUESTIONS GENERATED FROM NHTSA RESEARCHERS AND INTERESTED STAKEHOLDERS

IVI Research Questions

Explanation of research question table:

The research questions have been consolidated incorporated into the following table. Preceding and following each research question is a numerical ranking followed by a comment section. The numerical ranking preceding the research question represents VTTI's priority level for that research question. The ranking following the research question provides information as to whether that particular research question can be easily addressed by the current data collection system design. Details of each ranking are outlined below.

Research Question Priority

A priority ranking of '1' indicates that VTTI plans to design the data collection system to answer this question as well as address this question in the final report.

A priority ranking of '2' indicates that VTTI will not address this question in the final report. Other researchers can obtain access to the data set and analyze the data to answer this question.

Design of Data Collection System

A ranking of '1' indicates that the data collection system will be collecting the data necessary to answer this research question. Also, the data carries the necessary signature to enable triggering post hoc, allowing for efficient data reduction.

A ranking of '2' indicates that the data are available within the data collection system as currently proposed; however, there is no simple method (e.g. a post hoc trigger) to obtain that data. Data reduction would require either a sampling of the data set or intensive data reduction to obtain the information requested.

General Research Category: Driver Behavior and Performance				
Subcategory: Rear-End Crash/Near-Crash/Conflict Research Questions				
No.	**Priority**	**Research Question**	**Code**	**Comment**
1	 1 1 1 1 1	For each of the four lead-vehicle conditions: stopped >2 sec, decelerating, accelerating, and moving at a slower constant speed: What are the causal factors for conflict encounters? What is the relationship between eye glance behavior and the onset of conflict encounters? What devices distracted the drivers? What other distractions were present? What braking levels were selected by drivers for this encounter level?	1	Can get all data except ABS brake info. Could be done if we can get both ABS & non-ABS vehicles.
2	1 1 1 1 1	What are the causal factors for near-crash encounters? What is the relationship between eye glance behavior and the onset of near-crash encounters? What devices distracted the drivers? What other distractions were present? What braking levels were selected by drivers for this encounter level?	1	Can get all data except ABS brake info. Could be done if we can get both ABS & non-ABS vehicles.

General Research Category: Driver Behavior and Performance				
3	1	What are the kinematic or dynamic conditions at the onset of driver action (e.g., range, range rate, vehicle speed, and deceleration when braking was initiated)?	1	
4	1	Are rear-end conflicts good surrogates for rear-end crashes, either within subjects or between subjects?	1	
5	1	Are rear-end near-crashes good surrogates for rear-end crashes, either within subjects or between subjects?	1	
6	1	How accurate was the rear-end crash estimation analysis?	1	
7	1	How does lane keeping correlate with each encounter?	1	
8	1	Operationally define a "near-crash."	1	
9	1	Determine the drivers' reaction time to a stimulus. Can the stimulus be determined? Can the instant that the driver responded to a stimulus (e.g., brake light) be determined?	1 or 2	Depending upon specific requirements.
10	1	What is the reaction time between brake lights on and maximum deceleration for near-crash encounters?	1	
11	1	What turn signal use was applied?	1	
Subcategory: Distraction Issues				
No.	**Priority**	**Research Question**	**Code**	**Comment**
12	1	Characterize driver distraction as related to the different "driving states?" How does use of cell phones, navigation equipment, etc. affect driving behavior?	1 or 2	Depending upon the specific requirements.
13	1	How does eye glance behavior correlate with each encounter?	1	
14	2	What is the duration and frequency of various activities while driving, e.g., eating, drinking, tuning radio, phone conversation, etc? How does driving performance differ between these activities?	2	
15	2	What is the relationship between driving style and distraction in conflict and near-crash encounters?	1	
No.	**Priority**	**Research Question**	**Code**	**Comment**
16	2	NHTSA needs to find ways to empirically map driver distraction to actual driving characteristics. The VT Naturalistic Driving Project might be able to provide very useful data to support the SAVE-IT program, which NHTSA is just initiating. SAVE-IT could benefit if the VT Naturalistic Driving Project monitors in-vehicle device activation, for example, proportion of time radio or CD used and car occupancy, which could be a dichotomous variable of driver and driver plus others. There is a need to record use of system controls, wipers, headlights, and turn signals.	2	Appears feasible but we need specific research question and requirements to determine.
17	2	Measure driver's level of alertness or visual sampling rate. Based on previous research of Senders et al., drivers normally sample elements of the visual scene approx once per 3 sec.	2	Appears feasible but we need specific research question and requirements to determine.
Subcategory: Data Collection Method Issues				
No.	**Priority**	**Research Question**	**Code**	**Comment**
18	1	Is there a difference in overall *baseline* driver performance between **1-week** FOT data and **1-year** Naturalistic Driving Data?	1 or 2	1 = If we have sample of 10 leased GM vehicles. 2 = Depending upon specific requirements.

General Research Category: Driver Behavior and Performance				
19	1	Is there a difference in overall *baseline* driver performance between subjects driving "other people's" vehicles and subjects driving their own vehicles?	1 or 2	Depending upon whether dataset includes a subset of drivers using own vehicles vs. leased vehicles.
20	1	Record date vehicle purchased, vehicle mileage on odometer at start of field test.	1	
21	1	Monitor the incidence of secondary driver use.	1	
22	2	Collect data so that travel can be looked at by day of the week, date, time of day, trips/day. The characteristics of trips/day would provide a way to get a baseline measure of driving behavior and the range of inter- as well as intra-individual variation.	2	Appears feasible but specific requirements are necessary to determine.
23	2	When the driver is paying attention to the lead vehicle, what type of model best describes the driver's car following behavior and braking behavior when the lead vehicle slows to a stop?	2	Dependent upon specific criteria

General Research Category: Distribution of Events				
Subcategory: Rear-End Crash/Near-Crash/Conflict Research Questions				
No.	**Priority**	**Research Question**	**Code**	**Comment**
24	1	For each of the four lead-vehicle conditions: stopped >2 sec, decelerating, accelerating, and moving at a slower constant speed: What is the number of following-vehicle conflict encounters per VMT? What were the primary contributing factors and circumstances of each? What corrective actions were attempted by the SV and POV for each?	1	
25	1	What is the number of following-vehicle near-crash encounters per VMT? What were the primary contributing factors and circumstances of each? What corrective actions were attempted by the SV and POV for each?	1	
26	1 1 1	What is the number of rear-end conflict encounters per VMT where the POV changed lanes in front of the SV? What were the initial dynamic conditions of these encounters? What were the primary contributing factors and circumstances?	1	
27	1 1 1	What is the number of rear-end near-crash encounters per VMT where the POV changed lanes in front of the SV? What were the initial dynamic conditions of these encounters? What were the primary contributing factors and circumstances?	1	
28	1 1 1	What is the number of rear-end conflict encounters per VMT where the SV changed lanes behind the POV? What were the initial dynamic conditions of these encounters? What were the primary contributing factors and circumstances?	1	
29	1 1 1	What is the number of rear-end near-crash encounters per VMT where the SV changed lanes behind the POV? What were the initial dynamic conditions of these encounters? What were the primary contributing factors and circumstances?	1	
30	1 1 1	What is the number of lane change conflict encounters per VMT where the SV driver took corrective action to resolve a rear-end conflict encounter? To resolve a rear-end near-crash encounter? What were the primary contributing factors and circumstances?	1	
31	1 1 1	What is the number of lane change near-crash encounters per VMT where the SV driver took corrective action to resolve a rear-end conflict encounter? To resolve a rear-end near-crash encounter? What were the primary contributing factors and circumstances?	1	
32	1	What are the kinematic or dynamic conditions of these encounters? Examples: (1) Lead vehicle stopped scenario, what is the percentage of encounters where the following vehicle was traveling at 35 mph? What is the percentage of encounters where the following vehicle was traveling at 55 mph? Etc… (2) Lead vehicle suddenly braking, what is the percentage of encounters in which the headway was between 1.2 and 1.4 sec at onset of braking and lead vehicle average deceleration was between 0.1 and 0.2g?	1 or 2	Depending upon specific requirements.

General Research Category: Distribution of Events				
No.	**Priority**	**Research Question**	**Code**	**Comment**
33	1	Characterize the "driving states" and the pre-crash motion scenarios resulting in rear-end and lane-change collisions? What are the kinematic characteristics for a subject vehicle in relation to other vehicles in car following situations that can define the boundaries for the different "driving states"? Kinematic characteristics include: vehicle location, headway/range, range-rate, lateral clearance, yaw rate, velocity, acceleration, etc.	1	
34	1	What is the frequency/mile of different triggering mechanisms?	1	
Subcategory: Distraction Issues				
No.	**Priority**	**Research Question**	**Code**	**Comment**
35	1	What is the distribution of driver distraction types in encounters with each of the scenarios? For instance, what is the percentage of encounters with lead vehicle stopped in which the driver was using a cell phone?	1 or 2	Depending upon specific requirements.
Subcategory: General Data Collection Method and Baseline Driving				
No.	**Priority**	**Research Question**	**Code**	**Comment**
36	1	Quantify the correlation for each of the "driving states" and Heinrich's triangle relating conflict states to near-crash to crash events?	1	
37	2	"What is the distribution of 'transition' events in this population of drivers and driving?" In this case, "transitions" are based on the concept of states and transitions that VNTSC developed in the evaluation of the ICC FOT data and on the causal factor data element in NCSA crash data files. Lane changes and lead-vehicle braking are two common transitions. The description of transitions should include the dynamic conditions; e.g. distance between vehicles at the time of a lane change (and/or headway), level of braking by the lead-vehicle, speeds, etc.; as well as the traffic conditions; e.g. congested urban freeway, open rural road, etc.	1	We can get all data except for the gap distance between vehicles in adjacent lanes at time of a lane change.
38	2	What are distributions of descriptive parameters, such as number of brake applications per mile or number of steering wheel displacements of more than some nominal level for conditions such as, lane change, curves, avoidance, etc?	1	
39	2	What is distribution of response intensity (g levels) exerted by drivers?	1	
40	2	Is there a separate set of "driver states" definitions for different types of crashes (rear-end, lane change) or does a single set of definitions encompass all crash types?	1	
41	2	Can we characterize the driving behavior of drivers (braking, steering, acceleration, etc.) in their reaction to the different "driving states" – particularly for near-crash state?	1	
42	2	Can we quantify the different "driving states" by level of traffic flow?	1 or 2	Depending upon specific requirements.
43	2	Can/should/how do we characterize the behavior of a subject vehicle in relation to both a leading and following vehicle?	1 or 2	Depending upon specific requirements.
44	2	What percent of brake decelerations over .3g, .4g, and .5g involve responses to stopped, slowing, or high deceleration lead vehicles?	1	

General Research Category: Design of the Phase IV Study				
Subcategory: Vehicle Instrumentation				
No.	**Priority**	**Research Question**	**Code**	**Comment**
45	1	Are necessary measurements being gathered at an acceptable accuracy level?	1	
46	1	What are the specific performance requirements of inertial sensors and range-finding devices?	1	
47	1	What is the failure rate of the hardware?	1	
48	1	How much time does it take to install and uninstall equipment?	1	
49	1	What type of sensors (laser, radar, etc.) for range and range-rate sensing are the most cost-effective to collect the required "driving state" data? Issues to be considered include obtaining accurate readings in all weather, ability to track multiple targets, improving the accuracy of data and reducing the frequency of data dropouts, and the ability to detect stopped targets and to distinguish objects on the road from objects to the side of the road, etc.	1	Only for the sensors addressed in trade-off study portion of report.
50	1	What is the feasibility of utilizing rear-facing sensors and cameras in addition to forward-facing equipment to increase the data collection size?	1	
51	1	What are the pros and cons of using rear-facing sensors for rear-end crash characterization compared to forward sensors? Are both needed in Phase IV?	1	
Subcategory: Data Reduction and Analysis				
No.	**Priority**	**Research Question**	**Code**	**Comment**
52	1	How long does it take to reduce the video data per minute of data collected, for example?	1	
53	1	Define the trigger points for future research that can be used to distinguish the boundary conditions for each of the "driving states?"	1	
54	1	What are the recommended triggering methods for the Phase IV design?	1	
55	2	What is the relation between driver individual differences and causes of critical incidents? (Driver simple and complex reaction time, useful field of view, risk taking personality factors, aggressive personality factors, etc.)	1	Will add personality inventory factors to variable list.
56	2	Under what conditions are eye glance measurements good surrogates for rear-end crashes?	1	
57	2	Under what conditions are lane deviations good surrogates for rear-end crashes?	1	Best addressed in Phase IV.
58	2	What measurements are needed to know whether a rear-end crash is probable?	1	
59	2	How accurate is the reduced eye glance data? This would require a separate analysis of video taken from a subject whose glance directions have been calibrated separately.	2	

APPENDIX B: EVENT CODING DIRECTORY

This data directory contains the list of data variables and elements used to code naturalistic driving events. To the greatest extent possible, variables and elements have been selected to be compatible with Virginia Police Accident Report variables and NHTSA General Estimates System (GES) variables. The use of Virginia state PAR variables will permit direct comparisons between naturalistic driving events and police-reported crashes for the Northern Virginia area (i.e., Arlington and Fairfax). Selected GES variables have been adopted because they provide more information than those on the VA State PAR. Finally, additional variables have been compiled from a combination of sources to permit a more complete and detailed characterization of the event.

Like most accident databases, this one will be organized into several major "files," based on whether the variable applies to the whole event (the Event File), to one of the drivers/vehicles (the Driver/Vehicle Files), or to individual occupants, apart from driver-related information (the Occupant Files). For consistency, "D1" and "V1" will always refer to the naturalistic driving subject; "D2" and "V2" will refer to the other driver/vehicle. Since much more information will be available for D1/V1 than for D2/V2, there will be separate D1/V1 and D2/V2 data files. There will be an Occupant File for V1 to code information about V1 occupants, such as their seating position and injuries in crashes. There is no Occupant File for V2 since scant information will be available about V2 occupants.

Most variables in the list below will be accompanied by a "Source/comment" annotation; i.e., the VA or GES variable number, and any additional information needed to explain the purpose and rationale for the proposed variable. Within a variable, data elements shown in *italics* are elements that have been added or revised from the original source variable. Elements that are boxed are elements that will be omitted from the original VA PAR or GES variable.

Crashes, near-crashes, incidents (driver errors without a crash or near-crash), and baseline driving epochs (segments of normal driving selected to answer specific research questions) will be coded at different levels of detail. Almost all of the variables in this directory will be coded for crashes. A somewhat smaller set of variables will be coded for near-crashes. A much smaller set of variables will be coded for incidents and baseline epochs. These differences in coding detail result from two factors. First, they reflect the relative importance and priority of the different event types for this research. Secondly, they reflect the different amounts of information likely to be available relating to the events. In this directory, variables indicated as "C-N-I-B" will be coded for crashes, near-crashes, incidents, and baseline epochs. Variables indicated as "C" will be coded only for crashes, and so on. All variables will include an "unknown" alternative (generally 99) and many will include a "not applicable" alternative.

Event File

1. **Event Identifier(s) (C-N-I-B)**
Comment: Each event will be assigned a unique identifier through software. Identification scheme is TBD, but will include subject, time, and frame number identifiers.
Will originate in raw data stream

2. **Coder Identifier (C-N-I-B)**
Comment: Coder numbers will be assigned.
Will originate in data reduction software

3. **Event Classification (C-N-I-B)**
0 = Invalid trigger [no further coding]
1 = Baseline driving epoch (selected randomly)
2 = Incident (e.g., driver error)
3 = Near-Crash
4 = Crash, not police-reported
5 = Crash, police-reported, non-towaway
6 = Crash, police-reported, towaway (any vehicle)
Comment: Initial coding step. Invalid triggers result in no further coding. Other coding choices will determine specific subset of remaining variables to be coded.
Specified upon entry into data reduction software

4. **Most Severe Injury in Crash (C – crashes only)**
0 = No injury (O)
1 = Fatal (K)
2 = Visible signs of injury; e.g., bleeding wound or distorted member, or carried from scene (A).
3 = Other visible injury as bruises, abrasions, swelling, limping, etc. (B)
4 = No visible injury but complaint of pain or momentary unconsciousness (C)
Source/comment: VA PAR Variable 15. The "KABCO" classification system is the national standard for police accident reports. This variable and the previous one will be used together to stratify events for "Heinrich Triangle" analysis; e.g., Injury crash, Non-Injury Crash, Near-Crash, Incident. This variable will be coded only for crashes.
Specified upon entry into data reduction software

5. **Vehicles/Non-Motorists Involved (C-N)**
1 = 1 vehicle (Subject vehicle only)
2 = 2 vehicles
3 = 3 vehicles
4 = 4 or more vehicles
5 = Subject vehicle + pedestrian
6 = Subject vehicle + pedalcyclist
7 = Subject vehicle + animal
8 = Other, specify
Specified upon entry into data reduction software

6. **Date (C-N-I-B)**
Coded: Raw data from vehicle.

7. **Day of Week (C-N-I-B)**
Coded: Raw data from vehicle.

8. **Time (C-N-I-B)**
Comment: Raw data from vehicle. Entered as military (24 hour) time.

9. GPS Location (coordinates) (C-N)
Comment: Recording this variable may permit linkage to Geographic Information Systems relating to Northern Virginia roadways.
Coded in General State Variables: Road/Traffic Variables

10. Jurisdiction (C-N)
1 = Arlington/Fairfax
2 = Other
Comment: This variable will permits comparison with VA State accident data for Northern Virginia (i.e., Arlington and Fairfax)
Coded in General State Variables: Road/Traffic Variables

11. Traffic Control (C-N)
1 = No traffic control
2 = Officer or watchman
3 = Traffic signal
4 = Stop sign
5 = Slow or warning sign
6 = Traffic lanes marked
7 = No passing signs
8 = Yield sign
9 = One way road or street
10 = Railroad crossing with markings or signs
11 = Railroad crossing with signals
12 = Railroad crossing with gate and signals
13 = Other
Source: VA PAR Variable 1.
Coded in General State Variables: Road/Traffic Variables

12. Alignment (C-N)
1 = Straight level
2 = Curve level
3 = Grade straight
4 = Grade curve
5 = Hillcrest straight
6 = Hillcrest curve
7 = Dip straight
8 = Up curve [need definition]
9 = Other
Source: VA PAR Variable 3
Coded in General State Variables: Road/Traffic Variables

13. Weather (C-N-I-B)
1 = Clear
2 = Cloudy
3 = Fog
4 = Mist
5 = Raining
6 = Snowing
7 = Sleeting
8 = Smoke dust
9 = Other
Source: VA PAR Variable 4
Coded in General State Variables: Weather/Lighting Variables

14. Surface Condition (C-N-I-B)

1 = Dry
2 = Wet
3 = Snowy
4 = Icy
5 = Muddy
6 = Oily
7 = Other
Source: VA PAR Variable 5
Coded in General State Variables: Road/Traffic Variables

15. Light (C-N-I-B)

1 = Dawn
2 = Daylight
3 = Dusk
4 = Darkness, lighted
5 = Darkness, not lighted
Source: VA PAR Variable 7
Coded in General State Variables: Weather/Lighting Variables

16. Kind of Locality (C-N-I-B)

1 = School
2 = Church
3 = Playground
4 = Open Country
5 = Business/industrial
6 = Residential
7 = Interstate
8 = Other
9= *Construction Zone (Added)*
Source: VA PAR Variable 8
Coded in General State Variables: Road/Traffic Variables

17. Relation to Junction (Location Type) (C-N)

Non-Interchange Area

00 = Non-Junction
01 = Intersection
02 = Intersection-related
03 = Driveway, alley access, etc.
04 = Entrance/exit ramp
05 = Rail grade crossing
06 = On a bridge
07 = Crossover related
08 = Other, non-interchange area
09 = Unknown, non-interchange
20 = Parking lot [Added]

Interchange Area

10 = Non-Junction
11 = Intersection
12 = Intersection-related
13 = Driveway, alley access, etc.
14 = Entrance/exit ramp
16 = On a bridge
17 = Crossover related
18 = Other location in interchange area
19 = Unknown, interchange area

99 = Unknown if interchange

Source/comment: GES A9 (1988-91), with one addition. Current GES coding scheme is too detailed.
Coded in General State Variables: Road/Traffic Variables

18. Trafficway Flow (C-N-I-B)

1 = Not divided
2 = Divided (median strip or barrier)
3 = One-way traffic
Source: GES A11; coding will follow GES guidelines.
Coded in General State Variables: Road/Traffic Variables

19. Number of Travel Lanes (C-N-I-B)

1 = 1
2 = 2
3a = 3 lanes in direction of travel (divided or one-way trafficway)
3b = Undivided highway, 3 lanes total, 2 in direction of travel
3c = Undivided highway, 3 lanes total, 2 in direction of travel
4 = 4
5 = 5
6 = 6
7 = 7+
9 = Unknown
Source/comment: Similar to GES A12. If a divided trafficway, the number of travel lanes are only lanes in the direction of travel of the subject vehicle, V1. If an undivided trafficway, the number of travel lanes are all lanes regardless of their direction of travel. The element "3" has been expanded to cover all possible interpretations (when combined with Trafficway Flow).

20. Traffic Density (C-N-I-B)

1 = LOS A: free flow
2 = LOS B: Flow with some restrictions
3 = LOS C: Stable flow, maneuverability and speed are more restricted
4 = LOS D: Unstable flow – temporary restrictions substantially slow driver
5 = LOS E: Flow is unstable, vehicles are unable to pass, temporary stoppages, etc.
6 = LOS F: Forced traffic flow condition with low speeds and traffic volumes that are below capacity. Queues forming in particular locations.
Coded in General State Variables: Road/Traffic Variables

21. Type of Collision (or Near-Collision) (C-N)

1 = Rear-end (striking)
1b = Rear-end (struck)
2 = Angle
3 = Head on
4 = Sideswipe, same direction
5 = Sideswipe, opposite direction
6 = Fixed object in road
7 = Train
8 = Non-collision
9 = Fixed object – off road
10 = Deer
11 = Other animal
12 = Pedestrian
13 = Bicyclist
14 = Motorcyclist
15 = Backed into
16 = Other
Source: VA PAR Variable 5

Coded: in Nature of Incident/Crash Type

22. Driver 1 Hands on Wheel (C-N-I-B)
0 = None
1 = Left hand only
2 = Both hands
3 = Right hand only
99 = Unknown
Comment: This variable will be coded based on over-the-shoulder video footage, and will be coded for the time period just *prior* to the critical event (i.e., to capture pre-event behavior). For baseline epochs, the predominant behavior over the epoch will be coded.
Coded in General State Variables: Driver's General State

23. Event Diagram and Narrative (C-N)
Source/comment: VA. Consistent with the VA PAR, this will be a schematic of the event and a short narrative description. It will include street names or other specific locators; as well as speed limits (when known), traffic control devices, and other significant roadway design features. If the event is a crash, the schematic will include vehicle damage diagrams per the VA PAR.
Coded in General State Variables: Narrative/Diagram

<u>Driver/Vehicle 1 File</u>
Note: D1/V1 is always the study subject driver/vehicle.

1. V1 Driver Subject Number (C-N-I-B)
Source/comment: This variable, from the raw data stream, will be used to cross-link to datafile on driver subjects, including both principal subjects and their families (or other potential V1 drivers).
Coded from the raw data stream

2. V1 Vehicle Type (C-N-I-B)
1 = Corolla
2 = Camry
3 = Taurus
4 = Explorer
5 = Cavalier
6 = Malibu
7 = Mountaineer
8 = Sable
Comment: Study subjects will drive one of these eight vehicle types; this variable will be coded automatically from the raw data from the vehicle.
Coded from the raw data stream

3. Date when Data Collection Began (C, N, I, B)
Comment: From raw data from vehicle. This date will be numerically coded.
Coded from the raw data stream

4. Odometer Reading at Start of Study (C, N, I, B)
Comment: Raw data from vehicle. This variable will be coded numerically and will be used to derive the number of vehicle miles traveled at the end of the study.
Coded from the raw data stream

5. Odometer Reading at Start of Trip (C, N, I, B)
Comment: Raw data from vehicle. This variable will be coded numerically and will be used to derive the number of vehicle miles traveled prior to the event.
Coded from the raw data stream

6. Current Odometer Reading (C, N, I, B)
Comment: From raw data from vehicle. This date will be numerically coded.

Coded from the raw data stream

7. Experience Driving This Vehicle (C-N)
Source/comment: Measured in days. Derived automatically from the date and subject records of vehicle purchase or start of testing for leased vehicles; intended to help assess adaptation to new vehicles [Study Objective 4].
Coded from the raw data stream

8. Number of Occupants in V1 (Including Driver) (C)
Source/comment: GES Variable V10B. Coded as integer. Coded only for crashes because in-vehicle video does not show occupants other than the driver.
Coded from the PAR

9. Event Trigger(s) (C, N, I)
00 = None (i.e., crash with no trigger)
01 = Driver swerved to the left or right.
02 = Driver braked hard.
03 = Driver initiated the Critical Incident Button to indicate an event.
04 = Driver unintentionally crossed the lane boundary.
05 = Driver followed a lead vehicle too closely.
06 = Driver was being tailgated.
07 = Airbag was deployed.
08 = Cell phone or PDA is used in the vehicle when the vehicle is on.
Comment: All incidents and near-crashes, and most crashes, will be identified by one or more of these triggers. Analysts can code up to three of the above, in chronological order or, in the case of simultaneous events, in order of importance.
Coded from the raw data stream

10. Vehicle 1 Maneuver (C-N-I-B)
1a = Going straight, constant speed
1b = Going straight ahead, accelerating
1c = Going straight, but with unintentional "drifting" within lane or across lanes
2 = Slowing or stopping in traffic lane
3 = Starting in traffic lane
4 = Stopped in traffic lane
5a = Passing or overtaking another vehicle on left
5b = Passing or overtaking another vehicle on right
6 = Leaving a parked position
7 = Parked
8 = Entering a parked position
9a = Maneuvering to avoid an animal
9b = Maneuvering to avoid a pedestrian/pedalcyclist
9b = Maneuvering to avoid an object
9b = Maneuvering to avoid a vehicle
10 = Turning right
11 = Turning left
12 = Making U-turn
13 = Backing up (other than for parking purposes)
14a = Changing lanes, right-to-left
14b = Changing lanes, left-to-right
14c = Merging, right-to-left
14d = Merging, left-to-right
15a = Negotiating a curve
15b = Negotiating a curve, but with unintentional "drifting" within lane or across lanes
98 = Other
99 = Unknown

Source/comment: GES Variable V21, Vehicle Maneuver, with several expansions. Also very similar to VA PAR Variable 19/20.

11. V1 Accident [or Near-Accident] Type (C-N)
Source/comment: GES Variable V23. As shown in the attached. The rear-end crash scenarios will be expanded to include three possible subtypes (94, 95, and 96) associated with an accelerating lead vehicle.

12. V1 Incident Type (I – incidents only)
1 = Following too closely
2 = Being followed too closely
3 = Lane deviation
4 = Lane bust
5 = Swerve or hard steering
6 = Hard braking
7 = Hard braking/ABS activation
8 = Traction control activation
9 = RF sensor/Cell phone use
10 = Glare event
11 = Lane change error with vehicle present

12 = Other vehicle encroaching in lane.
Comment: This variable, coded for incidents only, attempts to anticipate and classify the type of crash involvement that could have resulted from the observed driver error.
Coded in Incident Type/Near-Crash/Crash Type

XX Incident Crash Type(I – incidents only)
1 = Rear-end, striking
2 = Rear-end, struck
3 = Road departure (left or right)
4 = Road departure (end)
5 = Sideswipe, same direction (left or right)
6 = Opposite direction (head-on or sideswipe)
7 = Violation of stop sign or signal at intersection
8 = Straight crossing path, not involving sign/signal violation
9 = Turn across path
10 = Turn into path (same direction)
11 = Turn into path (opposite direction)
12 = Backing, fixed object
13 = Backing into traffic
14 = Pedestrian
15 = Pedalcyclist
16 = Animal
17 = Other (specify)
99 = Unknown ‘
Comment: This variable, coded for incidents only, attempts to anticipate and classify the type of crash involvement that could have resulted from the observed driver error.

13. Critical/Precipitating Event for Vehicle 1 (C-N-I)
This Vehicle Loss of Control Due to:
001 = Blow out or flat tire
002 = Stalled engine
003 = Disabling vehicle failure (e.g. wheel fell off)
004 = Minor vehicle failure
005 = Poor road conditions (puddle, pothole, ice, etc.)
006 = Excessive speed
007 = Other or unknown reason
008 = Other cause of control loss

009 = Unknown cause of control loss

This Vehicle Traveling:

100 = Ahead, stopped on roadway more than 2 seconds
101 = Ahead, decelerated and stopped on roadway 2 seconds or less
102 = Ahead, traveling in same direction and decelerating
103 = Ahead, traveling in same direction and accelerating
104 = Ahead, traveling in same direction with slower constant speed
010 = Over the lane line on the left side of travel lane
011 = Over the lane line on right side of travel lane
012 = Over left edge of roadway
013 = Over right edge of roadway
014 = Unknown which edge
015 = End departure
016 = Turning left at intersection
017 = Turning right at intersection
018 = Crossing over (passing through) intersection
018 = This vehicle decelerating
019 = Unknown travel direction
020a = From adjacent lane (same direction), over left lane line behind lead vehicle, rear-end crash threat
020b = From adjacent lane (same direction), over right lane line behind lead vehicle, rear-end crash threat

Other Vehicle in Lane:

030 = Ahead, stopped on roadway more than 2 seconds
031 = Ahead, decelerated and stopped on roadway 2 seconds or less
032 = Ahead, traveling in same direction and decelerating
033 = Ahead, traveling in same direction and accelerating
034 = Ahead, traveling in same direction with slower constant speed
035 = Behind, traveling in same direction and accelerating
036 = Behind, traveling in same direction with higher constant speed
037 = Behind, stopped on roadway
050 = Stopped on roadway
051 = Traveling in same direction with lower steady speed
052 = Traveling in same direction while decelerating
053 = Traveling in same direction with higher speed
054 = Traveling in opposite direction
055 = In crossover
056 = Backing
057 = Unknown travel direction of the other motor vehicle

Another Vehicle Encroaching into This Vehicle's Lane:

060a = From adjacent lane (same direction), over left lane line in front of this vehicle, rear-end crash threat
060b = From adjacent lane (same direction), over left lane line behind this vehicle, rear-end crash threat
060c = From adjacent lane (same direction), over left lane line, sideswipe threat
060d = From adjacent lane (same direction), over right lane line, sideswipe threat
060e = From adjacent lane (same direction), other
061a = From adjacent lane (same direction), over right lane line in front of this vehicle, rear-end crash threat
061b = From adjacent lane (same direction), over right lane line behind this vehicle, rear-end crash threat
061c = From adjacent lane (same direction), other
062 = From opposite direction over left lane line.
063 = From opposite direction over right lane line
064 = From parallel/diagonal parking lane
065 = Entering intersection—turning in same direction
066 = Entering intersection—straight across path
067 = Entering intersection – turning into opposite direction

068 = Entering intersection—intended path unknown
070 = From driveway, alley access, etc – turning into same direction
071 = From driveway, alley access, etc – straight across path
072 = From driveway, alley access, etc – turning into opposite direction
073 = From driveway, alley access, etc – intended path unknown
074 = From entrance to limited access highway
078 = Encroaching details unknown

Pedestrian, Pedalcyclist, or other Non-Motorist:

080 = Pedestrian in roadway
081 = Pedestrian approaching roadway
082 = Pedestrian in unknown location
083 = Pedalcyclist/other non-motorist in roadway
084 = Pedalcyclist/other non-motorist approaching roadway
085 = Pedalcyclist/or other non-motorist unknown location
086 = Pedestrian/pedalcyclist/other non-motorist—unknown location

Object or Animal:

087 = Animal in roadway
088 = Animal approaching roadway
089 = Animal unknown location
090 = Object in roadway
091 = Object approaching roadway
092 = Object unknown location

Other:

098 = Other event/not applicable
099 = Unknown critical event

Source/comment: GES Variable V26 (1999-Later version), except that Elements 030-037 have been added to more fully characterize rear-end crash situations. These do not correspond to any current or past GES variables. Elements 050-053 will not be used since they are addressed by 030-037. Elements 060 and 061 have been expanded to address multiple rear-end and sideswipe crash-related scenarios. All coding on this variable will be checked for consistency with the previous variable, V1 Accident Type.
Coded in Precipitating Factors

14. Vehicle/Driver 1 Corrective Action Attempted (C-N-I)

0= No driver present
1 = No avoidance maneuver
2 = Braking (no lockup)
3 = Braking (lockup)
4 = Braking (lockup unknown)
5 = Releasing brakes
6 = Steered to left
7 = Steered to right
8 = Braked and steered to left
9 = Braked and steered to right
10 = Accelerated
11 = Accelerated and steered to left
12 = Accelerated and steered to right
98 = Other actions
99 = Unknown if driver attempted any corrective action
Source: GES V27, Corrective Action Attempted
Coded in Corrective/Evasive Maneuver

14b. Vehicle Control After Corrective Action

0 = No driver present
1 = Vehicle control maintained after corrective action
2 = Vehicle rotated (yawed) clockwise
3 = Vehicle rotated (yawed) counter-clockwise
4 = Vehicle slid/skid longitudinally – no rotation

5 = Vehicle slid/skid laterally – no rotation
9 = Vehicle rotated (yawed) unknown direction
20 = Combination of 2-9
94 = More than two vehicles involved
98 = Other or unknown type of vehicle control was lost after corrective action
99 = Unknown if vehicle control was lost after corrective action.
Source: GES Variable V28.

15. Average Deceleration During Braking (C-N)
Source/comment: Applicable only in cases where driver applied brakes as corrective action. Measured in feet/second/second from on-board recordings. Coded from raw data from vehicle. Average braking, beginning with brake application and ending with vehicle stopping, brake release, or impact.

16. Maximum Deceleration During Braking (C-N)
Source/comment: Applicable only in cases where driver applied brakes as corrective action. Measured in feet/second/second from on-board recordings. Coded from raw data from vehicle. Maximum deceleration in data stream during time period beginning with brake application and ending with vehicle stopping, brake release, or impact.

17. Steering Response (C-N)
Source/comment: Applicable only in cases where driver steered as corrective action. Measured as lateral acceleration and yaw rate.
Coded from Raw data from vehicle.

18. Windshield Wiper Activation (C, N, I, B)
0=Off
1-On
99=Unknown
Comment: Analysts will determine the windshield wiper activation through video reduction.
Coded in General State Variables: Weather/Lighting

19. Driver 1 Physical/Mental Impairment (C-N-I-B)
0 = None apparent
1 = Drowsy, sleepy, asleep, fatigued
2 = Ill, blackout
3a = Angry
3b = Other emotional state
4a = Drugs-medication
4b = Drugs-Alcohol
5 = Other drugs (marijuana, cocaine, etc.)
6 = Restricted to wheelchair
7 = Impaired due to previous injury
8 = Deaf
50 = Hit-and-run vehicle
97 = Physical/mental impairment – no details
98 = Other physical/mental impairment
99 = Unknown physical/mental condition
Source: GES D3, Driver Physical/Mental Condition. Element 3 expanded to separate anger from other emotions. Element 50 not applicable.
Coded in General State Variables: Driver's General State, Causal/Contributing Factors, & Precipitating Event

20. Driver 1 Drowsiness Rating (C, N)
Source/comment: An observer rating of drowsiness will be assigned for the 30 seconds prior to the event based on review of driver videos. For drowsiness levels above a criterion level (TBD), PERCLOS will be measured by the analyst. This variable will be coded for all crashes and near-crashes.
Coded in General State Variables: Driver's General State

21. Average PERCLOS (Percent Eyes Closed) (C, N)

Comment: For crashes and near-crashes where the driver's observer rating of drowsiness is above a criterion level (TBD), the average PERCLOS value for the 30 second pre-event period will be obtained through video reduction.

Coded in General State Variables: Driver's General State

22. Average Lane Deviation (C, N)

Comment: This will be a single value, obtained from the data stream, indicating an average degree of lane deviation (i.e., variability of lane position) for 30 seconds prior to impact or near-impact. Average lane deviation will be measured in inches using the center of the vehicle as a reference point to the center of the lane of travel. Lane deviations will be obtained at a rate of 10 Hz.

Coded in raw data stream.

23. Maximum Lane Deviation (C, N)

Comment: This will be a single value, obtained from the data stream, indicating a maximum lane deviation for the 30 seconds prior to impact or near-impact**.** Maximum lane deviation will be measured in inches using the center of the vehicle as a reference point to the center of the lane of travel. The maximum absolute value will be determined over a 30 second time span prior to the onset of the incident. Lane deviations will be obtained at a rate of 10 Hz.

Coded in raw data stream.

24. Driver 1 Time-On-Task (C-N-I-B)

Comment: The time that Driver 1 has been continuously driving will be recorded in minutes based on raw data from the vehicle. This variable will help to characterize the role of fatigue in driving.

Coded in raw data stream.

25. Driver 1 Eye Glance Reconstruction (C-N)

Eye glances for the previous 60 seconds will be classified using the following categories and described as a timed, narrative sequence of the following numbers:

1 = Center forward
2 = Left forward
3 = Right forward
4 = Left mirror
5 = Right mirror
6 = Left window
7 = Right window
8 = Instrument panel
9 = Other

Comment: The analysis will include a recording of time the driver's eyes were not "on the road;" i.e., straight ahead, forward right, or forward left. When possible, eye glances will be characterized in greater detail than the general directions and areas listed above; e.g., when known, the specific object of regard will be noted in the narrative. For the instrument panel, for example, specific components such as the radio/CD will be noted in the narrative. When applicable and possible, the eye glance reconstruction will also include an assessment of driver reaction time to a stimulus; e.g., braking reaction time following a potential crash-precipitating event.

Coded in General State Variables: Driver's General State

26. Driver 1 Alcohol Use (C-N)

0 = None known
1 = Use observed in vehicle without overt effects on driving
2 = Use observed in vehicle with overt effects on driving
3 = Use not observed but reported by police
4 = Use not observed or reported, but suspected based on driver behavior.

Source/comment: Similar to GES Variable V92 but modified to take advantage of instrumented vehicle capability.

Coded in General State Variables: Driver's General State & Causal/Contributing Factors

27. Driver 1 Vision Obscured by (C-N-I)

0 = No obstruction
1 = Rain, snow, fog, smoke, sand, dust
2a = Reflected glare
2b = Sunlight
2c = Headlights
3 = Curve or hill
4 = Building, billboard, or other design features (includes signs, embankment)
5 = Trees, crops, vegetation
6 = Moving vehicle (including load)
7 = Parked vehicle
8 = Splash or spray of passing vehicle [any other vehicle]
9 = Inadequate defrost or defog system
10 = Inadequate lighting system
11 = Obstruction interior to vehicle
12 = Mirrors
13 = Head restraints
14 = Broken or improperly cleaned windshield
15 = Fog
50 = Hit-and-run vehicle
95 = No driver present
96 = Not reported
97 = Vision obscured – no details
98 = Other obstruction
99 = Unknown whether vision was obstructed

Source: GES Variable D4. Note that Element 2 is expanded from the GES and that Elements 50, 95, and 96 are not applicable.

Coded in Causal/Contributing Factors & Precipitating Factors. May only be obtainable from PAR.

28. Driver 1 Distracted by (C-N-I-B)

0 = Not distracted
1 = Looked but did not see
2 = NOT USED [for consistency withGES]
3a = By other occupant in adjacent seat
3b = By other occupant in rear seat
3d = By child in adjacent seat
3d = By child in rear seat
4 = By moving object in vehicle
5 = While talking or listening to phone
6a = While dialing phone (hand-held)
6b = While dialing phone (hands free)
6c = Locating/dialing/reaching for phone
7 = While adjusting climate control
8a = While adjusting radio
8b = While manipulating cassette
8c = While manipulating CD
9 = While using other devices integral to vehicle *[text box to specify]*
10 = While using or reaching for other devices
11 = Drowsy, sleepy, asleep, fatigued
12a = Previous crash or highway incident
12b = Other outside person
12c = Outside animal
12d = Outside object
12e = Construction zone
13a = Eating
13b = Drinking

14a = Smoking related – reaching for
14b = Smoking related -- lighting
14c = Smoking related – smoking [only if judged a source of distraction]
14d = Smoking related -- extinguishing
15 = Reaching for stationary object in vehicle
16 = Pet in vehicle
17 = Insect in vehicle
18 = PDA (locating, reaching, operating, viewing)
95 = No driver present
96 = Not reported
97 = Inattentive or lost in thought
98 = Other distraction or inattention
99 = Unknown if distracted
Source: GES Variable D7. Note that Elements 8, 12, and 13 are expanded from the GES and that Elements 95 and 96 are not applicable.

29. Driver 1 Actions/Factors Relating to Crash/Incident (C-N-I-B)

Note: Analyst may code up to 3, in order of importance.
0 = None
1 = Exceeded speed limit
2= Inattentive or distracted
3 = Exceeded safe speed but not speed limit
4 = Driving slowly; below speed limit
5 = Driving slowly in relation to other traffic; not below speed limit
6 = Illegal passing (i.e., across double line) 2 = Inattentive or distracted (coded in previous variable)
7 = Passing on right
8 = Other improper or unsafe passing
9 = Cutting in, too close in front of other vehicle
10 = Cutting in, too close behind other vehicle
11 = Making turn from wrong lane (e.g., across lanes)
12 = Did not see other vehicle during lane change or merge
13 = Driving in other vehicle's blind zone
14 = Aggressive driving, specific, directed menacing actions
15 = Aggressive driving, other; i.e., reckless driving without directed menacing actions
16 = Wrong side of road, not overtaking
17 = Following too close
18 = Failed to signal, or improper signal
19 = Improper turn: wide right turn
20 = Improper turn: cut corner on left turn
21 = Other improper turning
22 = Improper backing, did not see
23 = Improper backing, other
24 = Improper start from parked position
25 = Disregarded officer or watchman
26 = Signal violation, apparently did not see signal
27 = Signal violation, intentionally ran red light
28 = Signal violation, tried to beat signal change
29 = Stop sign violation, apparently did not see stop sign
30 = Stop sign violation, intentionally ran stop sign at speed
31 = Stop sign violation, "rolling stop"
32 = Other sign (e.g., Yield) violation, apparently did not see sign
33 = Other sign (e.g., Yield) violation, intentionally disregarded
34 = Other sign violation
35 = Non-signed crossing violation (e.g., driveway entering roadway)
36 = Right-of-way error in relation to other vehicle or person, apparent recognition failure (e.g., did not see other vehicle)

37 = Right-of-way error in relation to other vehicle or person, apparent decision failure (i.e., did see other vehicle prior to action but misjudged gap)
38 = Right-of-way error in relation to other vehicle or person, other or unknown cause
39 = Sudden or improper stopping on roadway
40 = Parking in improper or dangerous location; e.g., shoulder of Interstate
41 = Failure to signal with other violations or unsafe actions
42 = Failure to signal, without other violations or unsafe actions
43 = Speeding or other unsafe actions in work zone
44 = Failure to dim headlights
45 = Driving without lights or insufficient lights
46 = Avoiding pedestrian
47 = Avoiding other vehicle
48 = Avoiding animal
49 = Apparent unfamiliarity with roadway
50 = Apparent unfamiliarity with vehicle; e.g., displays and controls
51 = Apparent general inexperience driving
52 = Use of cruise control contributed to late braking
53 = Other, specify

Willful Behavior
Source/comment: This variable came from the Light/Heavy Vehicle Interaction Study Taxonomy. Coded under Driver Behavior

1 = Aggressive driving
2 = Purposeful violation of traffic laws
3 = Use of vehicle for improper purposes (Intimidation/weapon)

Driver Proficiency
Source/comment: This variable came from the Light/Heavy Vehicle Interaction Study Taxonomy. Coded under Driver Behavior

1 = Violation of traffic laws
2 = Driving techniques (incompetent to safely perform driving maneuver)
3 = Vehicle kinematics (incompetent handling the vehicle)
4 = Driver capabilities (incompetent on what maneuvers are safe and appropriate)

30. Vehicle Contributing Factors (C-N-I)
0 = None
1 = Tires
2 = Brake system
3 = Steering system
4 = Suspension
5 = Power train
6 = Exhaust system
7 = Headlights
8 = Signal lights
9 = Other lights
10 = Wipers
11 = Wheels
12 = Mirrors
13 = Driver seating and controls
14 = Body, doors
15 = Trailer hitch
50 = Hit and run vehicle
97 = Vehicle contributing factors, no details
98 = Other vehicle contributing factors

99 = Unknown if vehicle had contributing factors
Source/comment: GES Variable V12. For consistency, all GES elements have been used, although most will be rare events.
Coded in Causal/Contributing Factors & Precipitating Factors

31. Driver's Action [reason for avoiding, swerving, sliding] (C-N-I)

0 = Not avoiding, swerving, or sliding
1 = Severe crosswind
2 = Wind from passing truck
3 = Slippery or loose surface
4 = Tire blow-out or flat
5 = Debris or objects in road
6 = Ruts, holes, bumps in road
7 = Animals in road
8 = Vehicle in road
9 = Phantom vehicle
10 = Pedestrian, pedalcyclist, or other non-motorist in road
11 = Water, snow, oil slick in road
50 = Hit-and-run vehicle
97 = Avoiding, swerving, or sliding, no details
98 = Other environmental contributing factor
99 = Unknown action
Source/comment: GES Variable D5. For consistency, all GES elements have been used, although most will be rare events.
Coded in Precipitating Factors

32. Vehicle Headway/Following Range for Rear-End, Lead Vehicle Moving Event (C-N-I-B)

0 = Not applicable
1-97 = Headway, in meters.
98 = Headway of 98 meters or greater
99 = Unknown headway
Comment: This information is applicable only to rear-end, lead-vehicle moving scenarios where the subject vehicle is the following vehicle. V1 headway/following range value will be available from the forward-facing Vorad Radar System. The value will be coded for the moment just prior to the critical event (e.g., prior to V1 braking).
Coded from data stream.

33. Vehicle Velocity (C, N)

Comment: This will be a single value, obtained from data stream, one frame prior to onset of precipitating event (e.g., beginning of braking to avoid a crash).
Coded from data stream.

34. Vehicle Velocity at Impact (C)

Comment: This will be a single value, obtained from the data stream, one frame prior to impact.
Coded from data stream.

35. Lateral Acceleration (C, N)

Comment: This will be a single value, obtained from the data stream, one frame prior to impact.
Coded from data stream.

36. Longitudinal Acceleration (C, N)

Comment: This will be a single value, obtained from the data stream, one frame prior to impact.
Coded from data stream.

37. Collision Delta V (C)

Comment: The change in velocity during the collision. This will be a single value, obtained in the data stream, summarizing the change in velocity of the vehicle associated with the impact.

Coded from data stream.

38. ABS Brake Activation (C, N, I, B)

0 = no
1 = yes
99 = unknown

Comment: This will indicate whether the ABS brakes were activated during the event. This information will be obtained from the in-vehicle network, if available.
Coded from data stream.

39. Traction Control (C, N, I, B)

0 = no
1 = yes
99 = unknown

Comment: This will be a single value stating whether the traction control system was activated during the event. This information will obtained from the in-vehicle network, if available.
Coded from data stream.

40. Cruise Control Status and Set Speed (C-N-I-B)

0 = Cruise control off
1-97 = Set speed of cruise control, if activated.
98 = Cruise control activated, unknown set speed
99 = Unknown if cruise control is activated.
Comment: For some study vehicle types (e.g., Ford Taurus), this data will be available from the vehicle network. When this information is available and the cruise control was on, this will be coded for the moment just prior to the critical event (e.g., prior to braking).
Coded from data stream.

41. Duration of Principal Prior Sleep Period (C)

Comment: This single value (in minutes) will be obtained during post-crash interview with subject. Subjects involved in crashes, police-reported and non-police-reported, will be interviewed to obtain this information.
Coded from post-crash interviews/PARs.

42. Time Awake Since Principal Sleep Period (C)

Comment: This single value (in minutes) will be obtained during post-crash interview with subject. Subjects involved in crashes, police-reported and non-police-reported, will be interviewed to obtain this information.
Coded from post-crash interviews/PARs.

43. Duration of Nap Prior to Collision (C)

Comment: This single value (in minutes) will be obtained during post-crash interview with subject. Subjects involved in crashes, police-reported and non-police-reported, will be interviewed to obtain this information. If there was no nap, the value will be zero.
Coded from post-crash interviews/PARs.

44. Time Awake Since Nap (C)

Comment: This single value (in minutes) will be obtained during post-crash interview with subject. Subjects involved in crashes, police-reported and non-police-reported, will be interviewed to obtain this information. If there was no nap, the value will be zero.
Coded from post-crash interviews/PARs.

V1 Occupant File
Information on occupants – number, seating position, injuries, etc. – will be available only for crashes. In-vehicle cameras will not show occupants other than the driver, and thus no information regarding these other occupants will be available for near-crashes, incidents, and baseline epochs.

1. **V1 Occupant Number (C)**
   Note: Each occupant in V1, including the driver, will be assigned an occupant number; e.g., P1-1 (the driver of V1), P1-2, etc.
   Coded in General State Variables: Driver's General State.

2. **V1 Occupant Seating Position (C)**
   Source/comment: Position numbers (1-8) will be assigned per VA PAR Variable 10.
   Coded in General State Variables: Driver's General State.

3. **V1 Occupant Sex(C)**
   1 = Male
   2 = Female
   3 = Unknown
   Coded in General State Variables: Driver's General State.

4. **V1 Occupant Age (C)**
   Source/comment: Will be obtained PARs, and also from subject records (e.g., family members).
   Coded in General State Variables: Driver's General State.

5. **V1 Occupant Safety Belt Usage (C)**
   1 = Lap/shoulder belt
   2 = Child safety/booster seat with safety belt
   3 = Child safety/booster seat without safety belt
   4 = Other safety belt used (describe)
   5 = None used
   99 = Unknown if used.
   Source/comment: Adapted from GES Variable P5. All study vehicles will be equipped with manual lap/shoulder belts. In-vehicle video cameras will reveal whether drivers are wearing safety belts, but other vehicle occupants will not be visible in these videos.
   Coded in General State Variables: Driver's General State.

6. **V1 Occupant Injury Severity (C)**
   0 = No injury (O)
   1 = Fatal (K)
   2 = Visible signs of injury; e.g., bleeding wound or distorted member, or carried from scene (A).
   3 = Other visible injury as bruises, abrasions, swelling, limping, etc. (B)
   4 = No visible injury but complaint of pain or momentary unconsciousness (C)
   Source/comment: VA PAR Variable 15. This variable will be coded only for crashes.
   Coded in General State Variables: Driver's General State.

7. **V1 Occupant Injury Narrative (C)**
   For each V1 occupant with injuries (1-4 above), a narrative description will be provided of occupant kinematics, contact point(s), role of safety equipment (e.g., airbag deployment), nature of injury(ies), disposition (i.e., whether transported or not), and, if applicable and available, medical diagnoses and outcomes.
   Coded in General State Variables: Driver's General State.

Driver/Vehicle 2 File

1. **Vehicle/Person 2 Type (C-N-I)**
   1 = Automobile
   2 = Van (minivan or standard van)

3 = Pickup truck
4 = Bus (transit or motor coach)
5 = School bus
6 = Single-unit straight truck
7 = Tractor-trailer
8 = Motorcycle or moped
9 = Emergency vehicle (police, fire, EMS) in service
10 = Other vehicle type
11 = Pedestrian
12 = Cyclist
13 = Animal
99 = Unknown vehicle type

Source/comment: Highly abridged version of GES V5, Body Type. Elements 6 and 7 could be expanded to identify more heavy truck types. If "Driver/Vehicle" 2 is a person (pedestrian or cyclist) or animal, most other D/V 1 File variables will be coded "not applicable."
Coded in General State Variables: Driver/Vehicle 2

2. **V2 Driver/Person Sex (C)**
1 = Male
2 = Female
3 = Unknown
Coded in General State Variables: Driver/Vehicle 2

3. **V2 Driver/Person Age (C)**
Source/comment: Determined from available sources (e.g., PAR) or estimated.
Coded in General State Variables: Driver/Vehicle 2

4. **Vehicle 2 Maneuver (C-N)**
1 = Going straight ahead
2 = Making right turn
3 = Making left turn
4 = Making U-turn
5 = Slowing or stopping
6 = Starting in traffic lane
7 = Starting from parked position
8 = Stopped in traffic lane]
9 = Ran off road right
10 = Ran off road left
11 = Parked
12 = Backing
13 = Passing
14 = Changing lanes
15 = Other
16 = Accelerating in traffic lane
17 = Entering a parked position
18 = Negotiating a curve
19 = Merging
Source/comment: VA PAR Variable 19/20; Elements 16-19 added for completeness and for better consistency with GES V21.
Coded in General State Variables: Driver/Vehicle 2

5. **Vehicle 2 Accident Type (C-N)**
Source/comment: GES Variable V23. As shown in the attached. The rear-end crash scenarios will be expanded to include three possible subtypes (94, 95, and 96) associated with an accelerating lead vehicle. A code will be added for "not applicable."
Coded in General State Variables: Driver/Vehicle 2

6. Critical/Precipitating Event for Vehicle 2 (C-N)

This Vehicle Loss of Control Due to:

001 = Blow out or flat tire
002 = Stalled engine
003 = Disabling vehicle failure (e.g. wheel fell off)
004 = Minor vehicle failure
005 = Poor road conditions (puddle, pothole, ice, etc.)
006 = Excessive speed
007 = Other or unknown reason
008 = Other cause of control loss
009 = Unknown cause of control loss

This Vehicle Traveling:

010 = Over the lane line on the left side of travel lane
011 = Over the lane line on right side of travel lane
012 = Over left edge of roadway
013 = Over right edge of roadway
014 = Unknown which edge
015 = End departure
016 = Turning left at intersection
017 = Turning right at intersection
018 = Crossing over (passing through) intersection
018 = This vehicle decelerating
019 = Unknown travel direction

Other Vehicle in Lane:

030 = Ahead, stopped on roadway more than 2 seconds
031 = Ahead, decelerated and stopped on roadway 2 seconds or less
032 = Ahead, traveling in same direction and decelerating
033 = Ahead, traveling in same direction and accelerating
034 = Ahead, traveling in same direction with slower constant speed
035 = Behind, traveling in same direction and accelerating
036 = Behind, traveling in same direction with higher constant speed
037 = Behind, stopped on roadway
050 = Stopped on roadway
051 = Traveling in same direction with lower steady speed
052 = Traveling in same direction while decelerating
053 = Traveling in same direction with higher speed
054 = Traveling in opposite direction
055 = In crossover
056 = Backing
057 = Unknown travel direction of the other motor vehicle

Another Vehicle Encroaching into This Vehicle's Lane:

060a = From adjacent lane (same direction), over left lane line in front of this vehicle, rear-end crash threat
060b = From adjacent lane (same direction), over left lane line behind this vehicle, rear-end crash threat
060c = From adjacent lane (same direction), over left lane line, sideswipe threat
060d = From adjacent lane (same direction), over left lane line, sideswipe threat
060e = From adjacent lane (same direction), other
061a = From adjacent lane (same direction), over right lane line in front of this vehicle, rear-end crash threat
061b = From adjacent lane (same direction), over right lane line behind this vehicle, rear-end crash threat
061c = From adjacent lane (same direction), over right lane line, sideswipe threat
061d = From adjacent lane (same direction), over right lane line, sideswipe threat
061e = From adjacent lane (same direction), other
062 = From opposite direction over left lane line.
063 = From opposite direction over right lane line

064 = From parallel/diagonal parking lane
065 = Entering intersection—turning in same direction
066 = Entering intersection—straight across path
067 = Entering intersection – turning into opposite direction
068 = Entering intersection—intended path unknown
070 = From driveway, alley access, etc – turning into same direction
071 = From driveway, alley access, etc – straight across path
072 = From driveway, alley access, etc – turning into opposite direction
073 = From driveway, alley access, etc – intended path unknown
074 = From entrance to limited access highway
078 = Encroaching details unknown

Pedestrian, Pedalcyclist, or other Non-Motorist:

080 = Pedestrian in roadway
081 = Pedestrian approaching roadway
082 = Pedestrian in unknown location
083 = Pedalcyclist/other non-motorist in roadway
084 = Pedalcyclist/other non-motorist approaching roadway
085 = Pedalcyclist/or other non-motorist unknown location
086 = Pedestrian/pedalcyclist/other non-motorist—unknown location

Object or Animal:

087 = Animal in roadway
088 = Animal approaching roadway
089 = Animal unknown location
090 = Object in roadway
091 = Object approaching roadway
092 = Object unknown location

Other:

098 = Other event/not applicable
099 = Unknown critical event

Source/comment: GES Variable V26 (1999-Later version), except that Elements 030-037 have been added to more fully characterize rear-end crash situations. These do not correspond to any current or past GES variables. Elements 050-053 will not be used since they are addressed by 030-037. Elements 060 and 061 have been expanded to address multiple rear-end and sideswipe crash-related scenarios. All coding on this variable will be checked for consistency with the previous variable, V1 Accident Type.

Coded: From PAR and/or video.

Coded in General State Variables: Driver/Vehicle 2

7. Vehicle 2 Corrective Action Attempted (C-N)

0 = No driver present
1 = No avoidance maneuver
2 = Braking (no lockup)
3 = Braking (lockup)
4 = Braking (lockup unknown)
5 = Releasing brakes
6 = Steered to left
7 = Steered to right
8 = Braked and steered to left
9 = Braked and steered to right
10 = Accelerated
11 = Accelerated and steered to left
12 = Accelerated and steered to right
98 = Other actions
99 = Unknown if driver attempted any corrective action

Coded: From PAR and/or video.

Source: GES V27, Corrective Action Attempted

Coded in General State Variables: Driver/Vehicle 2

8. Driver 2 Physical/Mental Impairment (C)

0 = None apparent
1 = Drowsy, sleepy, asleep, fatigued
2 = Ill, blackout
3a = Angry
3b = Other emotional state
4 = Drugs-medication
5 = Other drugs (marijuana, cocaine, etc.)
6 = Restricted to wheelchair
7 = Impaired due to previous injury
8 = Deaf
50 = Hit-and-run vehicle
97 = Physical/mental impairment – no details
98 = Other physical/mental impairment
99 = Unknown physical/mental condition
Coded: From PAR.
Source: GES D3, Driver Physical/Mental Condition. Element 3 expanded to separate anger from other emotions. Element 50 not applicable.
Coded in General State Variables: Driver/Vehicle 2

9. D2 Alcohol Use (C)

0 = None known
1 = Observed or reported by police
2 = Purported (e.g., by Subject Driver)
Coded: From PAR
Source/comment: Minimal information expected to be available to make this determination.
Coded in General State Variables: Driver/Vehicle 2

10. D2 Vision Obscured by* (C-N)

0 = No obstruction
1 = Rain, snow, fog, smoke, sand, dust
2a = Reflected glare
2b = Sunlight
2c = Headlights
3 = Curve or hill
4 = Building, billboard, or other design features (includes signs, embankment)
5 = Trees, crops, vegetation
6 = Moving vehicle (including load)
7 = Parked vehicle\
8 = Splash or spray of passing vehicle [any other vehicle]
9 = Inadequate defrost or defog system
10 = Inadequate lighting system
11 = Obstruction interior to vehicle
12 = Mirrors
13 = Head restraints
14 = Broken or improperly cleaned windshield
15 = Fog
50 = Hit & run vehicle
95 = No driver present
96 = Not reported
97 = Vision obscured – no details
98 = Other obstruction
99 = Unknown whether vision was obstructed
Coded: From PAR and/or video.
Source: GES Variable D4. Note that Element 2 is expanded from the GES and that Element 96 is not applicable. In many cases, determination of this varilable for D2 will be difficult.
Coded in General State Variables: Driver/Vehicle 2

11. Driver 2 Distracted by (C-N)

0 = Not distracted
1 = Looked but did not see
2 = NOT USED [for consistency with GES]
3 = By other occupants
4 = By moving object in vehicle
5 = While talking or listening to phone
6 = While dialing phone
7 = While adjusting climate control
8a = While adjusting radio
8b = While adjusting cassette or CD
9 = While using other devices integral to vehicle
10 = While using or reaching for other devices
11 = Drowsy, sleepy, asleep, fatigued
12a = Previous crash or highway incident
12b = Other outside person or object
13a = Eating
13b = Drinking
14 = Smoking related
95 = No driver present
96 = Not reported
97 = Inattentive or lost in thought
98 = Other distraction or inattention
99 = Unknown if distracted
Coded: From PAR and/or video
Source: GES Variable D7. Note that Element 8, 12, and 13 are expanded from the GES and that Elements 95 and 96 are not applicable. In many cases, determination of this variable for D2 will be difficult.
Coded in General State Variables: Driver/Vehicle 2

12. Driver 2 Actions/Factors Relating to Crash/Incident (C-N)

Note: Analyst may code up to 3, in order of importance.
0 = None
1 = Exceeded speed limit
2 = Inattentive or distracted (coded in previous variable)
3 = Exceeded safe speed but not speed limit
4 = Driving slowly; below speed limit
5 = Driving slowly in relation to other traffic; not below speed limit
6 = Illegal passing (i.e., across double line)
7 = Passing on right
8 = Other improper or unsafe passing
9 = Cutting in, too close in front of other vehicle
10 = Cutting in, too close behind other vehicle
11 = Making turn from wrong lane (e.g., across lanes)
12 = Did not see other vehicle during lane change or merge
13 = Driving in other vehicle's blind zone
14 = Aggressive driving, specific, directed menacing actions
15 = Aggressive driving, other; i.e., reckless driving without directed menacing actions
16 = Wrong side of road, not overtaking
17 = Following too close
18 = Failed to signal, or improper signal
19 = Improper turn: wide right turn
20 = Improper turn: cut corner on left turn
21 = Other improper turning
22 = Improper backing, did not see
23 = Improper backing, other
24 = Improper start from parked position

25 = Disregarded officer or watchman
26 = Signal violation, apparently did not see signal
27 = Signal violation, intentionally ran red light
28 = Signal violation, tried to beat signal change
29 = Stop sign violation, apparently did not see stop sign
30 = Stop sign violation, intentionally ran stop sign at speed
31 = Stop sign violation, "rolling stop"
32 = Other sign (e.g., Yield) violation, apparently did not see sign
33 = Other sign (e.g., Yield) violation, intentionally disregarded
34 = Other sign violation
35 = Non-signed crossing violation (e.g., driveway entering roadway)
36 = Right-of-way error in relation to other vehicle or person, apparent recognition failure (e.g., did not see other vehicle)
37 = Right-of-way error in relation to other vehicle or person, apparent decision failure (i.e., did see other vehicle prior to action but misjudged gap)
38 = Right-of-way error in relation to other vehicle or person, other or unknown cause
39 = Sudden or improper stopping on roadway
40 = Parking in improper or dangerous location; e.g., shoulder of Interstate
41 = Failure to signal with other violations or unsafe actions
42 = Failure to signal, without other violations or unsafe actions
43 = Speeding or other unsafe actions in work zone
44 = Failure to dim headlights
45 = Driving without lights or insufficient lights
46 = Avoiding pedestrian
47 = Avoiding other vehicle
48 = Avoiding animal
49 = Apparent unfamiliarity with roadway
50 = Apparent unfamiliarity with vehicle; e.g., displays and controls
51 = Apparent general inexperience driving
52 = Use of cruise control contributed to late braking
53 = Other, specify
Coded: From PAR and/or video.
Source/comment: This variable originated with VA PAR Variable 17/18 but has been greatly expanded. Element numbers do not correspond to any source variable. Analysts will code up to three factors for each driver, in descending order of judged importance.
Coded in General State Variables: Driver/Vehicle 2

13. Vehicle Contributing Factors for V2 (C-N)

0 = None
1 = Tires
2 = Brake system
3 = Steering system
4 = Suspension
5 = Power train
6 = Exhaust system
7 = Headlights
8 = Signal lights
9 = Other lights
10 = Wipers
11 = Wheels
12 = Mirrors
13 = Driver seating and controls
14 = Body, doors
15 = Trailer hitch
50 = Hit and run vehicle
97 = Vehicle contributing factors, no details
98 = Other vehicle contributing factors

99 = Unknown if vehicle had contributing factors
Coded: From PAR and/or video.
Source/comment: GES Variable V12. For consistency, all GES elements have been used, although most will be rare events and determination will often be difficult for D2.
Coded in General State Variables: Driver/Vehicle 2

14. Driver 2 Action [environmental reason for avoiding, swerving, sliding] (C-N)
0 = Not avoiding, swerving, or sliding
1 = Severe crosswind
2 = Wind from passing truck
3 = Slippery or loose surface
4 = Tire blow-out or flat
5 = Debris or objects in road
6 = Ruts, holes, bumps in road
7 = Animals in road
8 = Vehicle in road
9 = Phantom vehicle
10 = Pedestrian, pedalcyclist, or other non-motorist in road
11 = Water, snow, oil slick in road
50 = Hit and run vehicle
97 = Avoiding, swerving, or sliding, no details
98 = Other environmental contributing factor
99 = Unknown action
Coded: From PAR and/or video.
Source/comment: GES Variable D5. For consistency, all GES elements have been used, although most will be rare events.
Coded in General State Variables: Driver/Vehicle 2

15. Vehicle Headway/Following Range for Rear-End, Lead Vehicle Moving Event (C-N-I-B)
0 = Not applicable
1-97 = Headway, in meters.
98 = Headway of 98 meters or greater
99 = Unknown headway
Comment: This information is applicable only to rear-end, lead-vehicle moving scenarios where the subject vehicle is the leading vehicle. V2 headway/following range value will be available from the subject vehicle rearward-facing Vorad Radar System. The value will be coded for the moment just prior to the critical event (e.g., prior to V2 braking).
Coded in General State Variables: Driver/Vehicle 2

<u>V2 Occupant File</u>

Information on V2 occupants – number, seating position, injuries, etc. – will be available only for crashes. Subject vehicle cameras will not show occupants of the other vehicle, and thus no information regarding these other occupants will be available for near-crashes, incidents, and baseline epochs. Crash PARs, and comparable data collected for non-police-reported crashes, will be the source of occupant information.

1. V2 Occupant Number (C)
Note: Each occupant in V1, including the driver, will be assigned an occupant number; e.g., P1-1 (the driver of V1), P1-2, etc.
Coded in General State Variables: Driver/Vehicle 2

2. V2 Occupant Seating Position (C)
Source/comment: Position numbers (1-8) will be assigned per VA PAR Variable 10.
Coded in General State Variables: Driver/Vehicle 2

3. V2 Occupant Sex(C)
1 = Male

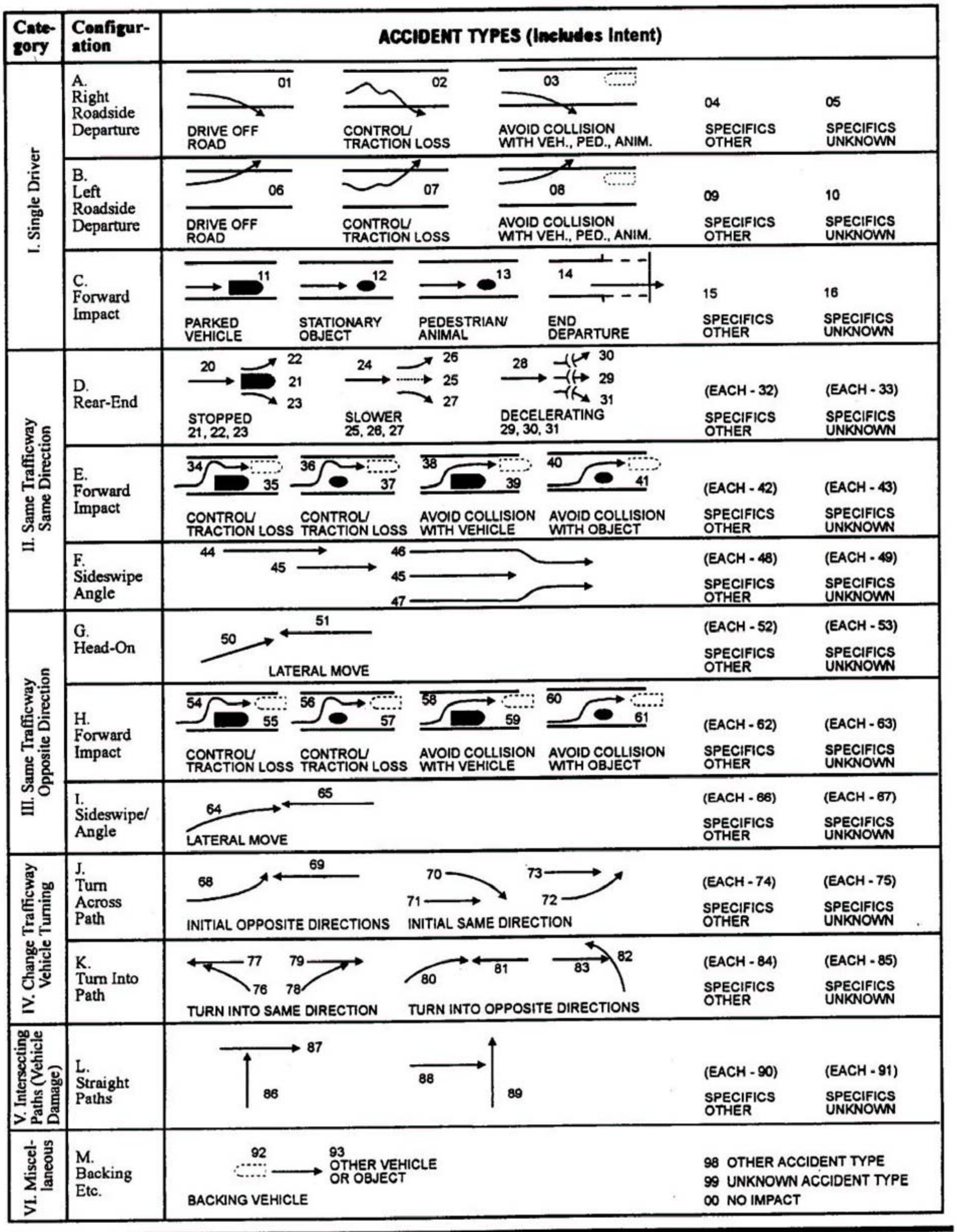
2 = Female
3 = Unknown
Coded in General State Variables: Driver/Vehicle 2

4. V2 Occupant Age (C)
Source/comment: Will be obtained from subject records (e.g., family members), driver interviews, or will be estimated from videos.
Coded in General State Variables: Driver/Vehicle 2

5. V2 Occupant Safety Belt Usage (C)
1 = Lap/shoulder belt
2 = Child safety/booster seat with safety belt
3 = Child safety/booster seat without safety belt
4 = Other safety belt used (describe)
5 = None used
99 = Unknown if used.
Source/comment: Adapted from GES Variable P5. Coded only for crashes.
Coded in General State Variables: Driver/Vehicle 2

6. V2 Occupant Injury Severity (C)
0 = No injury (O)
1 = Fatal (K)
2 = Visible signs of injury; e.g., bleeding wound or distorted member, or carried from scene (A).
3 = Other visible injury as bruises, abrasions, swelling, limping, etc. (B)
4 = No visible injury but complaint of pain or momentary unconsciousness (C)
Source/comment: VA PAR Variable 15. This variable will be coded only for crashes.
Coded in General State Variables: Driver/Vehicle 2

7. V2 Occupant Injury Narrative (C)
For each V2 occupant with injuries (1-4 above), a narrative description will be provided of occupant kinematics, contact point(s), role of safety equipment (e.g., airbag deployment), nature of injury(ies), disposition (i.e., whether transported or not), and, if applicable and available, medical diagnoses and outcomes.
Coded in General State Variables: Driver/Vehicle 2



NASS GES Analytical User's Manual, 1988-2000

APPENDIX C: INFORMATION ON THE VEHICLE NETWORK OF SELECTED VEHICLE MODELS

Variable	Corolla	Camry	Taurus	Explorer	Cavalier	Malibu
VIN #	no	no	no	no	no	no
vehicle speed	yes	yes	yes	yes	yes	yes
seatbelt attached	no	no	yes	yes	yes	yes
airbag deployed	trouble codes	trouble codes	yes	yes	yes	yes
L/R turn signals	no	no	no	no	yes	yes
head lamps	no	no	no	no	yes	yes
brake lamps	on/off	on/off	on/off	on/off	yes	yes
window wiper mode	no	no	yes	yes	no	no
tire pressure	no	no	no	no	no	no
brake pedal position	no	no	on/off	on/off	yes	on/off
gas pedal position	%	%	3 levels/%	3 levels/%	%	%
ABS system on/off	no	no	yes*	individual wheel	yes*	yes*
ABS active	no	no	yes*	resistance meas	yes*	yes*
wheel slip	no	no	no	no	yes*	no
wheel speed	no	no	yes**	yes **	yes*	individual
traction control active (engine)	no	no	yes*	yes*	yes*	yes*
traction control active (brake)	no	no	yes*	yes*	yes*	yes*
cruise on/off switch	no	no	yes*	Neither of our	no	no
cruise speed control active	no	no	yes*	Explorers have	no	yes (not switch-mode)
cruise set speed	no	no	yes*	cruise	no	no
cruise set speed switch	no	no	yes*	(should read it	no	no
cruise coast switch	no	no	yes*	if equipped)	no	no
cruise resume switch	no	no	yes*		no	no
cruise accelerate switch	no	no	yes*		no	no
steering wheel angle	no	no	no	no	no	no
steering wheel rate	no	no	no	no	no	no
steering wheel torque	no	no	no	no	no	no
climate fan speed switches	no	no	no	no	no	no
climate temp switches	no	no	no	no	no	no
climate multi zone switch	no	no	no	no	no	no
outside air temp	no	no	no	no	no	no
sun load	no	no	no	no	no	no
photo cell dark	no	no	no	no	no	yes
radio tuning	no	no	no	no	no	no

APPENDIX D: WASHINGTON POST NEWSPAPER ADVERTISEMENT

The Virginia Tech Transportation Institute
Will Be Recruiting Spring 2002 For A Driving Research Study in the DC/NoVA Area

Earn $150.00 per Month for One Year of Driving Your Own Vehicle

To Participate You Must:

- Drive at Least 25,000 Miles Per Year
- Have a Valid Driver's License
- Be Between 18 and 65 Years of Age
- Own your own vehicle
- Allow VTTI to Install Temporary Data Collection System in Your Vehicle

If Interested, Please Call
(800) 997-7836

or email
drivingstudy@vtti.vt.edu

APPENDIX E: TELEPHONE SCREENING QUESTIONNAIRE

Telephone Interviewer: *The objective of this study is to collect data on naturalistic driving behavior, such as how and when drivers steer and brake. There are no special tasks for the driver to perform; instead, the driver is requested to merely drive as they regularly would to their normal destinations. This instrumentation is designed such that it will in no way interfere with the driving performance of the vehicle and will not obstruct the driver in any way. Instrumentation will consist of hardware installed that will measure driving performance, and will include collecting video of the driver and possibly other passengers. Instrumentation of your vehicle will require that you drop off your vehicle at a convenient time, such as before work in the morning. You will be given Metro fare to get to your job or another location. Also, you will be given $150.00 per month as compensation. Are you interested in participating?*

If it becomes clear during any point that the driver does not have one of the specific vehicle types, tell him or her the following:

A few drivers will be selected to drive a leased vehicle for a period of approximately 12 months. The leased vehicle will also have data collection equipment installed, including instrumentation to collect video of the driver and possibly other passengers. You would not be given monetary compensation, but you would be able to drive the leased vehicle free of charge. Would you be interested in driving a leased vehicle?

If yes, continue. If the driver does not have one of the specific vehicle types needed nor a desire to drive a leased vehicle, thank the driver and discontinue the screening.

Name: ____

Age: ______ (If under 18, stop and tell the participant that they do not qualify for the study)

Gender

Address

Telephone

Cell Phone

Email

Valid License? ? □Yes □No
If answer is no, stop and tell the participant that they do not qualify for the study.
If yes, continue.

Average Number of Miles Driven Per Year: ___________________ miles

Own Vehicle? □Yes □No

Make of Vehicle __________________

Model of Vehicle __________________

Vehicle Body Type _______________

Year of Vehicle __________________

Please answer the following questions:

Driving experience
Drive to work how many days per week?

Avg. mileage per day
Avg. mileage per year
Driving history
Traffic violations
Accident involvement
Occupation
Location of home/work
Most frequently traveled routes
License type (CDL, Basic, Learners' Permit)
Vehicle Information

Any plans to sell or trade vehicle in next year?

Are you the primary or secondary driver of vehicle? ☐ Primary ☐ Secondary

Will you be the exclusive driver of the vehicle for the one-year period? ☐Yes ☐No

Who else will be driving the vehicle during the one-year period?

____
Name Age

____
Name Age

____
Name Age

____
Name Age

All drivers of the vehicle must sign an informed consent form. Will any of the possible drivers of vehicle object to participating in this study and signing an informed consent form (minors must obtain parental permission to participate)?

☐Yes ☐No
If yes, driver is ineligible.

Do you work within walking distance to a Metro stop? ☐Yes ☐No
Do you live within walking distance to a Metro stop? ☐Yes ☐No

Thank you for your time and interest. We will be making driver selections in the next few weeks and we will contact you if you are selected to be a participant. Do you have any questions for us at this time? Thank you and have a nice day.

APPENDIX F: EXAMPLE HEALTH ASSESSMENT QUESTIONS

1. Do you have a history of any of the following? If yes, please explain.

Stroke	No____	Yes________________________________
Brain tumor	No____	Yes________________________________
Head injury	No____	Yes________________________________
Epileptic seizures	No____	Yes________________________________
Respiratory disorders	No____	Yes________________________________
Motion sickness	No____	Yes________________________________
Inner ear problems	No____	Yes________________________________
Dizziness, vertigo, or other balance problems		
	No____	Yes________________________________
Diabetes	No____	Yes________________________________
Migraine, tension headaches		
	No____	Yes________________________________

2. (Females only) Are you currently pregnant?

   Yes _____ No _____

3. Are you currently taking any medications on a regular basis? If yes, please list them.

   Yes _____ ____

   No _____

4. Results of vision test: Right eye________________ Left eye __________________
5. Results of hearing test: Right ear________________ Left ear ___________________

APPENDIX G: THE DULA DANGEROUS DRIVING INDEX

Please answer each of the following items as honestly as possible. Please read each item carefully and then circle the answer you choose on the form. If none of the choices seem to be your ideal answer, then select the answer that comes closest. THERE ARE NO RIGHT OR WRONG ANSWERS. Select your answers quickly and do not spend too much time analyzing your answers. If you change an answer, erase the first one well.

1. I drive when I am angry or upset.

   A. Never B. Rarely C. Sometimes D. Often E. Always

2. I lose my temper when driving.

   A. Never B. Rarely C. Sometimes D. Often E. Always

3. I consider the actions of other drivers to be inappropriate or "stupid."

   A. Never B. Rarely C. Sometimes D. Often E. Always

4. I flash my headlights when I am annoyed by another driver.

   A. Never B. Rarely C. Sometimes D. Often E. Always

5. I make rude gestures (e.g., giving "the finger"; yelling curse words) toward drivers who annoy me.

   A. Never B. Rarely C. Sometimes D. Often E. Always

6. I verbally insult drivers who annoy me.

   A. Never B. Rarely C. Sometimes D. Often E. Always

7. I deliberately use my car/truck to block drivers who tailgate me.

   A. Never B. Rarely C. Sometimes D. Often E. Always

8. I would tailgate a driver who annoys me.

   A. Never B. Rarely C. Sometimes D. Often E. Always

9. I "drag race" other drivers at stop lights to get out front.

   A. Never B. Rarely C. Sometimes D. Often E. Always

10. I will illegally pass a car/truck that is going too slowly.

   A. Never B. Rarely C. Sometimes D. Often E. Always

11. I feel it is my right to strike back in some way, if I feel another driver has been aggressive toward me.

   A. Never B. Rarely C. Sometimes D. Often E. Always

12. When I get stuck in a traffic jam I get very irritated.

   A. Never B. Rarely C. Sometimes D. Often E. Always

13. I will race a slow moving train to a railroad crossing.

   A. Never B. Rarely C. Sometimes D. Often E. Always

14. I will weave in and out of slower traffic.

   A. Never B. Rarely C. Sometimes D. Often E. Always

15. I will drive if I am only mildly intoxicated or buzzed.

A. Never B. Rarely C. Sometimes D. Often E. Always

16. When someone cuts me off, I feel I should punish him/her.

A. Never B. Rarely C. Sometimes D. Often E. Always

17. I get impatient and/or upset when I fall behind schedule when I am driving.

A. Never B. Rarely C. Sometimes D. Often E. Always

18. Passengers in my car/truck tell me to calm down.

A. Never B. Rarely C. Sometimes D. Often E. Always

19. I get irritated when a car/truck in front of me slows down for no reason.

A. Never B. Rarely C. Sometimes D. Often E. Always

20. I will cross double yellow lines to see if I can pass a slow moving car/truck.

A. Never B. Rarely C. Sometimes D. Often E. Always

21. I feel it is my right to get where I need to go as quickly as possible.

A. Never B. Rarely C. Sometimes D. Often E. Always

22. I feel that passive drivers should learn how to drive or stay home.

A. Never B. Rarely C. Sometimes D. Often E. Always

23. I will drive in the shoulder lane or median to get around a traffic jam.

A. Never B. Rarely C. Sometimes D. Often E. Always

24. When passing a car/truck on a 2-lane road, I will barely miss on-coming cars.

A. Never B. Rarely C. Sometimes D. Often E. Always

25. I will drive when I am drunk.

A. Never B. Rarely C. Sometimes D. Often E. Always

26. I feel that I may lose my temper if I have to confront another driver.

A. Never B. Rarely C. Sometimes D. Often E. Always

27. I consider myself to be a risk-taker.

A. Never B. Rarely C. Sometimes D. Often E. Always

28. I feel that most traffic "laws" could be considered as suggestions.

A. Never B. Rarely C. Sometimes D. Often E. Always

APPENDIX H: SLEEP HYGIENE QUESTIONNAIRE

GENERAL SLEEP HABITS AND PREFERENCES

1. When you are working:
what time do you go to bed ____:____ am/pm and wake up____:____am/pm

2. When you are not working:
what time do you go to bed ____:____ am/pm and wake up____:____am/pm

3. Do you keep a fairly regular sleep schedule? Yes_____ No_____
If no, please explain____

4. If you could set your own schedule:
When would you go to bed ____:____ am/pm and wake up____:____am/pm

5. How much sleep do you usually get?________

6. How much sleep would you ideally like to get?________

7. Do you do shift work Yes_____ No_____; If yes, please describe ___________________________________
____

8. Please describe your customary work schedule ____
____

SLEEP SYMPTOMS RELATED TO GENERAL SLEEP HABITS

"initial insomnia"
9. How long does it usually take for you to fall asleep? _________

10. Do you have difficulty getting to sleep? _________

11. If yes, how often do you have difficulty getting to sleep?

all the time_____ frequently_____ sometimes_____ infrequently

12. If yes, how does this vary with your work schedule?____________________________________
____

"middle insomnia"
13. How often do you wake up during the night?______

14. When you wake up during the night, how often do you then have difficulty getting back to sleep

all the time_____ frequently_____ sometimes_____ infrequently

15. If yes, how does this vary with your work schedule?____________________________________
____

"terminal insomnia"
16. Do you ever wake up earlier in the morning (or latter part of sleep period) than you'd like Yes_____ No_____

17. If yes, how many minutes or hours early do you wake on those occasions __________

18. If yes, when you wake up earlier than you'd like, how often do you then have difficulty getting back to sleep

all the time_____ frequently_____ sometimes_____ infrequently

19. If yes, how does this vary with your work schedule?____
____

"excessive daytime sleepiness"
20. Do you often feel uncomfortably sleepy during the day? Yes_____ No_____

21. Do you often feel exhausted although not particularly sleepy during the day? Yes_____ No_____

22. Do you ever have an irresistible urge to sleep or find that you fall asleep in unusual / inappropriate situations? Yes_____ No_____;

23. Do you usually nap during the day (or between major sleep periods)? Yes_____ No_____

24. If yes to 20-23 how does this vary with your work schedule?________________________________
____

SUBSTANCE-RELATED SLEEP PROBLEMS
25. What medications do you take? at what dosage? and at what dosage schedule?__________________________
____
____

26. Which, if any of these medications affect your sleep either by alerting (e.g., sudafed) or sedating (e.g., antihistamines) you, please describe ____
____

27. How does your use of these medications vary with your work schedule?______________________________
____

sleeping pills
28. Have you ever taken any medication to help you sleep? Yes_____ No_____

29. Do you currently take any medication, either prescription or O.T.C., to help you sleep? Yes_____ No_____

30. If yes to 29., what medication(s)?, dosage?, dosage schedule? _____________________________________
____

31. If yes to 29., how often do you take medication to help you sleep?

every night (sleep period)_____ more than once per week_____ once per week _____ once a month or less_____

32. If yes to 29., have your sleep medications ever lost their beneficial effect or have you had to increase their dose to help you sleep? Yes_____ No_____; If yes, please describe ____
____

33. If yes to 29., how does this vary with your work schedule?____
____

caffeine
34. Do you drink caffeinated beverages (coffee, tea, coca cola, mountain dew, jolt cola)? Yes_____ No_____

35. If yes, what kinds?_________________________; which is your favorite?_____________

36. How many cups/glasses per day? _______

37. Do you adjust your intake to help you to sleep? Yes_____ No_____; to stay awake? Yes_____ No_____

38. If yes to 34., how does this vary with your work schedule?________________________________
____

other stimulants
39. Do you take other stimulants (ephedrine, herbal mixtures, ritalin, amphetamines, cocaine) Yes_____ No_____

40. If yes to 45., please describe type, dosage?, dosage schedule?________________________________
____

41. If yes to 45., how does this vary with your work schedule?________________________________
____

alcohol
42. How often do you drink alcohol?

never_____ every day_____ more than once per week_____ once per week _____ once a month or less_____

43. If not "never" on 42., how much do you drink at one time?

one drink (cocktail, beer, wine)____; two drinks______; three drinks______; more than 3 drinks_____

44. If not "never" on 42., how does this vary with your work schedule?________________________________
____

45. Have any of the following applied to you at any point in your life: You repeatedly drank too much? Alcohol caused problems for you? Someone objected to your drinking? You had periods where you "blacked out" or lost consciousness after drinking? You have gotten in trouble because of your drinking? Yes_____ No_____

46. Do any of the above (45.) currently apply to you? Yes_____ No_____

other substances
47. Have you ever used any recreational drugs such as marijuana, LSD, cocaine, etc? Yes_____ No_____

48. Do you currently use such drugs? Yes_____ No_____,

49. If yes to 47, which one(s)____

50. If yes to 47, how often do you use such drugs?

every day_____ more than once per week_____ once per week _____ once a month or less_____

51. If yes to 47., how does this vary with your work schedule?________________________________
____

52. Have any of the following applied to you at any point in your life: You repeatedly used such substances? Such substances caused problems for you? Someone objected to your use of such substances? You have gotten in trouble because of your use of such substances? Yes_____ No_____

53. Do any of the above (52.) currently apply to you? Yes_____ No_____

nicotine
54. Do you smoke cigarettes, cigars, pipe or chew or snuff tobacco? Yes_____ No_____

55. If yes to 54, which one(s) and how much per day____

56. If yes to 54, Do you adjust intake to help you sleep? Yes_____ No_____; to stay awake? Yes_____ No_____

PRIMARY SLEEP DISORDERS

57. Have you ever been diagnosed with any sleep disorders such as Narcolepsy, Sleep Apnea, Periodic Limb Movement, Sleepwalking, Restless Leg Syndrome, Nightmares, Night Terrors? Yes_____ No_____
If yes, please describe____

Psychophysiological Insomnia

58. Do you worry about getting enough sleep? Yes_____ No_____

59. If yes, how much does worrying about getting enough sleep bother you?

a lot_____ moderately_____ mildly_____ not at all_____

60. How physically or psychologically harmful to you do you consider not getting enough sleep?

a lot_____ moderately_____ mildly_____ not at all_____

Sleep Disordered Breathing

61. What is your height?_______ your weight?________ your collar size?_______

62. Have you ever experienced any of the following during or related to your sleep?

______Snoring that disturbs others

______Choking

______Stopping breathing

______Tightness in chest

______Sputtering/gagging

______Difficulty breathing

______Difficulty concentrating

______Irresistible urge to sleep during day

______Gasping

______Morning Headaches

______Congested nose or allergy at night

______Waking with coughing fits

______Throat dry when wake up

______Forgetfulness

63. Has a bed partner ever complained or expressed concern about your snoring or breathing patterns during sleep? Yes_____ No_____; If yes, please describe:____
____

64. Have you ever had or been advised to have oral, nasal or throat surgery? Yes_____ No_____; If yes, please describe:____
____

Narcolepsy

65. Have you ever had weakness in your legs or felt your muscles go limp when excited, frightened, or surprised? Yes_____ No_____; If yes, please describe including how often this occurs:______________________
____

66. Have you ever woken up and found yourself unable to move? Yes_____ No_____; If yes, please describe including how often this occurs: ____
____

67. Have you ever had hallucinations when going to sleep or upon waking up? Yes_____ No_____; If yes, please describe including how often this occurs: ____

____

Parasomnias

68. Do you have frequent nightmares or disturbing dreams? Yes_____ No_____; If yes, please describe including how often this occurs: ____

____

69. Have you or your bed partner ever found yourself acting parts or all of your dreams? Yes_____ No_____; If yes, please describe including how often this occurs: ____

____

70. Do you grind your teeth in your sleep or sleeptalk? Yes_____ No_____; If yes, please describe including how often this occurs:____

____

Periodic Limb Movement and Restless Leg Syndrome

71. Have you ever awoken yourself by a kicking or twitching of your legs at a time other than right when falling asleep? Yes_____ No_____; If yes, please describe including how often this occurs: ______________________

____

72. Has your bed partner or anyone else reported that your legs kick or twitch during sleep? Yes_____ No_____; If yes, please describe including how often this occurs: ____

____

73. Are you ever bothered by a crawling or burning sensation in your legs while trying to go to sleep or during the night? Yes_____ No_____; If yes, please describe including how often this occurs and how you deal with it:

____

____

SLEEP DISORDERS RELATED TO OTHER MEDICAL CONDITIONS

74. Do you have arthritis, back pain, or any other pain that keeps you awake? Yes_____ No_____; If yes, please describe including how often this occurs: ____

____

75. Have you ever been diagnosed with chronic fatigue syndrome or fibromyalgia: Yes_____ No_____; If yes, please describe:____

76. Have you ever had any of the following: seizures; high blood pressure; liver problems; kidney problems; thyroid problems; stroke; heart attack; congestive heart failure; or heart arrhythmias (such as slow or fast heart rate or arterial fibrillation)? Yes_____ No_____; If yes, please describe:____

____

77. Have you ever had a serious head injury, brain surgery, stroke or lost consciousness after sustaining a head injury? Yes_____ No_____; If yes, please describe:____

____

SLEEP DISORDERS RELATED TO PSYCHIATRIC DISORDERS

78. Have you ever seen a psychologist, psychiatrist, or mental health counselor? Yes_____ No_____

79. If yes, what did you see him or her for?____

80. Have you ever been diagnosed with any psychiatric disorders such as depression or anxiety disorders? If yes, please describe: ____

____

81. Have you ever taken any of the following medications: Prozac, Paxil, Zoloft, Luvox, or any other psychiatric medications? Yes_____ No_____

82. If yes, what were you taking and what did you take these medications for?______________________________
____

Depression:
83. How has your mood been lately? ____

84. Do you ever feel sad or down? Yes_____ No_____; If yes, please describe:____________________________
____

85. If yes, how often do you feel this way? ____

86. How has your energy level been recently? ____

87. How has your appetite been recently? ____

88. Is this different from your usual energy level or appetite? Yes_____ No_____; If yes, please describe:________
____

89. Have you lost or gained weight recently? Yes_____ No_____; If yes, please describe:____________________
____

90. Have you had any difficulty concentrating or thinking clearly lately? Yes_____ No_____; If yes, please describe:____

Mania/hypomania:
91. Have you ever felt so good or "on top of the world" that other people thought that you were not your normal self? Yes_____ No_____; If yes, please describe:____
____

92. Has there ever been an extended period of time when you felt so irritable that you couldn't help shouting at people or getting arguments? Yes_____ No_____; If yes, please describe:_________________________________
____

93. Have you ever felt that you were especially important in some way or that you have powers to do things others can't do? Yes_____ No_____; If yes, please describe:____
____

94. Do you ever feel as though your thoughts are racing? Yes_____ No_____; If yes, please describe:________
____

95. Do you ever find that you need less sleep than usual or that you have an unusual amount of energy? Yes_____ No_____; If yes, please describe:____
____

96. Have there ever been times when you did something you wouldn't usually do or something that could cause problems for you or your family such as spending an excessive amount of money or being more sexually active than is normal for you? Yes_____ No_____; If yes, please describe:_____________________________________
____

Anxiety Disorders:
97. Do you ever feel tense, nervous or unable to relax? Yes_____ No_____; If yes, please describe:__________
____

98. How often do you feel this way?
all the time_____ frequently_____ sometimes_____ infrequently

99. When you are feeling worried, are you able to turn your attention away from the worrisome thoughts to other, more pleasant thoughts? Yes_____ No_____; If yes, please describe:___________________________________
____

100. Have you ever had a panic attack when you suddenly felt frightened, anxious or extremely uncomfortable? Yes_____ No_____; If yes, please describe:____
____

101. If yes, to 110. did you feel dizzy or shaky, did your heart start racing or pounding, did you have trouble breathing, or did you feel as though you were choking? Yes_____ No_____; If yes, please describe:__________
____

102. Have you ever been bothered by thoughts that didn't make any sense but kept coming back to you even when you tried not to have them, for example thoughts that something awful was going to happen or thoughts that you were being contaminated by germs? Yes_____ No_____; If yes, please describe:__________________________
____

103. Has there ever been anything that you had to do over and over again and couldn't resist doing like washing your hands a lot or checking something several times to make sure you've done it right? Yes_____ No_____; If yes, please describe:____
____

Psychosocial Stressors:
104. Are there any current circumstances in your life that are making you feel particularly depressed, anxious or upset and causing symptoms such as excessive worry or poor sleep? Yes_____ No_____; If yes, please describe:
____
____

APPENDIX I: SENSORS AND INSTRUMENTS TO MEASURE LISTED VARIABLES

Variable	**Measured by-**	**Specifications**
Brake status* (On/Off)	Network	
Throttle position*	Network	
Turn signal status*	VTTI installed sensor	
Device activation via RF sensor	RF Sensor – *Alpha Lab Scientific Instruments* "Micro Alert"	
Incident push-button	VTTI development	
Wheel slip (traction)* (For those models where available)	Network	
Traction control activation* (For those models where available)	Network	
Cruise control status* (For those models where available)	Network	
Cruise control set speed* (For those models where available)	Network	
ABS status* (For those models where available)	Network	
Airbag deployment*	Network	
Video: Camera views		
Forward view	Camera NTSC, CCD black and white	0.05 Lux sensitivity, 420 TV lines resolution
Driver's face/left side of vehicle	Camera NTSC, CCD black and white	0.05 Lux sensitivity, 420 TV lines resolution
Driver-over right shoulder, head, arms, & feet	Camera NTSC, CCD black and white	0.05 Lux sensitivity, 420 TV lines resolution
Rear –view and back right corner from back window/trunk of vehicle	Camera NTSC, CCD black and white	0.05 Lux sensitivity, 420 TV lines resolution
Audio	*Electic* microphone- short period recording	Driver activated with incident push-button
Vehicle Latitude/longitude/elevation/heading	GPS - *Trimble* Lassen Model SK-11	
Velocity*	Network	
ABS (On/Off)*	Network	
Traction control (On/Off)* (For those models where available)	Network	
Lateral Acceleration	Accelerometer - *Analog Devices ADXL202*	±2 g range, rated for 1,000 g shock load
Longitudinal Acceleration	Accelerometer - *Analog Devices ADXL202*	±2 g range, rated for 1,000 g shock load
Forward-facing range & range-rate	Eaton Vorad EVT-300	
Rear-facing range and range-rate	Eaton Vorad EVT-300	
Yaw rate	*Systron Donner*-Rate Gyro AQRS-0075-1009	Rated for 75°/sec & temp dev < 7°/sec
Normalized Lane Position	Video machine vision	Detect vehicle position in lane
Lane Deviation (yes/no)	In-house software	Detect lane crossing

APPENDIX J: INFORMED CONSENT FOR DRIVERS OF PRIVATE VEHICLES

INFORMED CONSENT FOR PARTICIPANTS IN RESEARCH PROJECTS INVOLVING HUMAN SUBJECTS

Title of Project:	Naturalistic Driving Study
Research Conducted by:	Virginia Tech Transportation Institute (VTTI)
Research Sponsored by:	National Highway Traffic Safety Administration (NHTSA)
Investigators:	Dr. Tom Dingus, Dr. Vicki Neale, Ms. Sheila Klauer, Dr. Ron Knipling, Ms. Heather Foster

I. PURPOSE OF THIS RESEARCH PROJECT

The objective of this study is to instrument drivers' personal vehicles to collect data on driving behavior. There are no special tasks for the driver to perform; instead, the driver is requested to merely drive as they regularly would to their normal destinations. This instrumentation is designed such that it will in no way interfere with the driving performance of the vehicle and will not obstruct the driver in any way. Due to the number of vehicles that are being instrumented and the time period involved, it is likely that crashes and the events leading up to them will be recorded.

One hundred high-mileage drivers are being recruited to participate in this research. All age groups and both men and women are being asked to participate. To participate, drivers must have a valid drivers' license and own a vehicle of which they are the primary driver for the experimental period of one year.

II. Procedures and subject responsibilities

The following describes procedures for the study and participant responsibilities:

<u>Preparation for study</u>:

1. Review entire study information package
2. Read this informed consent form carefully; make a note of any questions. You may call Ms. Heather Foster of VTTI (703-538-8447) to discuss any questions.
3. Sign and date this form.
4. Ensure that any person likely to drive the instrumented vehicle has signed this informed consent form. (If you wish to add another driver at a later time, an informed consent form can be obtained from VTTI.)
5. Provide close-up pictures (head-shots) of all consenting drivers.

<u>In-processing (requires two hours):</u>

6. Call Ms. Heather Foster of VTTI at 703-538-8447 to schedule an appointment for in-processing.
   In-processing will ordinarily be scheduled for 8-10am or 4-6pm on weekdays, and 9-11 am on Saturdays, at the VT Northern Virginia Center, 7054 Haycock Road, Falls Church, VA 22043. (Parking is available in the Visitors Parking Lot)
7. Bring the following to the subject in-processing:
   - Signed informed consent form (this document)
   - Valid driver's license
   - Proof of insurance for your vehicle
   - Vehicle registration
   - Social Security Number
   - Two forms of identification
8. Listen to a short overview orientation to the study, and "Q&A" discussion. Sign remaining administrative forms; a copy of all signed forms will be provided to you for your records.

9. Take a vision exam.
10. Take a hearing exam. (Note: a free hearing exam is available for all prospective drivers, family members, and other frequent passengers, provided they agree to the re-testing in the event of a crash.)
11. Complete surveys regarding your health, sleep hygiene, stress levels, overall personality, and driving behaviors and practices.
12. Take one or more brief performance tests.
13. Schedule your vehicle for equipment installation. (see below)

Equipment installation:

14. Bring your vehicle to Hurley's Auto Audio (1524 Springhill Road, McLean, VA 22102, Phone 703-790-8744) for equipment installation this will require a full day. We will provide $10 to cover Metro fare or other transportation needs.

Data collection during driving:

15. Wear your seatbelt at all times.
16. Drive your vehicle as you normally would.
17. Do not wear sunglasses unless absolutely necessary
18. In the event of a safety-related incident, [i.e. a crash, near-crash, driving error, or unsafe condition involving your vehicle or adjacent vehicles], press the red incident button located above the rear-view mirror after the incident as soon as it is safe to do so. For one minute, a microphone (directed toward the driver) will be activated; during this time, please briefly describe what happened, and why. In particular, what was the driving error that caused the incident?

Data downloading:

Note: the location of your vehicle will be known to VTTI researchers via a radio transmitter providing Global Positioning System (GPS) coordinates. This information will be used to locate vehicles for data downloading.

19. Permit VTTI researchers to access your vehicle (at your home or work location) every 1-4 weeks to download data. Most data downloads will require a data line to be plugged into a data port near the vehicle license plate on the outside of the vehicle. (No access to the inside of the vehicle is required.) Subject to your approval, data downloads will be completed between 7am and 11pm.

Equipment maintenance:

20. In the event of equipment malfunctioning or damage, notify VTTI as soon as possible.
21. Permit a service call at your home or office for repairs (if preferred, vehicle may be brought to Hurley's). If repairs cannot be made in a service call, bring the vehicle in to Hurley's for repairs. We will provide $10 to cover Metro fare or other transportation needs.

In the event of a crash (applies to all collisions, regardless of severity):

22. Contact VTTI as soon as possible after the crash. (Accident reporting instructions and phone numbers will be placed in glove box during equipment installation.)
23. Participate in a short phone interview with VTTI about the crash.
24. Schedule an appointment for hearing re-testing, to be conducted **as soon as possible** after the crash. Re-testing is conducted at Professional Hearing Services (6231 Leesburg Pike Suite 512 Falls Church, VA 22044 Phone 703-536-1666). Re-testing results will be provided to you and to VTTI.
25. Encourage all passengers whose hearing has been tested to schedule this re-testing.
26. If the crash is police-reported, request a copy of the Police Accident Report from the police, and provide a copy to VTTI. VTTI will remove all personal identifiers to ensure confidentiality. "Personal identifiers" include names, addresses, phone numbers, and license plate numbers.
27. Request and provide copies of medical report(s) associated with your crash injuries and treatment. For some crashes, crash and injury information may already be available to NHTSA, and thus to this study, in conjunction with other NHTSA-sponsored studies in the Northern Virginia area.
28. Permit VTTI and/or Hurley's to check and test the vehicle instrumentation.

In the event of an airbag deployment:

29. Permit a Special Crash Investigation team from NHTSA to inspect the vehicle.
30. Participate in an in-person interview with the Crash Investigation team.

Equipment de-installation:
VTTI will contact you at the end of the 12-month study, to schedule equipment de-installation and out-processing.

31. Bring your vehicle to Hurley's Auto Audio for equipment de-installation, which will require a full day. We will provide $10 to cover Metro fare or other transportation needs.
32. Inspect your vehicle at Hurley's and sign form to verify that all recording equipment has been removed, and that the vehicle has been restored to its original state. Keep copy for your records.

Out-processing/study completion (requires one hour):

33. Complete out-processing administrative paperwork.
34. Complete short questionnaires regarding stress levels and driving behavior and performance over the past year, and study evaluation.
35. Receive final payment for your participation.

Equipment Installation and Data Collection

You are being asked to drive with the instrumentation for approximately one year. No holes will be drilled into your vehicle to mount equipment. Instead, holes holding existing apparatus will be used. The data collection system is approximately 8" x 18" x 24." The computer/data storage system is housed in the back of the trunk and mounted to the trunk "roof" (not to the trunk lid). A camera module will be mounted above the rear-view mirror and an incident push-button will be located on the camera module. This will be done without drilling holes or making any permanent modifications to the vehicle. Wires will not be visible.

As part of the data collection system, forward- and rearward-looking radar will be installed behind the front and rear license plates. For the radar to function, we will need to replace you state license plate with plastic plates for the duration of the study. You will be provided with a temporary registration and an authorization letter from the state DMV for your records. At the end of the study your original license plates will be reinstalled on the vehicle.

The data on the vehicle will be downloaded via a data port located behind the rear license plate. Once the data is downloaded, it will be stored on a project specific data server that will be accessed only by research staff affiliated with the project.

The data collection system is designed to require no maintenance and will not require you to perform any maintenance. However, if a diagnostic check of the data confirms a disruption of the data collection, a technician will be assigned to correct the problem. To perform the maintenance, VTTI or Hurley's will contact you to receive permission to work on the vehicle and schedule the repair. We will try to avoid interfering with your commuting schedule.

Insurance

Please note that since you are driving your own vehicle, Virginia Tech is not liable for the expenses incurred in any accident you may have. In the event of an accident, you are not responsible for coverage of the instrumentation in the vehicle.

Participants in a study are considered volunteers, regardless of whether they receive payment for their participation. Under Commonwealth of Virginia law, workers compensation does not apply to volunteers; therefore, the participants are responsible for their own medical insurance for bodily injury. Appropriate health insurance is strongly recommended to cover these types of expenses.

If you should become injured in an accident, whether in or out of an automobile, the medical treatment available to you would be that provided to any person by emergency medical services in the vicinity where the accident occurs.

Automatic Collision Notification

The vehicle will also be equipped with an automatic collision notification system, triggered by collision impacts. The system is intended to notify VTTI in the event of a collision impact. When serious impacts are detected by

VTTI staff, they will notify local emergency services. *However, VTTI cannot guarantee continuous 24-hour coverage or coverage of all vehicle locations.* Therefore, in the event of a crash, you should not expect an emergency response based on this system. *Notify police and emergency services as you otherwise would following a crash.* However, this automatic collision notification system *may* enable emergency service to be dispatched to you faster after a crash.

III. RISKS

The risk to you is no more than you would normally incur while driving. All data collection equipment is mounted such that, to the greatest extent possible, it does not pose a hazard in any foreseeable way. None of the data collection equipment will interfere with any part of your normal field of view. The addition of the data collection systems to the vehicle will in no way affect the operating or handling characteristics of the vehicle.

Please note that you are being asked not to wear sunglasses unless absolutely necessary; however, if at any time you are suffering from glare problems (e.g., from the sun shining directly into your face) and cannot see the roadway and your surrounding environment, sunglasses are recommended.

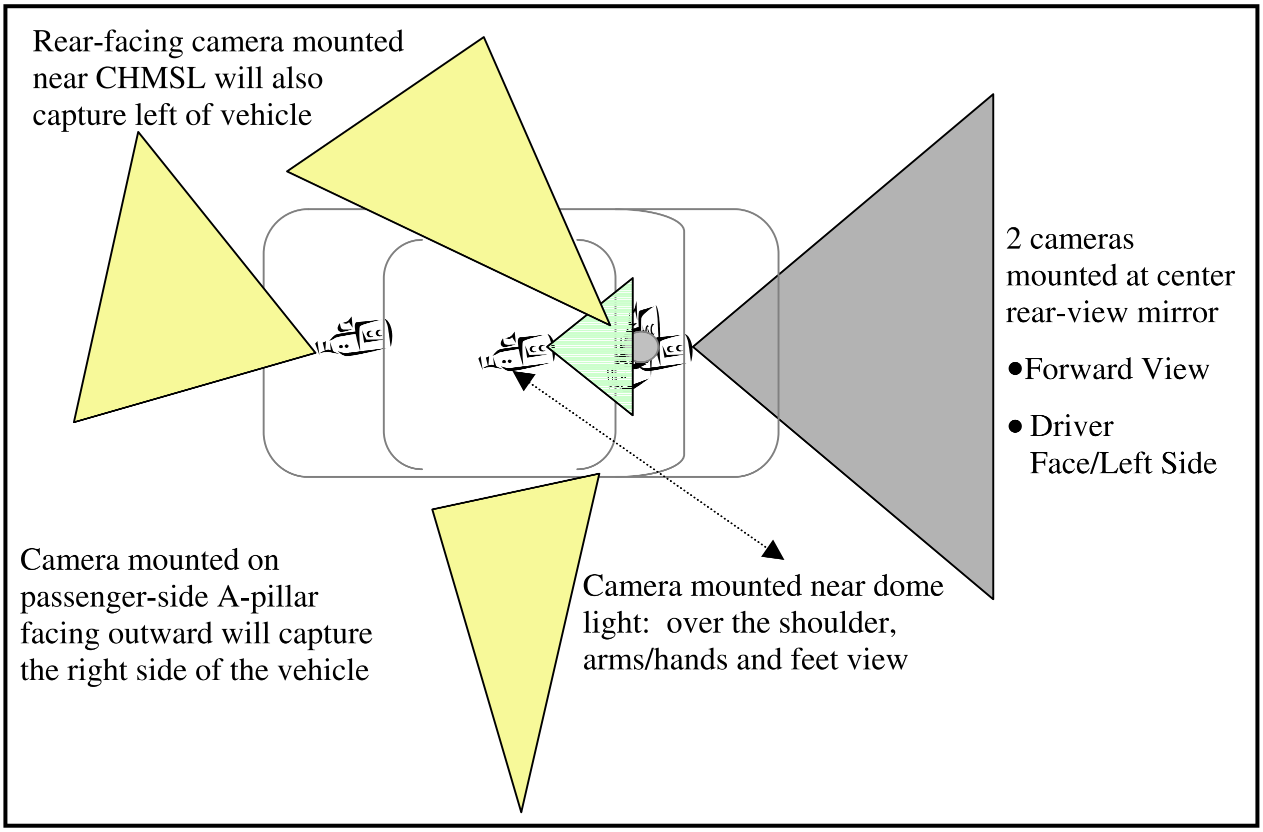
IV. BENEFITS

While there are no direct benefits to you from this research, you may find the experiment interesting. No promise or guarantee of benefits is being made to encourage participation. Your participation will help to improve the body of knowledge regarding driving behavior and performance.

V. EXTENT OF ANONYMITY AND CONFIDENTIALITY

Video information will be taken during the course of data collection. The data gathered in this experiment will be treated with confidentiality. Drivers' names will be separated from the collected data. A coding scheme will be employed to identify the data by subject number only (e.g., Driver No. 3).

While you are driving the vehicle, a camera will record your face and the left exterior side of vehicle, the right exterior side of the vehicle, the forward view, the rear-view, and the instrument panel view. This is shown below. Note that no other passengers in the vehicle will be within the camera view. Also, there is audio recording capability in the vehicle, but it will only record for one minute when you activate the incident push button. Please note that the audio microphone is directional and will only record your voice from the driver's seat.



The data from this study will be stored in a secured area at the Virginia Tech Transportation Institute. Access to the data will be under the supervision of Dr. Tom Dingus, Dr. Vicki Neale, Ms. Sheila Klauer, Dr. Ron Knipling, and Ms. Heather Foster. Data reductionists assigned to work on this project will also have access to your data. Data reduction will consist of examining driving performance under various conditions. In addition, the project sponsor may request portions of the data for research use if you give permission in Section X of this informed consent form. The video will not be released to anyone other than individuals working on the project without your written consent.

If you are involved in a crash while participating in this study, the data collection equipment in your vehicle will likely capture the events leading up to the event. The data collection equipment SHOULD NOT be given to police officers or any other party. You are under NO LEGAL OBLIGATION to mention that you are participating in this study.

We will do everything we can to keep others from learning about your participation in the research. To further help us protect your privacy, the investigators have obtained a Confidentiality Certificate from the Department of Health and Human Services. With this Certificate, the investigators cannot be forced (for example by court subpoena) to disclose information that may identify you in any federal, state, or local civil, criminal, administrative, legislative, or other proceedings. Disclosure will be necessary, however, upon request of DHHS for audit or program evaluation purposes.

You should understand that a Confidentiality Certificate does not prevent you or a member of your family from voluntarily releasing information about yourself or your involvement in this research. Note however, that if an insurer, employer, or someone else learns about your participation, and obtains your consent to receive research information, then the investigator may not use the Certificate of Confidentiality to withhold this information. This means that you and your family must also actively protect your own privacy. In addition to the Confidentiality Certificate, we have also obtained approval through the NHTSA Human Use Review Panel for your protection.

Finally, you should understand that the investigator is not prevented from taking steps, including disclosing information to authorities, to prevent serious harm to yourself or others. For example, if we learned about offenses such as child abuse or habitual driving under the influence, we would take appropriate action to protect you and someone else, even though we will still maintain privacy of the data.

VI. Compensation

You will be compensated $125.00 per month for approximately 12 months of participation in this study. If you choose to withdraw from participation prior to the 12-month period, you will be compensated for the proportion of time that you have participated. You will also receive a $300 study completion bonus at the end of the 12-month period and equipment de-installation. This bonus will be provided at the out-processing.

In addition to this compensation, you will be given $10 for travel on the days that instrumentation is installed and removed.

VII. Freedom to Withdraw

You are free to withdraw from the study at any time without penalty. If you choose to withdraw, you will be compensated for the portion of the time of the study.

VTTI has the right to terminate your participation in the study at any time. For example, VTTI may withdraw you from the study if the quantity or quality of data is insufficient for study purposes or if you pose a threat to yourself or to others. Subjects withdrawn from the study will receive pro-rated payment (at $125 per month) and will be required to schedule equipment de-installation as soon as possible.

VIII. Approval of Research

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

_____________________________ IRB Approval Date

_____________________________ Approval Expiration Date

IX. Driver's Responsibilities

I voluntarily agree to participate in this study. I understand the procedures and responsibilities described above, in particular in **Section II, Procedures and Subject Responsibilities.**

X. Driver's Permission

Check one of the following:

- ☐ VTTI **has my permission** to give the videotape including my image to the National Highway Traffic Safety Administration. I understand that the client will only use the videotape for research purposes.
- ☐ VTTI **does not have my permission** to give the videotape including my image to the National Highway Traffic Safety Administration. I understand that VTTI will maintain possession of the videotape, and that it will only be used for research purposes.

I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

Signature of Driver: _______________________________________ Date:_____________

Signature of Additional Driver:

____ Date: _____________

Signature of Legal Guardian if any additional driver is minors:

____ Date: _____________

Signature of Additional Driver:

____ Date: _____________

Signature of Legal Guardian if any additional driver is minors:

____ Date: _____________

Signature of Additional Driver:

____ Date: _____________

Signature of Legal Guardian if any additional driver is minors:

____ Date: _____________

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

Ms. Heather Foster (703) 538-8447/hfoster@vtti.vt.edu
Research Specialist/Northern Virginia Center, Virginia Tech Transportation Institute

Dr. Ronald R. Knipling (703) 538-8439/rknipling@vtti.vt.edu
Northern Virginia Site Manager/Falls Church, Virginia Tech Transportation Institute

Dr. Vicki L. Neale (540) 231-1514/vneale@vtti.vt.edu
Co- Principal Investigator, Virginia Tech Transportation Institute

Dr. David M. Moore (540) 231-4991/moored@vt.edu
Chair, IRB
Office of Research Compliance
Research & Graduate Studies

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

APPENDIX K: INFORMED CONSENT FOR DRIVERS OF LEASED VEHICLES

INFORMED CONSENT FOR PARTICIPANTS IN RESEARCH PROJECTS INVOLVING HUMAN SUBJECTS

Title of Project:	Naturalistic Driving Study
Research Conducted by:	Virginia Tech Transportation Institute (VTT)
Research Sponsored by:	National Highway Traffic Safety Administration (NHTSA)
Investigators:	Dr. Tom Dingus, Dr. Vicki Neale, Ms. Sheila Klauer, Dr. Ron Knipling, Ms. Heather Foster

I. PURPOSE OF THIS RESEARCH PROJECT

The objective of this study is to collect data on driving behavior. There are no special tasks for the driver to perform; instead, the driver is requested to merely drive as they regularly would to their normal destinations. This instrumentation is designed such that it will in no way interfere with the driving performance of the vehicle and will not obstruct the driver in any way. Due to the number of vehicles that are being instrumented and the time period involved, it is likely that crashes and the events leading up to them will be recorded.

One hundred high-mileage drivers are being recruited to participate in this research. All age groups and both men and women are being asked to participate. To participate, drivers must have a valid drivers' license and own a vehicle of which they are the primary driver for the experimental period of one year.

II. Procedures and Subject responsibilities

The following describes procedures for the study and participant responsibilities:

Preparation for study:

1. Review entire study information package.
2. Read this informed consent form carefully; make a note of any questions. You may call Ms. Heather Foster of VTTI (703-538-8447) to discuss any questions.
3. Sign and date this form.
4. Ensure that any person likely to drive the instrumented vehicle has signed this consent form. (If you wish to add another driver at a later time, an informed consent form cal be obtained from VTTI.)
5. Provide close-up pictures (head-shots) of all consenting drivers.

In-processing (requires two hours):

6. Call Ms. Heather Foster of VTTI at 703-538-8447 to schedule an appointment for in-processing. In-processing will ordinarily be scheduled for 8-10am or 4-6pm on selected weekdays, and 9-11 am on Saturdays, at the VT Northern Virginia Center, 7054 Haycock Road, Falls Church, VA 22043. (Parking is available in the Visitors Parking Lot.)
7. Bring the following to the subject in-processing:
   - Signed informed consent form (this document)
   - Valid driver's license
   - Social Security Number
   - Two forms of identification
8. Listen to a short overview orientation to the study, and "Q&A" discussion. Sign remaining administrative forms; a copy of all signed forms will be provided to you for your records.
9. Review insurance protocol for the leased vehicle.
10. Take a vision exam.
11. Take a hearing exam. (Note: a free hearing exam is available for all prospective drivers, family members, and other frequent passengers, provided they agree to the re-testing in the event of an airbag deployment.)
12. Complete surveys regarding your health, sleep hygiene, stress levels, overall personality, and driving

behaviors and practices.

13. Take one or more brief performance tests.
14. Schedule VTTI delivery of the leased vehicle to your home or workplace.

Data collection during driving:

15. Wear your seatbelt at all times.
16. Drive your vehicle as you normally would.
17. Do not wear sunglasses unless absolutely necessary.
18. In the event of a safety-related incident, [i.e. a crash, near-crash, driving error, or unsafe condition involving you vehicle or adjacent vehicles], press the red incident button located above the rear-view mirror after the incident as soon as it is safe to do so. For one minute, a microphone (directed toward the driver) will be activated; during this time, please briefly describe what happened, and why. In particular, what was the driving error that caused the incident?

Data downloading:

Note: the location of your vehicle will be known to VTTI researchers via a radio transmitter providing Global Positioning System (GPS) coordinates. This information will be used to locate vehicles for data downloading.

19. Permit VTTI researchers to access the vehicle (at your home or work location) every 1-4 weeks to download data. Most data downloads will require a data line to be plugged into a data port near the vehicle's rear license plate on the outside of the vehicle. (No access to the inside of the vehicle is required.) Subject to your approval, data downloads will be completed between 7am and 11pm.

Equipment and vehicle maintenance:

20. In the event of equipment malfunction or damage, notify VTTI as soon as possible.
21. Permit a service call at your home or office for repairs (if preferred, vehicle may be brought to Hurley's). If repairs cannot be made in a service call, bring the vehicle to Hurley's for repairs. VTTI will provide $10 to cover Metro fare or other transportation needs.
22. Buy regular, unleaded gasoline for the vehicle. Perform regular safety checks; e.g., once monthly, check tire pressure, oil level, and other fluids. Have oil changes and other preventive maintenance performed per a schedule and instructions provided to you by VTTI.

In the event of a crash: Study Procedures (applies to all collisions, regardless of severity);

23. Contact VTTI as soon as possible after the crash. (Accident reporting instructions and phone numbers will be left in the glove box of the leased vehicle.)
24. Participate in a short phone interview with VTTI about the crash. In addition, since you are driving a vehicle owned by the State of Virginia, there are two reporting requirements following accidents, one for this study and one for the state (Virginia Tech Motor Pool), which will be explained to you during in-processing.
25. Schedule an appointment for hearing re-testing, to be conducted **as soon as possible** after the crash. Re-testing is conducted at Professional Hearing Services (6231Leesburg Pike Suite 512 Falls Church, VA 22044 Phone 703-536-1666). Re-testing results will be provided to you and to VTTI.
26. Encourage all passengers whose hearing has been tested to schedule this re-testing.
27. If the crash is police reported, request a copy of the Police Accident Report from the police, and provide a copy to VTTI. VTTI will remove all personal identifiers to ensure confidentiality. "Personal identifiers" include names, addresses, phone numbers, and license plate numbers.
28. Request and provide copies of medical report(s) associated with your crash injuries and treatment. For some crashes, crash and injury information may already be available to NHTSA, and thus to this study, in conjunction with other NHTSA-sponsored studies in the Northern Virginia area.
29. Permit VTTI and/or Hurley's to check and test the vehicle instrumentation.

In the event of a crash: Virginia Tech Motor Pool Procedures

30. Follow the instructions in the glove compartment.
31. Contact VTTI as soon as possible, we will assist you in filing the Virginia Tech Motor Pool accident report.

In the event of an airbag deployment:

32. Permit a Special Crash Investigation team from NHTSA to inspect the vehicle.

33. Participate in an in-person interview with the Crash Investigation team.

Vehicle Return:

VTTI will contact you at the end of the 12-month study, to schedule out-processing and return of the leased vehicle.

34. Bring your leased vehicle to the VT North Virginia Center to return. VTTI will provide $10 to cover Metro fare or other transportation.

Out-processing/study completion (requires one hour):

35. Complete out-processing administrative paperwork.
36. Complete short questionnaires regarding stress levels, driving behavior and performance over the past year, and study evaluation.

Equipment Installation and Data Collection

You are being asked to drive with the instrumentation for approximately one year. The data on the vehicle will be downloaded via a data port located behind the rear license plate. Once the data is downloaded, it will be stored on a project specific data server that will be accessed only by research staff affiliated with the project.

The data collection system is designed to require no maintenance and will not require you to perform any maintenance. However, if a diagnostic check of the data confirms a disruption of the data collection, a hardware engineer will be assigned to correct the problem. To perform the maintenance, VTTI or Hurley's will contact you to receive permission to work on the vehicle and schedule the repair. We will try to avoid interfering with your commuting schedule.

Automobile Insurance

In the Commonwealth of Virginia, responsibility for automobile insurance resides with the owner of the vehicle. In the event of an accident or injury in a Virginia Tech automobile, the University will provide automobile liability coverage for property damage and personal injury. The total policy amount per occurrence is $2,000,000. This coverage (unless the other party was at fault, which would mean all expense would go to the insurer of the other party's vehicle) would apply in case of an accident for all volunteers and would cover medical expenses up to the policy limit. In the event of an accident, you must notify the police and the VT Motor Pool (contact information will be left in the glove compartment of the leased vehicle).

VT also carries as a part of its automobile liability insurance a "Med Pay" endorsement that will pay up to $5,000 in medical expenses, until fault in an accident is determined, at which time all medical expenses would go to the insurer of the vehicle at fault.

If you are working as an employee for another company, you may be deemed to be driving in the course of your employment, and your employer's worker's compensation provisions may apply in lieu of the Virginia Tech and Commonwealth of Virginia insurance provisions, in case of an accident. The particular circumstances under which worker's compensation would apply are specified in Virginia law. If worker's compensation provisions do not apply in a particular situation, then Virginia Tech and Commonwealth of Virginia insurance will provide coverage.

Medical Insurance

Participants in a study are considered volunteers, regardless of whether they receive payment for their participation; under Commonwealth of Virginia law, workers compensation does not apply to volunteers; therefore, if not in an automobile, the participants are responsible for their own medical insurance for bodily injury. Appropriate health insurance is strongly recommended to cover these types of expenses.

If you should become injured in an accident, whether in or out of an automobile, the medical treatment available to you would be that provided to any person by emergency medical services in the vicinity where the accident occurs.

A Virginia Tech automobile accident report form is located in the glove compartment of the vehicle you will be driving and outlines what you should do if you become involved in an accident and are not incapacitated.

Automatic Collision Notification

The vehicle will also be equipped with an automatic collision notification system, triggered by collision impacts. The system is intended to notify VTTI in the event of a collision impact. When serious impacts are detected by VTTI staff, they will notify local emergency services. *However, VTTI cannot guarantee continuous 24-hour coverage or coverage of all vehicle locations.* Therefore, in the event of a crash, you should not expect an emergency response based on this system. *Notify police and emergency services as you otherwise would following a crash.* However, this automatic collision notification system *may* enable emergency service to be dispatched to you faster after a crash.

III. RISKS

The risk to you is no more than you would normally incur while driving. All data collection equipment is mounted such that, to the greatest extent possible, it does not pose a hazard in any foreseeable way. None of the data collection equipment will interfere with any part of your normal field of view. The addition of the data collection systems to the vehicle will in no way affect the operating or handling characteristics of the vehicle.

Please note that you are being asked not to wear sunglasses unless absolutely necessary; however, if at any time you are suffering from glare problems (e.g., from the sun shining directly into your face) and cannot see the roadway and your surrounding environment, sunglasses are recommended.

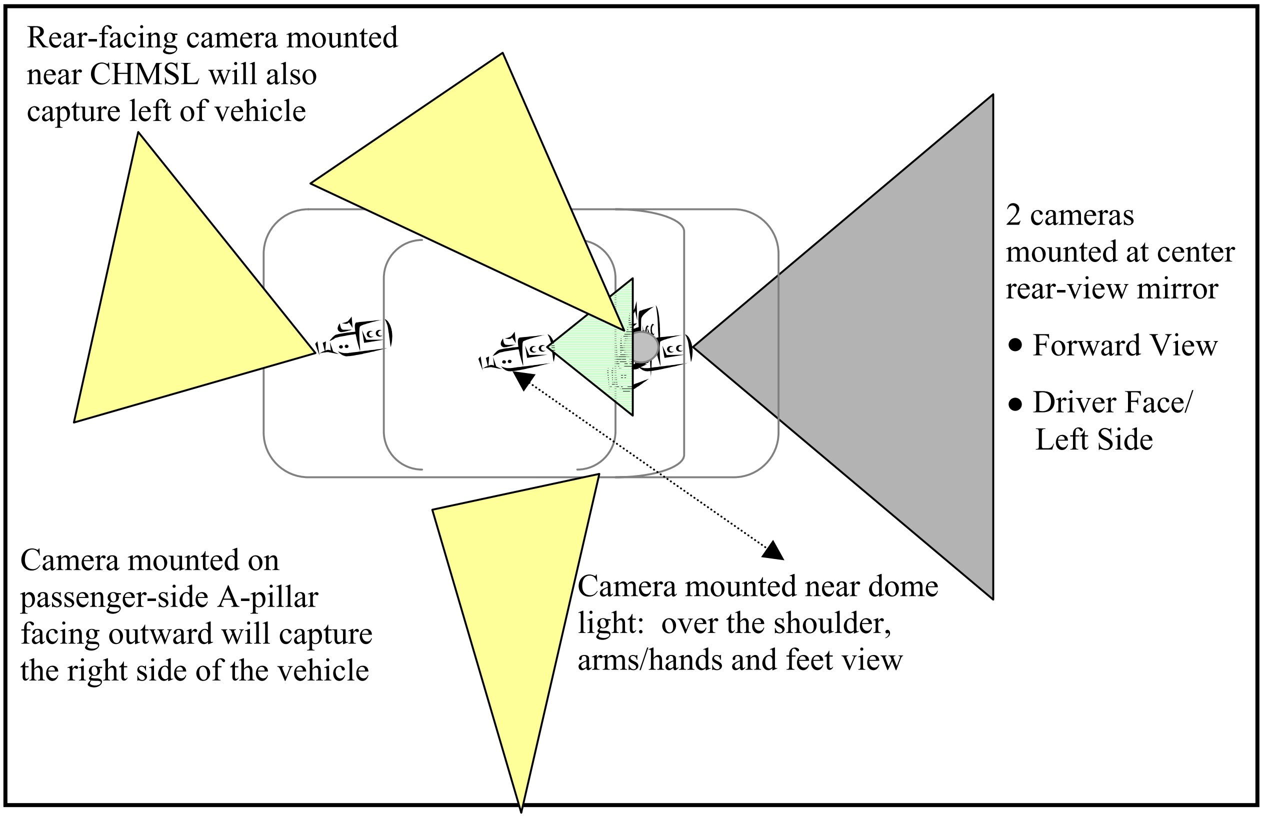
IV. BENEFITS

While there are no direct benefits to you from this research, you may find the experiment interesting. No promise or guarantee of benefits is being made to encourage participation. Your participation will help to improve the body of knowledge regarding driving behavior and performance.

V. EXTENT OF ANONYMITY AND CONFIDENTIALITY

Video information will be taken during the course of data collection. The data gathered in this experiment will be treated with confidentiality. Driver names will be separated from the collected data. A coding scheme will be employed to identify the data by subject number only (e.g., Driver No. 3).

While you are driving the vehicle, a camera will record your face and the left exterior side of vehicle, the right exterior side of the vehicle, the forward view, the rear-view, and the instrument panel view. This is shown below. Note that no other passengers in the vehicle will be within the camera view. Also, there is audio recording capability in the vehicle, but it will only record for one minute when you activate the incident push button. Please note that the audio microphone is directional and will only record your voice from the driver's seat.



The data from this study will be stored in a secured area at the Virginia Tech Transportation Institute. Access to the data will be under the supervision of Dr. Tom Dingus, Dr. Vicki Neale, Ms. Sheila Klauer, Dr. Ron Knipling, and Ms. Heather Foster. Data reductionists assigned to work on this project will also have access to your data. Data reduction will consist of examining driving performance under various conditions. In addition, the project sponsor may request portions of the data for research use if you give permission in Section X of this informed consent form. The video will not be released to anyone other than individuals working on the project without your written consent.

If you are involved in a crash while participating in this study, the data collection equipment in the vehicle will likely capture the events leading up to the event. The data collection equipment SHOULD NOT be given to police officers or any other party. You are under NO LEGAL OBLIGATION to mention that you are participating in this study.

We will do everything we can to keep others from learning about your participation in the research. To further help us protect your privacy, the investigators have obtained a Confidentiality Certificate from the Department of Health and Human Services. With this Certificate, the investigators cannot be forced (for example by court subpoena) to disclose information that may identify you in any federal, state, or local civil, criminal, administrative, legislative, or other proceedings. Disclosure will be necessary, however, upon request of DHHS for audit or program evaluation purposes.

You should understand that a Confidentiality Certificate does not prevent you or a member of your family from voluntarily releasing information about yourself or your involvement in this research. Note however, that if an insurer, employer, or someone else learns about your participation, and *obtains your consent* to receive research information, then the investigator may not use the Certificate of Confidentiality to withhold this information. This means that you and your family must also actively protect your own privacy. In addition to the Confidentiality Certificate, we have also obtained approval through the NHTSA Human Use Review Panel for your protection.

Finally, you should understand that the investigator is not prevented from taking steps, including disclosing information to authorities, to prevent serious harm to yourself or others. For example, if we learned about offenses such as child abuse or habitual driving under the influence, we would take appropriate action to protect you and someone else, even though we will still maintain privacy of the data.

VI. Compensation

Your compensation for participating in this study is free use of the vehicle assigned to you during the course of the study. In addition, you will receive liability, collision, and comprehensive insurance on the leased vehicle free of charge, which will be explained to you in detail.

VII. Freedom to Withdraw

You are free to withdraw from the study at any time without penalty. If you choose to withdraw, prior to the approximate 12 month period, you must return the vehicle.

VTTI has the right to terminate your participation in the study at any time. For example, VTTI may withdraw you from the study if the quantity or quality of data is insufficient for study purposes or if you pose a threat to yourself or to others. Subjects withdrawn from the study will be required to return the leased vehicle as soon as possible.

VIII. Approval of Research

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

___________________________ ________________________________

IRB Approval Date Approval Expiration Date

IX. Driver's Responsibilities

I voluntarily agree to participate in this study. I understand the procedures and responsibilities described above, in particular in **Section II, Procedures and Subject Responsibilities.**

X. Driver's Permission

Check one of the following:

- ☐ VTTI **has my permission** to give the videotape including my image to the National Highway Traffic Safety Administration. I understand that the client will only use the videotape for research purposes.

- ☐ VTTI **does not have my permission** to give the videotape including my image to the National Highway Traffic Safety Administration. I understand that VTTI will maintain possession of the videotape, and that it will only be used for research purposes.

I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

Signature of Driver: ____ Date:_____________

Signature of Additional Driver:

____ Date: _____________

Signature of Legal Guardian if any additional driver is minors:

____ Date: _____________

Signature of Additional Driver:

____ Date: _____________

Signature of Legal Guardian if any additional driver is minors:

____ Date: _____________

Signature of Additional Driver:

____ Date: _____________

Signature of Legal Guardian if any additional driver is minors:

____ Date: _____________

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

Ms. Heather Foster (703) 538-8447/hfoster@vtti.vt.edu
Research Specialist/Northern Virginia Center, Virginia Tech Transportation Institute

Dr. Ronald R. Knipling (703) 538-8439/rknipling@vtti.vt.edu
Northern Virginia Site Manager/Falls Church, Virginia Tech Transportation Institute

Dr. Vicki L. Neale (540) 231-1514/vneale@vtti.vt.edu
Co- Principal Investigator, Virginia Tech Transportation Institute

Dr. David M. Moore (540) 231-4991/moored@vt.edu
Chair, IRB
Office of Research Compliance
Research & Graduate Studies

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

DOT HS 809 536
December 2002

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

People Saving People
www.nhtsa.dot.gov