HEAD-UP DISPLAYS AND DISTRACTION POTENTIAL

National Highway Traffic Safety Administration

RFP DTNH22-14-R-00049

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Statement of Work

Volume I – Technical Proposal

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[redacted]

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1 INTRODUCTION

1.1 OBJECTIVES

The Virginia Tech Transportation Institute (VTTI) has assembled a highly capable research team and provides the following proposal in response to the National Highway Traffic Safety Administration's (NHTSA) Request for Proposal (RFP) *DTNH22-14-R-00049: Head-Up Displays and Distraction Potential*. This document contains a proposed Statement of Work (SOW), including (Part I) a technical approach from which each of the contract requirements will be met; (Part II) data quality and analysis techniques, and (Part III) qualifications of the proposed personnel.

As indicated within the RFP, the main objective of the project is to determine whether Head-Up Display (HUD) technology changes the driver's ability to process information on the forward road scene and respond to crash imminent situations. A supporting objective is to identify surrogate measures of distraction similar to eyes-off-road time for drivers using the HUD versus a Head-Down Display (HDD) in different driving situations. The scope of the project is limited to HUD displays to address the following issues:

- Identify the main visual distraction issues involved with using HUD versus HDD Human Machine Interfaces (HMI).
- Identify metric(s) that are sensitive to potential distractions resulting from using a HUD versus a HDD.
- Determine whether a surrogate measure of distraction increases when drivers use candidate HUD systems (i.e., when a driver is viewing the HUD and road with a potential target or road and HUD with a target).
- Identify a method to determine or manipulate the driver's focal distance to near or far displays.
- Identify any unintended consequences associated with HUD systems.
- Describe potential minimum performance specifications for HUD systems and their advantages/disadvantages.

1.2 THE VTTI TEAM

This task order will be performed by VTTI and the Western Transportation Institute (WTI). Dr. Gregory Fitch, a Research Scientist and User Experience Group Leader in the Center for Automated Vehicle Systems at VTTI, will serve as the Principle Investigator and Senior Technical Program Manager. Dr. Fitch is an experienced researcher of driver performance with technology. He is currently supporting NHTSA in investigating the distraction potential of wearable devices with head-mounted displays. He is familiar with how the proposed study's requirements relate to this research. Dr. Nicholas Ward, a Professor of Mechanical and Industrial Engineering at Montana State University and the Director of the Center for Health and Safety Culture (Western Transportation Institute), will serve as a Co-PI through a subcontract to VTTI. Dr. Ward has considerable research experience in the design and evaluation of automotive HUDs as part of his early work within European-based projects (e.g., PROMETHEUS, UNIBRIMMI (Barfield & Dingus, 1998)) with connected vehicle applications. Both VTTI and WTI are well known to NHTSA and have a proven track record of delivering practical findings to NHTSA based on sound human factors research methods. The role that each team member will play is described in this document.

The team has a great deal of experience executing driver distraction studies and has the facilities and personnel in place to support NHTSA. Dr. Fitch was the lead investigator for the NHTSA study titled *The Impact of Hand-held and Hands-free Cell Phone Use on Driving Performance and Safety-Critical Event Risk* (Fitch et al., 2013). This study investigated driver distraction resulting from cell phone use using multiple analyses that investigated an often contentious issue using a fair and balanced approach. Furthermore, the study was performed under an aggressive timeline and produced high quality deliverables to NHTSA. Dr. Fitch is also currently investigating the distraction potential of Google Glass for NHTSA. It is anticipated that the work proposed in this document will leverage the methods and findings from Dr. Fitch's previous and ongoing driver distraction research.

Dr. Ward has a demonstrated research background in driver perception and performance with HUDs. He has also extensively studied driver distraction and driver interaction with intelligent vehicle systems. His expertise and insight will help lay a foundation for a successful project. Dr. Ward played a primary role in authoring a literature review and designing questionnaires for NHTSA's seat belt interlock system task order. He produced quality deliverables on time, which facilitated the request for information collection under the Paper Reduction Act.

The study will be performed at VTTI, where access to the Virginia Smart Road, a controlled-access test track, and neighboring roads will be used to investigate both direct and indirect measures of driver performance with HUDs. Notably, the Virginia Smart Road will be used to present drivers with surprise obstacles that require quick avoidance maneuvers in a safe and controlled manner. These obstacles include a fake muffler being dropped from a lead vehicle at the remote command of an in-vehicle experimenter, as well as the remote control change of an intersection's phase from green to yellow to red. This aspect alone makes the team's approach quite unique. VTTI's past experience with the methods proposed also minimizes technical, budgetary, and scheduling risks to NHTSA.

VTTI conducts projects of all sizes and scope for many sponsors, with approximately 300 active projects at any given time. Having the tools described above readily available allow projects to be executed efficiently while minimizing costs. With almost 400 faculty, staff and students, VTTI has the resources to devote to complete this project on time.

In summary, the team is ready to fulfill the objectives of this project through the delivery of quality and timely research products. We find this topic to be both of great interest and great importance, and we look forward to working with NHTSA to save lives.

1.3 BACKGROUND

1.3.1 Head-Up Displays

A HUD is a form of display technology that uses an image generator, image projector, and image combiner to display information within an optical plane within the forward field of the operator. This technology has been developed primarily for military and commercial aviation applications, but gained attention for automotive applications with the advent of Intelligent Transportation Systems during the 1990's (Ward & Parkes, 1994). Information to support task performance may either be in the form of (1) "non-conformal" content that is an abstraction of real world objects and positioned within the HUD without regard to the position referenced object in the environment (e.g., speedometer, fuel level, navigation arrows), or (2) "conformal" content that is an augmentation of real world objects and superimposed over the reference object in the environment (e.g., augmented lane markings, infra-red images overlaid on a night-time scene) (Kiefer, 1995; Ward & Parkes, 1994). The focus of the research proposed in this document is on non-conformal automotive HUDs.

1.3.2 Using HUDs to Mitigate Driver Distraction

The HUD is designed to keep the eye position forward and facilitate processing of information in both the HUD and external scene (Ward & Parkes, 1994). By displaying information close to the external scene, HUDs can reduce the time drivers take to transition between displayed information and objects in the environment, a benefit termed the "HUD Benefit Time Window" (Kiefer, 1995; Kiefer, 1998). In contrast, information presented on an Head-Down Display (HDD) requires longer transition times and can lead to longer "eyes off road" time, which has been shown to correspond with safety-critical event risks (Klauer, Guo, Sudweeks, & Dingus, 2010). However, it should be noted that the HUD Benefit Time Window is dependent on the position of the HUD images; the farther the HUD images are displayed from the driver's primary focal point when driving, the longer the transition time will be, increasing the time drivers are not attending to the road.

In addition, primary task performance can be somewhat supported by enabling the eyes to focus on information in both the HUD and external environment (Kiefer, 1995). This is achieved when the HUD images are located close to the driver's primary focal point and projected beyond the driver's natural resting focal distance (preferably at a focal distance that is the same as target objects in the environment). Specifically, because the human eye does not accommodate to perceive depth beyond 22 ft., focusing the HUD images at this distance is sufficient to eliminate the need to accommodate between the road and a display (note that focal depths of 22 ft. or greater are termed optical infinity for this reason). Under such conditions, the time spent changing accommodation between the roadway and a display is reduced, allowing drivers to return their focus to the road sooner.

1.3.3 Potential Driver Distraction from HUDs

Despite the intended benefits of HUDs, a number of human factors issues have been identified, primarily from HUD applications in the aviation sector (Crawford & Neal, 2006; Martin-Emerson & Wickens, 1997; Prinzel Iii et al., 2004; Ververs & Wickens, 1998). Admittedly, there are fundamental differences between the operational environment and primary tasks for flying and driving. For example, the flying environment is information sparse such that the HUD becomes the primary display, whereas the driving environment is information rich so that the HUD may function as a secondary information source (Kiefer, 1995). Nevertheless, several reviews have noted that some issues may have implications for HUD usability in automotive applications (Gabbard, Fitch, & Kim, 2014; Kiefer, 1995; Ward & Parkes, 1994) . The following is a list of some of the issues that may be most important for automotive applications, especially for older drivers.

1.3.3.1 Visual Clutter

Because of the necessity to directly view objects in the information rich driving environment, visual clutter from non-conformal HUD content may obstruct detection of relevant hazards in that environment (Ward & Parkes, 1994). This suggests that automotive applications should consider placing non-conformal HUD content outside the area of fovea vision (Kiefer, 1995). Clutter is less of an issue for conformal applications because the HUD representation and actual object are integrated as a single object (Ververs & Wickens, 1998).

1.3.3.2 Accommodation
If the HUD apparatus or its projected image forces the eyes to accommodate at a distance closer than their natural resting state, the result will be that the apparent resolution of an object is reduced and its apparent distance is increased (Kiefer, 1995). This suggests that the distance of the focal plane may be an important factor in the perceptual and cognitive demand of processing HUD content. HUDs that are focused along a vehicle's windshield (less than optical infinity) could pose a problem in this regard.

1.3.3.3 Cognitive Capture
The type of HUD information and its display properties (e.g., brightness, contrast) can capture driver attention — especially under high workload conditions (Kiefer, 1995), thereby impeding the normal scanning of the wide driving environment (Parkes, Ward, & Bossi, 1995). This suggests the need to not only measure the propensity for cognitive capture when evaluating automotive HUDs, but also reviewing design considerations to reduce its effect (such as use of on-demand rather than continuous displays).

1.3.3.4 Driving Scene
Not only can HUD content clutter the driving scene, but the visual complexity of the driving environment may act as a background that distorts the perception of the HUD content (Ward, Parkes, & Crone, 1995). The resulting additional effort to identify and interpret the HUD content would increase both perceptual and cognitive demand, thereby impacting primary task resources. This suggests the need to evaluate HUD information in different (dynamic) environments and review design options for HUD display parameters that may reduce this effect such as content brightness and contrast (Kiefer, 1995).

1.3.4 Assessing when Drivers Look at a HUD
To assess driver performance with HUDs, it is important to identify when drivers are looking at the display. Traditional measures such as eye glance location can be used to assess where a driver is looking, but are challenged in measuring what focal depth the driver is accommodating to. A brief review of the various options available to measure drivers' visual attention to a HUD is presented below, along with their benefits and drawbacks.

1.3.4.1 Video Reduction
Tracking where a driver is looking can be performed by observing video of the drivers' eyes. Cameras are equipped inside the vehicle and directed at the driver's face. A close-up of the driver's eyes can further support this measurement. Recorded video is then analyzed by trained and experienced data reductionists who identify general locations where the driver is looking throughout a trial. The location the driver is looking is typically classified according to the forward roadway, instrument panel, rear and side view mirrors. On its own, it can be a challenge to determine whether a driver is looking at a HUD or the roadway. However, when the onset of a glance to the HUD is known (e.g., when asked by an experimenter to do so), determining when and for how long the drivers look at the HUD becomes more achievable. The true benefit of video reduction is that the method is easy and reliable to setup and execute. The test vehicle also only has to be instrumented once.

1.3.4.2 Eye Tracking Equipment
Video-based eye trackers track the movement of the eye by projecting an infrared light on the eye, creating corneal reflections. These reflections are then tracked by cameras and used to quantify eye movement. This is illustrated in Figure 1.

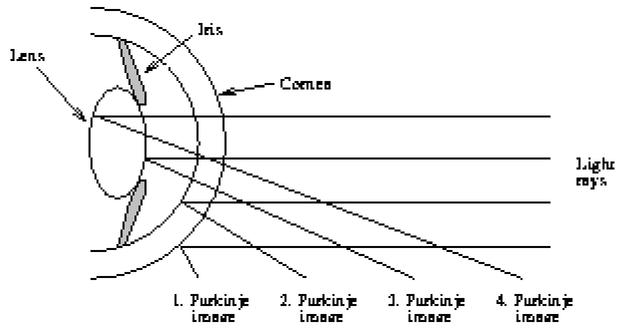


Figure 1: The four Purkinje Images

As shown in Figure 1, Purkinje image 3 and 4 both are reflections off the surface of the lens. Any change in the lens' shape will alter the direction and location of the Purkinje images. Video recording of the Purkinje image can therefore be used to determine the gaze location and eye accommodation. However, the setup and reliability of the eye-trackers inside a moving vehicle amongst ambient light can greatly reduce their practicality. Calibration time can be substantially long and can also pose an issue for certain skin complexions and facial structures. Although there are eye tracking systems that advertise self-calibration in a matter of seconds, these systems typically carry a high cost. One specific eye tracking model that may be adequate for this study is SensoMotoric Instruments (SMI) Eye Tracking Glasses 2. This eye tracker is minimally invasive and self-calibrating. It is specifically designed for use outside of a laboratory and has been used in a driving context. Gaze location can be reported, and accommodation can be very roughly assessed from the raw data. VTTI has yet to work with this eye-tracker. Pilot testing is required to validate the manufacturer's claims before incorporating the equipment into a study.

It may also be possible to analyze the glance location patterns to assess whether a driver is looking at the road versus at a HUD. It is foreseeable that the eye glance saccade differentials when looking at the road will be greater than the saccade differentials when looking at a display. Pilot work is required to assess the degree to which these patterns differ and whether the approach can be reliable.

1.3.4.3 Optometers and Autorefractors

Optometers, or autorefractors, are instruments used to measure the eye's refractive state. The use of an optometer can be very useful in detecting the eye's accommodation. This equipment delivers highly repeatable and accurate measurements, provided it is used in a controlled setting. Optometers are often fully vetted for their accuracy and consistency. The most common type is the binocular autorefractors, for example the WAM 5500 Advanced (see Figure 2). These autorefractors use open view windows to measure accommodation power in both eyes. They can be used on patients with or without corrective eyewear. This optometer can also be used with any visual target. However, this equipment is often large and bulky. Without interfering with the integrity of the equipment, it is unlikely to find one that will realistically fit in a vehicle. Furthermore, like many of the forms, this equipment is sensitive to noise, and usually requires a bite piece or chin rest to stabilize the head and reduce unnecessary and detrimental movement. In the 1990's, Takeda developed a three-dimensional Optometer (TDO), which allowed for free movement of the head (eliminating the need for a chin rest or bite bar). However, as shown in Figure 3, the TDO III system requires sizeable space not only for the head-mounted equipment, but to also counterbalance the weight applied to the participant's head.

Figure 2. WAM 5500 Advanced.

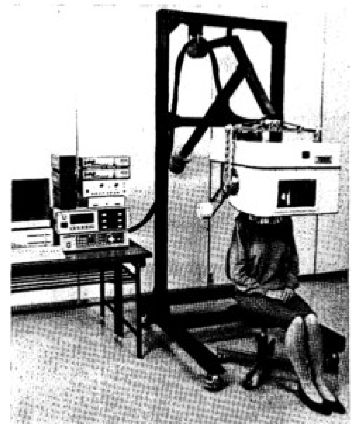


Figure 3: The Three-Dimensional Optometer III system.

Because no one way can confidently measure drivers' accommodation to a HUD, other performance measures that are sensitive to the driver viewing a HUD should be incorporated into the study. In assessing a HUD's ability to support primary task performance, it has been common to measure longitudinal vehicle control, lateral vehicle control, and (critical) object detection (Fadden, Ververs, & Wickens, 1998). For example, it has been demonstrated that processing primary task information within a HUD configuration compared to a HDD configuration can reduce vehicle speed variability (Liu & Wen, 2004). It has also been shown that the detection of pedestrians on the road is faster when cued by information presented in a HUD compared to when cued by information displayed on a HDD (Ablabmeier, Poitschke, Wallhoff, Bengler, & Rigoll, 2007; Kiefer, 1998).

2 PART I: TECHNICAL APPROACH

The following section presents the VTTI team's technical approach to investigating the distraction potential of HUDs. It is important to note that resources have been allocated based on the team's present understanding of priorities. The team is flexible and can shift allocations collaboratively with NHTSA as deemed appropriate during the planning phase of this project. The following tasks are based on the RFP's Section C.5 which states the Specific Requirements for the research effort.

2.1 TASK 1: KICK-OFF MEETING & PROJECT MANAGEMENT PLAN

As part of Task 1, the VTTI team will schedule and conduct an initial meeting with the NHTSA COR (TO) via teleconference. The teleconference will take place within one (1) week after task order award (ATOA). Both VTTI and WTI will attend the teleconference. The purpose of the teleconference is to have an initial discussion about all issues relating to the Task Order and the accomplishment of its objectives. VTTI will provide minutes from the meeting as a written record of the discussions.

In addition, Task 1 also involves the development of a project management plan (PMP) within two (2) weeks ATOA. The PMP will be developed by VTTI and will document the overall approach to the management of this research effort (e.g., schedule, risk management plans, staff/resource allocation plans, control practices, and interactions with stakeholders if applicable). This document will be updated as needed to reflect authorized changes to the contract. VTTI will coordinate and document any changes based on NHTSA COR (TO) approval.

VTTI will also schedule and conduct biweekly teleconferences to provide updates to the COR (TO) on the status of the milestones and deliverables. WTI will also attend these teleconferences and will provide updates of their progress.

<u>Deliverables and Milestones</u>

- Teleconference (M)
- Bi-weekly conference calls (M)
- Minutes from initial call (D)
- Project Management Plan (PMP) (D)
    - Revised PMP addressing comments from the COR (TO)
    - Change request(s) (if needed)
    - Updates to PMP (if needed)

2.2 TASK 2: LITERATURE REVIEW

The literature review task will be performed by WTI. WTI will review publications on the topic of HUDs for vehicles to identify knowledge gaps related to visual attention, focal distances, effects on reactions to events, in-vehicle HUD display elements, and experimental approaches that should be addressed within this project. WTI will only review published literature on static HUDs specifically related to automotive applications (and not aviation). The review will also only focus on research published after the existing automotive HUD reviews published by Kiefer (1995) and Ward and Parkes (1994). WTI will also perform a scan of the current HUD technology to find the best suited for the goals of the study. This will consist of reviewing manufacturer and other related websites for images and videos that demonstrate how the technology operates.

The literature review will attempt to support the selection and evaluation of a surrogate metric for glance duration. This information, if available, will help determine an experimental design to examine visual distraction from the use of HUDs. The literature review will identify all previously determined visual metrics for determining visual distraction for HUDs as well as the supportive empirical evidence and the rationale. The literature review, as well as input from NHTSA, will then be used to guide the design of the experiments and determine these surrogate metric(s).

Upon receipt of the NHTSA approval of the Literature Review and Research Plan, the VTTI team will pursue IRB approval as appropriate.

<u>Deliverables and Milestones</u>

- Draft Literature Review and Research Plan (D)
- Revised Literature Review that has been approved by NHTSA (D)

2.3 TASK 3: RESEARCH PLAN AND BRIEFING

Based on findings from the literature review, VTTI will develop a research plan that presents a detailed approach for data collection, reduction, and analysis. The VTTI team will design this plan considering the research scoping issues listed in the 'Objectives' section above, new information obtained from the literature review, and understanding of the current practice. The main data collection effort will consist of a study to collect objective data focused on accomplishing the following:

- Identify the main visual distraction issues involved with using HUD versus HDD HMI.
- Identify metric(s) that are sensitive to potential distractions resulting from using a HUD versus a HDD.
- Determine whether a surrogate measure of distraction increases when drivers use candidate HUD systems (i.e., when a driver is viewing the HUD and road with a potential target or road and HUD with a target).
- Identify a method to determine or manipulate the driver's focal distance to near or far displays.
- Identify any unintended consequences associated with HUD systems.
- Describe potential minimum performance specifications for HUD systems and their advantages/disadvantages.

The proposed experimental approach to meet these objectives is described below.

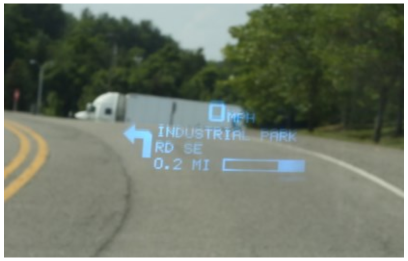
2.3.1 Experimental Approach

This study will consist of a focused on-road evaluation of commercially-available HUDs. Both an OEM and aftermarket HUD will be tested (Figure 4). The OEM HUD will be that equipped on a 2010 Buick Lacrosse. The aftermarket HUD will be the Garmin's navigational HUD. These two HUDs were selected to investigate the role of the HUD's focal depth (i.e., the OEM HUD is focused at 2.5 m, while the aftermarket HUD is projected on the windshield). Driver performance when using these HUDs will be compared to driver performance when using the Buick Lacrosse's HDD (Figure 4). It should be noted that the two HUDs and the HDD were selected for this study so that our results can be related to focal distance and driver accommodation. Specifically, the displays compared in this study have similar content, use similar format, and have similar interactions that will allow the location of the information to be evaluated in a practical manner.

Figure 4. Left: 2010 Buick Lacrosse HUD. Center: 2010 Buick Lacrosse HDD. Right: Garmin Navigational HUD.

It should be noted that other HUD technology was considered for inclusion in the experiment. Table 1 presents a summary of the benefits and drawbacks of using each type of display. Ultimately, an OEM HUD and OEM HDD were selected because they met the study requirements and were both available on the same VTTI fleet vehicle. The aftermarket HUD was selected because it had a closer focal depth than the OEM HUD and is bright enough to display images during daylight.

Table 1. HUD Selection Rational

	OEM HUD	**Aftermarket HUD**	**Cell Phone HUD**
Technology	2010 Buick Lacrosse	Garmin Navigational HUD	HUDWAY iPhone App
Image			
Benefits	• Commercially available • Similar font to OEM HDD • Similar content to OEM HDD • Similar interaction to OEM HDD • Reflected off windshield with focal depth of 2.5 m • Vertical position adjustable • Display brightness sufficient for daytime use	• Commercially available • Similar content to hand-held iPhone HDD • Similar content to OEM HUD • Reflected off windshield • Display brightness sufficient for daytime use	• Commercially available • Reflected off windshield • Content exact duplicate as HDD iPhone app
Drawbacks	• Horizontal position not adjustable • Content layout not exact duplicate of OEM HDD display • Images and interaction is simplistic	• Vertical position not adjustable • Content layout not exact duplicate of hand-held iPhone app or OEM HUD • Images and interaction is simplistic • iPhone HDD layout presents more information than the HUD layout	• Display intensity insufficient for daytime use

Each driver's test session will take place on both public roads as well as on the Virginia Smart Road, a 2.2-mile controlled test track. Testing on public roads will allow the investigation of drivers' visual behavior, vehicle control, and task completion time under normal traffic demands. Testing on the Virginia Smart Road will allow the controlled investigation of drivers' emergency response to surprise events when looking at a display. The approach for each component is described below.

The public road component will consist of drivers following an orange Virginia Department of Transportation (VDOT) pickup truck at 60 mph. Drivers will experience three conditions that involve reading information displayed on an OEM HUD, aftermarket HUD, and OEM HDD. The envisioned tasks include:

- Reading the distance to next turn
- Reading the street name of next turn
- Reading the speedometer
- Reading the engine's RPM, and
- Reading the name of the radio channel

The public road course consists of a 14-mile stretch of road on a two-lane divided highway in Christiansburg, Virginia (Figure 1). The course contains a parking facility where drivers will complete a survey about their interactions with each display. Each driver will experience the OEM HUD, the aftermarket HUD, and the OEM HDD on a separate lap in a counter-balanced order. Their task completion time, eyes-off-road time, eyes-on-display time, mean speed, standard deviation of speed, mean headway, standard deviation of headway, standard deviation of lane position, and subjective opinions of interacting with the display will be compared using within-subject statistical analyses. Drivers will also wear a light-weight head-mounted camera that will capture what aspects of the roadway are obstructed by the HUD images.

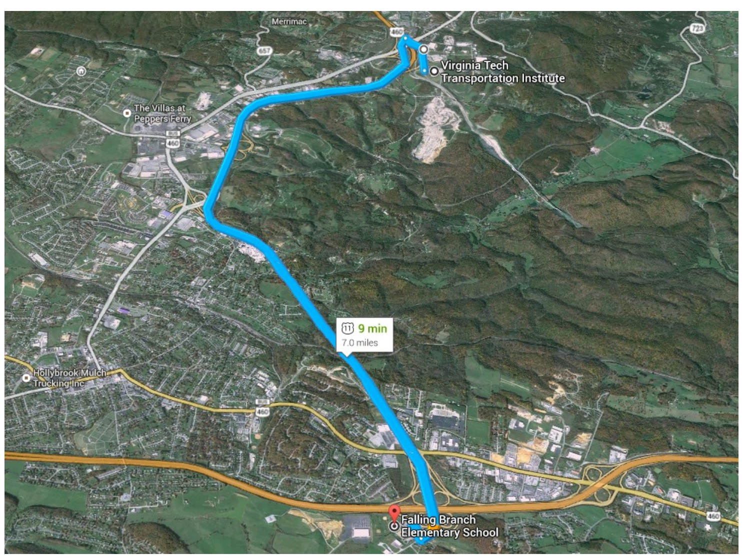


Figure 5. 14-Mile Two-Lane Divided Highway Public Road Course in Christiansburg, Virginia

Drivers will then be asked to follow the lead pickup truck onto the Virginia Smart Road. The purpose will be to investigate drivers' emergency response performance to two surprise events in a controlled and safe manner. Unknowing to the driver, the lead pickup truck will drop a fake muffler at the command of the in-vehicle experimenter. The muffler-drop event will be executed as the driver engages in a task with a display. The display the driver is asked to use will either be the OEM HUD, the aftermarket HUD, the OEM HDD, or no display at all (i.e., drivers will not be asked to look at a display during the surprise event). Because the information displayed on the devices used in this study is simplistic, creativity is required to devise tasks that adequately demand the driver's visual attention during the surprise event. The proposed approach (that will be pilot tested) is to ask the driver to watch the display and report when it flashes red. Because the display will never flash red, it is expected that drivers will watch the display long enough to not see the onset of the surprise event. Similar approaches have been successfully used in previous studies performed by VTTI (Fitch, Bowman, & Llaneras, 2014; Fitch, Hankey, Kleiner, & Dingus, 2011). Drivers' response performance to the surprise event will be measured in terms of gaze response time, throttle response time, brake response time, and swerve response time. Furthermore, the head camera will capture whether the HUD image obstructed the drivers' view of the muffler. Afterwards, drivers will be debriefed. Those that elect to continue the study will complete a questionnaire about their experience with the display during the surprise event.

The lead pickup truck will then pull to the side of the road to allow the subject vehicle to drive the remainder of the Virginia Smart Road alone. Drivers will be asked to perform a series of tasks "that are too hard to be performed on public roads" with the display. At the experimenter's command, they will be asked to track a component of the display (an example might be to track the engine's RPMs and to adjust the throttle until the RPMs reach a set amount). During this task, the intersection phase will change from green, to a short yellow, to red. Drivers' response performance to the light will be measured in the same fashion as their response to the first surprise event. Drivers will use the same display as they did in the first surprise event. Drivers will then complete a survey about the second surprise event. Drivers' response performance and opinions during the first and second surprise events will be investigated separately. Their response performance across the four display conditions will be investigated using between-subjects statistical analyses. If pilot testing shows that drivers are not adequately distracted during the second surprise event because they are suspicious of a hazard, then the second surprise event may be eliminated.

Overall, this study will allow an investigation of how drivers' interaction with, and vehicle control when using, displays of different focal depths differ. The public road component will allow the investigation of drivers' visual scanning behavior and whether HUDs generate unintended disruptions in this behavior. The Virginia Smart Road component will allow the investigation of potential delays in response to surprise events, which can provide insight on the distraction potential of HUDs and their impact on transportation safety. These measures included in this investigation may be found to be surrogate measures of HUD distraction.

2.3.2 Experimental Design

2.3.2.1 Public Road Component

The experimental design consists of a three (OEM HUD, OEM HDD, and Aftermarket HUD) within-subject study. A total of 48 drivers between the ages of 50 and 60 years old will be recruited in order to investigate the difficulties this segment may have in accommodating to the displays. Each driver will experience the three displays in a counter-balanced order based on a balanced Latin Square design. Drivers will be asked to perform various display reading tasks at the command of the in-vehicle experimenter. They will be told that their reading performance will be scored. The dependent variables will be drivers' task accuracy, task duration, eyes-on-display-time, eyes-off-road-time (a glance to a HUD will be categorized as off-road because of known deficiencies in selective attention to simultaneously process superimposed and background information (Neisser & Becklen, 1975)), mean speed, standard deviation of speed, mean headway, standard deviation of headway, standard deviation of lane position, and subjective opinions of interacting with the display. Whether the lead vehicle is obstructed by the HUD image during each task will also be recorded. Drivers' visual behavior in between display tasks will be sampled from each condition. Whether visual behavior changes when a HUD is available will be investigated (Note, the HUDs will be disabled during the HDD condition). This will provide insight on whether HUDs generate unintended consequences on drivers' visual scanning behavior.

2.3.2.2 Virginia Smart Road Component

The experimental design consists of a four (OEM HUD, OEM HDD, Aftermarket HUD, Baseline) between-subjects study. The 48 drivers from the public road component will be equally divided into the four display conditions (12 drivers in each condition). Drivers will encounter a surprise event as they are reading the display (or just driving if they are in the baseline condition). The dependent variables will be drivers' gaze response time, throttle response time, brake response time, swerve response time, and subjective assessment of how distracted they were during the task. This experimental design will also be used to investigate drivers' response performance to the second surprise event (i.e., intersection phase change).

2.3.3 Research Plan Considerations

The proposed experiments in this project do not abide by the Standard NHTSA Test Subject Pool described in the Phase 1 of NHTSA's Driver Distraction Guidelines. The proposed experimental design will serve the study objectives and statistical power needed to achieve the objectives. The VTTI team will work closely with the COR (TO) in identifying which methods can and/or will be implemented. The results from the study are expected to help generate a method for determining focal distance and a surrogate measure for eyes-off-road time that can determine the distraction potential for viewing a HUD during a safety critical event.

The research plan will include the following:

- Research questions and hypotheses
- Objective and subjective data to be collected
- Target population, participation characteristic, sample size, and recruitment methods
- Equipment
- Data collection methods and instruments
- Data analysis methods
- Data quality test and verification
- Expected outcomes
- Timeline for key research activities

The VTTI team will present the research plan to the COR (TO) at a project meeting in Washington, D.C. The purpose of this meeting will be to discuss the technical approach to meet the project objectives (i.e., data collection, reduction, and analysis plan); present the project management plan (i.e., timeline, resource allocation, risk management, and quality control); and clarify any questions. The VTTI team will submit and discuss the briefing materials with the COR (TO) prior to the briefing date. Presentations will be submitted as Microsoft Power Point files. Any videos, handouts, or other material will also be submitted to the COR (TO). VTTI will provide minutes from the meeting as a written record of the discussions. The VTTI team will use the feedback obtained at the briefing to modify the research plan, if applicable, (with guidelines from the NHTSA COR (TO)). Final briefing materials will be submitted in the briefing plus any revisions identified during the meeting.

<u>Deliverables and Milestones</u>

- Briefing materials (draft, revisions, final) (D)
- Briefing on research plan (M)
- Minutes from briefing (D)
- Research plan (draft, revisions, and final version) (D)

The revised versions of all reports will be submitted back to NHTSA within two weeks after receiving NHTSA's comments. It is expected that NHTSA's comments on the reports will take two weeks for all deliverables except for comments on the final report, which are expected to take four weeks.

2.4 TASK 4: DOCUMENT PREPARATION FOR INSTITUTIONAL REVIEW BOARD (IRB)

Upon receipt of the NHTSA approval of the Literature Review and Research Plan, VTTI will pursue IRB approval as appropriate. IRB documentation will be submitted to the COR (TO). VTTI will comply fully with 49 CFR Part 11, DOT's regulation governing Protection of Human Subjects, and with NHTSA Order 700-5, which sets forth the Agency's policies and procedures for the protection of human subjects participating in research supported directly or indirectly by NHTSA, including through contracts, grants and cooperative agreements.

<u>Deliverables and Milestones</u>

- Draft documents for IRB approval (e.g., recruitment questionnaire, research protocol, etc.) (D)
- Final documents submitted for IRB approval (D)
- Approval letter(s) (D/M)
- Amendments to IRB and approval documents (if necessary)

2.5 TASK 5: OBTAIN OFFICE OF MANAGEMENT AND BUDGET (OMB) CLEARANCE

VTTI will provide the necessary documentation to the COR (TO) regarding the study in support of NHTSA's application for OMB approval. Documentation may include survey instrument, questionnaires, research methods, experimental design, etc. VTTI will support this activity by providing technical reviews, revisions, and responses to technical comments by the reviewers. Reviewers include staff at

NHTSA, Office of the Secretary of Transportation (OST), Bureau of Transportation Statistics (BTS) (part of Research and Innovative Technology Administration (RITA)), and OMB. Recruitment questionnaires, surveys, and/or other information collection for this research program may be subject to review and approval by OMB under the Paperwork Reduction Act (PRA). If it is required, NHTSA will submit an Information Collection Request (ICR) that consists of a set of documents that describe what information is needed, why it is needed, how it will be collected, and how much collecting the information will cost the respondents and the government.

A brief description of the documents included in an ICR is provided below:

- 18 supporting statements: Include the purpose, scope, and benefit(s) of the collection. It is comprised of two parts: Part A – Justification and Part B – Statistical Methods. Attachments will include the data collection instrument(s).
- 60-day Federal Register Notice: Informs the public of intent to ask for clearance for the collection of information and solicits comments for a 60-day period. This notice includes, for example, the purpose of the information collection, how you plan to collect the information, estimated number of respondents, and estimated total annual burn.
- 30-day Federal Register Notice: Submitted to the Federal Register after 60-day comment closes. Addresses comments received from the 60-day notice and notifies the public that the clearance request will be submitted to OMB.

<u>Deliverables/Milestones</u>

- Survey instrument, questionnaires, research methods, etc. (identified as part of the research plan) (D)
- Comments and edits to18 supporting statements; 60-day Federal Registry Notice; and 30-day notice for Federal Registry (D)
- Respond to comments and questions from NHTSA, BTS, OST, and OMB on survey instrument, questionnaires, research methods, etc. (D)
- Publish 60-day Federal Register Notice (M)
- Publish 30-day Federal Register Notice (M)
- ICR to BTS (M)
- ICR to NHTA ICCO (M)
- ICR to OST (M)
- ICR to OMB (M)
- Obtain OMB approval

2.6 TASK 6: EXECUTE RESEARCH PLAN

The VTTI team will conduct recruitment, data collection, data reduction, and data analysis as described in the approved research plan and conduct inferential statistical analyses of the data to test the hypotheses described therein. VTTI will provide a status briefing to discuss initial data reduction and analysis in Washington, D.C. VTTI will document any issues that may emerge during initial data reduction and analysis, assess the impact of these issues, and identify solutions for any issue encountered. The VTTI team will submit and discuss the briefing materials with the COR (TO) prior to the briefing date. The VTTI team will provide minutes documenting, issues, comments and any action items resulting from this status briefing.

Deliverables and Milestones

- Complete initial data reduction and analysis (M)
- Status briefing materials (draft, revisions, and final) (D)
- Status briefing (M)
- Minutes from status briefing (D)
- Complete data collection (M)
- Complete data reduction and analysis (M)

2.7 TASK 7: DOCUMENTATION

The VTTI team will document the work completed in this Task Order. Project documentation will address all questions identified in the final research plan. The following will be performed:

2.7.1 Task 7.1: Final Briefing

The VTTI team will present the findings during a final briefing at NHTSA in Washington, D.C. The presentation will include an executive summary of the most significant findings followed by a technical presentation describing the work in more detail. Presentations will be submitted as Microsoft Power Point files. All materials to be used for the final briefing will be submitted in advance. VTTI will address comments from the NHTSA COR (TO) prior to the briefing. Any videos, handouts or other materials will also be submitted to NHTSA. Final briefing materials will be submitted after the meeting. Final briefing materials are the materials used in the briefing plus any revisions and action identified during the briefing. VTTI will provide minutes from the meeting as a written record of the discussions. VTTI will use the feedback obtained at the final briefing to modify the draft final report, if applicable, (with guidelines from the COR (TO)).

2.7.2 Task 7.2: Draft Final Report

The VTTI team will submit a draft final report documenting all work completed in this Task Order. The report will be approximately 100 pages or less, with unlimited appendices (not included in the 100-page limitation) providing additional detail and explanations as needed. VTTI is responsible for addressing comments by the COR (TO) before the report is circulated for agency review.

2.7.3 Task 7.3: Comment Resolution Document

The COR (TO) will compile comments received from agency review of the draft final report in a ‘Comment Resolution Document’. The VTTI team will review all comments and provide a response indicating whether and how comments will be addressed in the final report. VTTI will contact the COR (TO) with any questions on the comments received.

2.7.4 Task 7.4: Final Report

The VTTI team will revise the draft report to address comments from agency review. The draft report becomes a final report after the VTTI team has satisfactorily addressed comments made by the COR (TO) and those by other agency reviewers.

2.7.5 Task 7.5: Research Summary

The VTTI team will submit a research summary. This document is intended to provide a quick overview of a report's most meaningful findings. This should cater to a less technical audience than the main report. Relevant photographs, charts and tables shall be placed in this summary. An executive summary is not a substitute for a five-page summary, as these typically report more than just the most meaningful findings and lack photos, charts and tables. These summaries will form the basis for a NHTSA publication "Vehicle Safety Research Notes."

2.7.6 Task 7.6: Lessons Learned

The VTTI team will document lessons learned on a continuous and periodic basis. Lessons learned refer to knowledge gained through experience or study that could inform similar projects in the future. These will be compiled in a letter or brief project memorandum delivered at the end of the project.

2.7.7 Task 7.7: Manuscript (optional)

The VTTI team has the option to write a draft manuscript for possible peer-review journal submission. The COR (TO) will review and provide comments. This manuscript and other information related to this Task Order shall not be published, divulged to any third party, or released to the public without prior written approval by the COR (TO) (see base contract Section H.3.1).

Deliverables and Milestones

- Final briefing materials (draft, revisions, final version) (D)
- Final briefing at NHTSA (M)
- Minutes from final briefing (D)
- Final report (draft, revisions, and final version) (D)
- Comment resolution document (D)
- Research summary (draft, revisions, and final version) (D)
- Lessons learned (D)
- Manuscript (optional)

2.8 TASK 8: PROJECT MANAGEMENT COMMUNICATIONS

2.8.1 Subtask 8.1: Status Teleconferences and Minutes

The VTTI team will schedule bi-weekly telephone meetings with NHTSA. VTTI can schedule additional meetings with the NHTSA COR (TO) as needed. The principal investigator will be responsible for scheduling the meeting and establishing the agenda. Meeting topics can include but are not limited to technical progress, project schedule, issues requiring resolution, and upcoming tasks. VTTI will provide an agenda 24 hours in advance of the call. Minutes will include, but are not limited to the following: current status, issues and actions items. In some instances, the principal investigator may request an e-mail update in lieu of the telephone meetings; these requests should be sent to the NHTSA COR (TO) for approval. VTTI will provide minutes as described above within three days for all meetings with NHTSA, scheduled or unscheduled, and in person or by telephone.

Subtask 8.2: Monthly Progress Reports

The progress and challenges of the project will be documented in monthly reports. VTTI will submit these electronically in Microsoft Word format to NHTSA by the 10th day following the month being reported on and will include information as outlined in the RFP and as suggested in the IDIQ Master Agreement. The purpose of this report is to describe the status of the technical tasks, costs, and schedule.

2.9 SUMMARY OF MILESTONES AND DELIVERABLES

Table 1 summarizes the Milestones and Deliverables for this project.

Table 2. Milestones and Deliverables

Task	Deliverable(D) /Milestone(M)	Description	Time After Task Order Award
1	**Kick-Off Meeting & Project Management Plan**		
1	M	Initial Teleconference	Within 1 Week ATOA
2	D	Minutes from initial teleconference	Within 2 Days After Task 1
3	D	Project Management Plan (PMP) – DRAFT	Within 2 Weeks ATOA
4	D	Project Management Plan (PMP) – REVISION	Within 3 Days After Receiving Comments From COR(TO)
5	D	Updates To PMP	If And When Modifications To TO Are Processed And Approved.
2	**Literature Review**		
6	D	Literature Review/Current Practice -- DRAFT	Within 2 Months ATOA
7	D	Literature Review/Current Practice -- REVISION	Within 3 Days After Receiving Comments From COR(TO)
3	**Research Plan and Briefing**		
8	D	Briefing Materials – DRAFT	Within 2.5 Months ATOA
9	D	Briefing Materials – REVISION	Within 2 Days After Receiving Comments From COR(TO)
10	D	Briefing Materials – FINAL	Within 3 Days After Briefing
11	D	Briefing On Research Plan	Within 3 Months ATOA
12	D	Minutes From Briefing	Within 2 Days After Briefing
13	D	Research Plan – DRAFT	Within 3 Months ATOA
14	D	Research Plan – REVISION	Within 3 Months ATOA
15	M	Research Plan – FINAL	After NHTSA Notification Of Approval
4	**Document Preparation for Institutional Review Board (IRB)**		
16	D	Draft Documents For IRB Approval	Prior To Recruitment And Data Collection
17	D	Final Documents Submitted For IRB Approval	Prior To Recruitment And Data Collection
18	D/M	Approval Letter(S)	TBD
19	D	Amendments To IRB And Approval Documents (If Needed)	TBD
5	**Obtain Office of Management and Budget (OMB) Clearance**		
20	M	Complete Survey, Questionnaires, Research Design, Etc.	See Item No. 15
21	D	Comments And Edits To PRA documents (When Applicable) And Respond To Comments And Questions From PRA Review Process (When Applicable)	Within 3 Days After Receiving Questions From COR(TO)
22	M	Obtain OMB Approval	Within 10 Months ATOA
6	**Execute Research Plan**		
23	M	Complete Initial Data Reduction Analysis	Within 14 months ATOA
24	D	Status Briefing – DRAFT	Within 14.4 months ATOA
25	D	Status Briefing – REVISION	Within 3 days after receiving comments to COR(TO)
26	M	Status Briefing – PRESENTATION	Within 14.5 months ATOA
27	D	Status Briefing – MINUTES	Within 2 days after briefing
28	M	Complete Data Collection	Within 18 months ATOA
29	M	Complete Data Reduction/Analysis	Within 21 months ATOA

Task	Deliverable(D) /Milestone(M)	Description	Time After Task Order Award
7	**Documentation**		
30	D	Final Briefing Materials – DRAFT	Within 22 months ATOA
31	D	Final Briefing Materials – REVISIONS	Within 3 days after receiving comments from COR(TO)
32	M	Final Briefing Presentation	Within 23 months ATOA
33	D	Final Briefing Materials – FINAL	Within 3 days after briefing
34	D	Minutes From Final Briefing	Within 3 days after briefing
35	D	Research Summary – DRAFT	Within 22 months ATOA
36	D	Research Summary – REVISION	Within 3 days after receiving comments from COR(TO)
37	D	Research Summary – FINAL	Within 2 weeks after receiving comments from Agency Review
38	D	Final Report – DRAFT	Within 24 months ATOA
39	D	Final Report – REVISIONS	Within 1 week after receiving comments from COR(TO)
40	D	Final Report – FINAL	Within 2 weeks after receiving comments from Agency Review
41	D	Comment Resolution Document	Within 2 weeks after receiving comments from Agency Review
42	D	Lessons Learned (optional)	Within 27 months ATOA
43	D	Manuscripts	Within 28 months ATOA
8	**Project Management Communications**		
44	M	Teleconference	Bi-weekly
45	D	Teleconference Minutes	Within 2 days of monthly teleconference
46	D	Monthly Progress Report	10th Day Of Each Month

Table 3. Project Gantt Chart

					2014				2015												2016											
ID	Task	Milestone (M)/ Deliverable (D)		Target Due Date	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
1		Initial teleconference (M)		Within 1 week ATOA (9/8/2014)	M																											
2		Minutes from initial teleconference		Within 2 days after Task 1 (9/10/2014)	D																											
3			Draft	Within 2 weeks ATOA (9/15/2014)	D																											
4	1	Project Management Plan	Revision	Within 3 days after receiving comments from COR(TO)	D																											
5		Updates to PMP		If an when modifications to TO are processed and approved.	D																											
6			Draft	Within 2 months ATOA (11/1/2014)		D																										
7	2	Literature Review/ Current Practice	Revision	Within 3 days after receiving comments from COR(TO)		D																										
8			Draft	Within 2.5 months ATOA (11/15/2014)			D																									
9			Revision	Within 2 days after reveiving comments from COR(TO)			D																									
10		Briefing Materials	Final	Within 3 days after briefing (12/4/2014)			D																									
11	3	Briefing on research plan		Within 3 months ATOA (12/1/2014)			D																									
12		Minutes from briefing		Within 2 days after briefing (12/3/2014)			D																									
13			Draft	Within 3 months ATOA (12/1/2014)			D																									
14			Revision	Within 3 months ATOA (12/1/2014)			D																									
15		Research Plan	Final (M)	After NHTSA notification of approval*			M																									
16		Draft documents for IRB approval		Prior to recuitment and data collection			D																									
17	4	Final documents submitted for IRB approval		Prior to recuitment and data collection			D																									
18		Approval letter(s) (D/M)		TBD			D/M																									
19		Amendments to IRB and approval documents (if needed)		TBD			D																									
20		Complete Survey, questionnaires, research design, etc. (M)		See Item No. 15 **			M																									
21	5	Comments and edits to PRA*** documents (when applicable) and Repsond to comments and questions from PRA review process (when applicable)		Within 3 days after receiving questions from COR(TO)			D																									
22		Obtain OMB approval (M)		Within 10 months ATOA (7/1/2015)										M																		
23		Complete initial data reduction analysis (M)		Within 14 months ATOA (11/2/2015)														M														
24			Draft	Within 14.4 months ATOA (11/12/2015)															D													
25	6		Revision	Within 3 days after revceiving comments to COR(TO)															D													
26			Presentation (M)	Within 14.5 months ATOA (11/16/2015)															M													
27		Status briefing	Minutes	Within 2 days after briefing (11/18/2015)															D													
28		Complete data colelction (M)		Within 18 months ATOA (3/1/2016)																		M										
29		Complete data reduction/analysis (M)		Within 21 months ATOA (6/1/2016)																					M							
30			Draft	Within 22 months ATOA (7/1/2016)																						D						
31			Revision	Within 3 days after receiving comments from COR(TO)																						D						
32			Presentation (M)	Within 23 months ATOA (8/1/2016)																							M					
33			Final	Within 3 days after briefing (8/4/2016)																								D				
34		Final briefing	Minutes	Within 3 days after briefing (8/4/2016)																								D				
35			Draft	Within 22 months ATOA (7/1/2016)																						D						
36			Revision	Within 3 days after receiving comments from COR(TO)																							D					
37	7	Research Summary	Final	Within 2 weeks after receiving comments from Agency Review																						D						
38			Draft	Within 24 months ATOA (9/1/2016)																								D				
39			Revision	Within 1 week after receiving comments from COR(TO)																								D				
40		Final Report	Final	Within 2 weeks after receiving comments from Agency Review																									D			
41		Comment resolution document		Within 2 weeks after receiving comments from Agency Review																									D			
42		Lessons learned (optional)		Within 27 months ATOA (12/1/2016)																											D	
43		Manuscripts		Within 28 months ATOA (1/1/2017)																												D
44			Teleconference (M)	Bi-weekly	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
45	8	Status meetings	Minutes	Withing 2 days of monthly teleconference		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
46		Progress reports		by the 10th day following the month being reported.		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D

2.10 PROJECT MANAGEMENT

This section presents the project team's approach to managing the project requirements. An explanation of the methods and procedures for planning, administering, and completing specific project tasks is provided. Details on how VTTI will track costs, maintain schedules, and ensure a high level quality of service are also provided.

VTTI is the largest university-level research center at Virginia Tech and one of the five largest transportation institutes nationwide. The Institute has over 400 employees, including a full-time fiscal staff managed by a finance director, and a full-time editorial and document production staff managed by an operations director.

2.10.1 Overall Approach

Effective project management is critical for the successful completion of this research effort. As such, VTTI has assembled a team with extensive experience in all aspects of the project. As mentioned in the introduction, Dr. Greg Fitch will serve as the PI and Senior Technical Program Manager for this project. He will oversee the work of the individuals working on project tasks and ensure the quality of the final resultant analysis. Dr. Nicholas Ward will serve as a Co-PI. Dr. Ward also has extensive experience in investigating driver performance with HUDs and their distraction potential. Included on the team are researchers within the User Experience Group that Dr. Fitch leads in the Center for Automated Vehicle Systems at VTTI. The personnel are experienced with performance data collection and analysis efforts for NHTSA projects. The team will also be supported by three specialty groups at VTTI. The first is VTTI's data reduction group. They will assist in the execution of a consistent data reduction that undergoes a quality control review. The second group is the participant recruitment group. They will assist the research team in recruiting drivers from the neighboring areas who meet the study's selection criteria. Finally, the third group is the editing group. They will provide a technical editing review of all reports going to NHTSA. Overall, the individuals involved as lead researchers for each task collectively represent decades of experience in performing research and providing useful, pragmatic, and sound reports to the U.S. DOT.

Note that this organization of the research team reflects VTTI's understanding of the project needs and requirements. However, if the project requirements change, VTTI has the flexibility to modify the teaming and organization as needed. VTTI has extensive experience in handling dynamic data collection and analysis efforts and the communication requirements for projects of this magnitude. This is evident via past research studies including, but not limited to, related efforts identified in Section 1.1.

2.10.2 Planning, Scheduling, and Control Practices

Dr. Fitch will track the technical progress of the project team's research, working closely with the individual researchers to ensure project milestones are met and technical issues are resolved in a timely manner with the COR (TO). As part of this process, VTTI's team of technical editors and budget/contract coordinators serve as key points of contact for the PM. A master calendar of deliverable due dates will be created, maintained, and managed by the technical editor in order to ensure timely delivery of project milestones. Per the IDIQ, VTTI will verify that the submitted technical reports and papers are in accordance with the "Guidelines for Quality Assurance of Report or Paper." VTTI will provide all reports in either Microsoft Word or PDF or other reasonable format as desired by the COR (TO). Documents will be transmitted by electronic medium, such as email or ftp. If the document has charts and graphs, VTTI will insert the Excel chart or graph at the appropriate locations in the publication and ensure proper formatting of nearby text. For photographs and other graphics, VTTI will select graphics that are at least 72 dpi and between 120 by 90 and 600 by 400 pixels. If a photograph is supplied by an outside source (national organization, etc.), VTTI will include a release form indicating that the human subjects in the photo authorize NHTSA to use the photo in its publications and on its Internet site.

Dr. Fitch will work closely with VTTI's team of budget/contract coordinators to ensure appropriate cost control practices are exercised for this TO. This supervision will support the project team in meeting project deliverables on time and within budget. In addition to monthly overall project and task expenditures provided in monthly reports, further information regarding expenditures are provided during the continuous invoicing process so that NHTSA may review and confirm details, if necessary.

The project team will notify Dr. Fitch of problems that may arise during the execution of this TO. Dr. Fitch will consult VTTI's previous experiences with TOs and provide guidance appropriate to each situation. If the problem is novel, he will work with the project team to determine appropriate courses of action and outline their implications. Dr. Fitch will then present the suggested solutions to the COR (TO) and the Contracting Officer's Technical Representative (COTR) and work with NHTSA to select the desired course of action. Dr. Fitch will inform the project team how the COR (TO)/COTR wishes to address the issue and ensure execution is successful.

2.10.3 Required Facilities

The proposed research will use the Virginia Smart Road located in Blacksburg, Virginia. The Smart Road (**Error! Reference source not found.**) is a two-mile closed course section of highway dedicated for research, including an intersection that provides a four-way approach which can be controlled with signal lights. The intersection (**Error! Reference source not found.**) can provide an ideal setting for the evaluation of driver response to vehicle control infrastructure.

Figure 6. Virginia Smart Road

Figure 7. Signalized Intersection on the Virginia Smart Road

2.10.4 Risk Management Approach

This risk management plan (RMP) describes the internal and external sources of risk involved. The risks named within this section are classified with a rating for three aspects of each individual risk: (a) the impact on the project cost, schedule, or scope, (b) the probability of that risk occurring, and (c) the ability of that risk to be mitigated. These levels are defined in **Error! Reference source not found.**.

Table 4. Risk Rating and Probability Definitions

Risk Rating/Impact on Cost, Schedule, and/or Scope	Risk Probability	Ability to Mitigate Risk
4 = Catastrophic: Major impact	4 = High Risk (>10%)	4 = None
3 = Critical: Significant impact	3 = Medium Risk (Between 5% and 10%)	3 = Low
2 = Marginal: Low impact	2 = Low Risk (Between 1% and 5%)	2 = Medium
1 = Negligible: Insignificant impact	1 = Negligible Risk (Less than 1%)	1 = Excellent

Sources of Risk

Risks are identified along a taxonomy including technical, institutional, funding, environmental, personnel, and commercial risks. For each source of risk, the risk rating and probability is provided, along with a description of the risk and the planned mitigation strategy.

<u>Technical</u>

1. Vehicle malfunction (Risk = 2; Probability = 2; Mitigation = 1). The malfunction of a test or other research-related vehicle during data collection. This risk can impact project cost and scheduling. The

probability of this risk will be reduced by proper maintenance and inspection of all experimental vehicles by trained VTTI personnel. If a vehicle malfunctions, VTTI has the necessary in-house resources to either quickly troubleshoot and fix the vehicle or replace the vehicle with another suitable one from its test vehicle fleet.

2. Lack of available participants/participant attrition (Risk = 3; Probability = 3; Mitigation = 2). Participants either fail to enroll for the study or do not complete their scheduled participation. This risk can impact project scheduling. The probability of this risk will be reduced by scheduling participation well in advance and ensuring experimental protocols have been developed to minimize induced attrition. To address this issue, VTTI has developed a specific group focused on recruitment of participants which includes an extensive database of willing participants who have submitted their contact information to VTTI. This group is also configured to recruit participants though a variety of methods ranging from targeted advertising to cold-calling. If participants are unwilling to participate, the root cause of their reluctance will be determined and adjustments to the study protocols to address such concerns will be performed. If a participant fails to complete the study, VTTI will quickly replace this individual with another comparable person.

3. Apparatus failure (Risk = 2; Probability = 3; Mitigation = 2). This is defined as the failure of an experimental system such as a data acquisition system (DAS), display, or other experimental technology critical to the project. This risk can impact project cost, schedule, and scope. The probability of this risk will be reduced by ensuring that the design of all critical systems is fully tested prior to implementation. If an apparatus malfunctions, VTTI has the necessary in-house resources to quickly troubleshoot and fix the apparatus. In most cases, VTTI has spare equipment on-site and/or can quickly manufacture suitable replacements.

Institutional

4. Failure to obtain IRB approval (Risk = 4; Probability = 1; Mitigation = 1). This is defined as the failure to obtain the appropriate IRB approval to use human participants. This risk can impact project scheduling and scope. The probability of this risk will be reduced by using VTTI's in-house IRB reviewers, who are directly involved in the development and oversight of all IRB-related materials. IRB materials will be submitted in a timely fashion, allowing for adequate time for a full IRB review if deemed necessary by the Virginia Tech IRB. Because of the close relationship that VTTI has with Virginia Tech's IRB, all issues can be quickly communicated and resolved by the principal investigators. If concerns are identified, the research protocol(s) will be updated collaboratively with the IRB and the U.S. DOT to ensure acceptance from both stakeholders.

5. Facilities availability (Risk = 4; Probability = 1; Mitigation = 1). The necessary facility (Virginia Smart Road test track and reductionist laboratory) is not available when needed for the project. This risk can impact project scheduling. The probability of this risk will be reduced by using a unified scheduling system for each VTTI resource. Unified scheduling ensures that the resources are made available across all concurrent projects. Should unpredicted facility constraints arise, the issue will be thoroughly investigated to understand the available options. Suitable alternative facilities and/or timeline will be developed and collaboratively refined with the U.S. DOT to ensure changes are acceptable.

Funding

6. Delays or unanticipated changes in funding (Risk = 4; Probability = 1; Mitigation = 2). Funding is delayed. This risk can impact project cost, schedule, and scope. The probability of this risk will be reduced by working closely with the sponsor to ensure that the project has been adequately defined prior to implementation and that all internal Virginia Tech documents are handled in a timely fashion. Should funding issues arise, VTTI will work with the U.S. DOT to determine the impact and develop a suitable plan that can be executed within the available resources.

Environmental

7. Loss of test sessions due to adverse weather (Risk = 4; Probability = 3; Mitigation = 3). Adverse weather events result in the loss of scheduled test times. This risk can impact project scheduling. The probability of this risk will be reduced by ensuring adequate test time is scheduled when adverse weather is most likely, and quickly rescheduling participants when adverse weather events occur. If an adverse weather event makes it impossible to maintain the current project schedule, VTTI will work with the U.S. DOT to revise the project schedule to accommodate this unavoidable delay.

Personnel

8. Loss of key project personnel (Risk = 3; Probability = 1; Mitigation = 2). This is defined as the loss of key personnel who are critical to the project. This risk can impact project scheduling. The probability of this risk will be reduced by ensuring multiple individuals are fully briefed on the project's scope, purpose, method, and progress at all times. This will allow for backup personnel to take over, if needed. The key for mitigating this risk is for all key personnel to remain active in the interactions with NHTSA so they understand the direction of the project and can quickly step in and direct the work of the team.

9. Substandard performance (Risk = 3; Probability = 1; Mitigation = 1). Performance from project personnel is inadequate. This risk can impact project cost and schedule. The probability of this risk will be reduced by the PI closely monitoring project progress, and by the PI remaining in communication with appropriate personnel from the sponsor. The PI has the ultimate responsibility for the performance of the project and will address substandard performance and put in place a timely plan to rectify the issues.

10. Injury during testing (Risk = 4; Probability = 1; Mitigation = 1). This is defined as the injury of a participant or project personnel in the course of data collection. This risk can impact the project schedule and scope. The probability of this risk will be reduced by ensuring that the project method has been approved by the Virginia Tech IRB, which is responsible for ensuring the projection of human participants, as well as ensuring all data collection methods have been fully tested prior to implementation. Should an event occur, VTTI has specific response protocols in place in the case of emergencies, and will execute such procedures as appropriate.

Commercial

11. Commercial off-the-shelf (COTS) technology performance (Risk = 3; Probability = 1; Mitigation = 2). COTS technology does not perform as needed. This risk can impact project cost and scheduling. The probability of this risk will be reduced by working with COTS technology suppliers to ensure any COTS technology has been adequately scoped prior to inclusion in project planning and that adequate

alternatives to the technology are available. If a COTS technology malfunctions, VTTI has the necessary in-house resources to either quickly troubleshoot and fix the COTS technology or work with the COTS vendor to resolve the issue or replace the failed unit. If needed, suitable alternatives will either be obtained or manufactured at VTTI facilities.

Summary

The purpose of this RMP is to describe the risks associated with the project; these risks are summarized in the following risk matrix (**Error! Reference source not found.**). This document provides VTTI's summary of the foreseeable risks (both internal and external) as well as the mitigation strategy VTTI believes will best serve the needs of the project. By working closely with all stakeholders, this RMP should help to ensure project success.

Table 5. Risk Matrix

ID	Category	Description	Risk Impact	Risk Probability	Mitigation Ability
1	Technical	Vehicle malfunction	2	2	1
2		Lack of available participants/attrition	3	3	2
3		Apparatus failure	2	3	2
4	Institutional	Failure to obtain IRB approval	4	1	1
5		Facilities availability	4	1	1
6	Funding	Delays in funding	4	1	2
7	Environmental	Loss of test sessions due to adverse weather	4	3	3
8	Personnel	Loss of key project personnel	3	1	2
9		Substandard performance	3	1	1
10		Injury during testing	4	1	1
11	Commercial	COTS technology performance	3	1	2

2.10.5 Organizational and Management Approach Summary

Overall, VTTI has assembled a highly experienced and capable team that has a proven track record of meeting NHTSA's expectations for contracted research. The team is ready to support NHTSA and deliver practical findings based on a sound research approach. Notable team qualities include the following:

- The VTTI Team includes human factors researchers, transportation scientists, and outreach specialists. Each of these contributors can provide the required capabilities to achieve the goals of NHTSA.
- The VTTI Team recognizes that products that are not translated into implementable results cannot meet NHTSA's goals to improve safety, prevent injuries, and reduce economic costs. This is why VTTI has assembled a team that will manage the process in its entirety, from research plan development to documenting the study's findings.
- VTTI has substantial experience in successfully managing similar Task Order contracts.

- VTTI's quality control measures and procedures have worked effectively in the management of previously awarded Task Orders.

In summary, VTTI is confident it has put together a world-class team that can provide NHTSA with the expertise necessary to successfully complete the requested research. The team firmly believes in NHTSA's mission and will diligently assist NHTSA in meeting its key program objectives.

3 PART II: DATA QUALITY AND ANALYSIS TECHNIQUES

3.1 HUD AND IN-VEHICLE TECHNOLOGIES

HUD technology presents many opportunities and challenges to mitigate driver distraction, improve driver comfort, and engage drivers with their vehicles. On one hand, the reduction of the distance the eyes need to travel between the road and a display can minimize the amount of time required to view a display relative to a traditional HDD. There is also an added benefit in that peripheral roadway information can be processed while viewing a HUD, allowing some aspects of vehicle control, like lane keeping, to be partially supported. On the other hand, humans have difficulty simultaneously processing two displays overlaid on each other. Viewing HUDs while driving may therefore prevent drivers from perceiving events in the environment, particularly centrally-located hazards such as a braking lead vehicle. There is also a concern that HUDs whose focal depth is less than 22 ft. require the eyes to accommodate to be viewed. Because older drivers have difficultly accommodating to view these displays, they may take more time to process the displayed information compared to younger drivers. There is also a concern that if drivers perceive HUDs to be safer than HDDs that they may not regulate the length of time they spend looking at the HUD. The HUD may therefore negatively alter drivers' visual scanning behavior. The benefits and drawbacks of using a HUD in a vehicle must therefore be fully investigated and properly understood.

3.2 EXPERIMENTAL APPROACH

The proposed approach is to perform an on-road evaluation of commercially-available HUDs. HUD technology has advanced to the point where on-road tests of various configurations can generate insight on their distraction potential. One configuration of interest to NHTSA is a display's focal depth. Although equipment exists to dynamically adjust a HUD's focal depth (and VTTI has industry connections with manufacturers of such technology), the VTTI team proposes the use commercial HUDs that have different focal depths to simplify the study's design and generate practical findings within a reasonable scope. Testing will take place on both public roads and on a controlled test track. Each location offers unique benefits to the investigation. Drivers will transition from the public road to the controlled test track in a single test session. The type of data collected and analyses performed will be tailored to each test component.

The investigation of the effects of HUDs on driver performance must carefully consider the type of information displayed on a HUD and the tasks drivers perform with this information. It is recognized that current HUD content is simplistic and may not require extensive visual attention to be processed. It is also recognized that even though HDDs present various informational content, the content used in the study must be similar to that presented on the HUDs in order to not confound the results. As such, the types of tasks performed with the displays need to be carefully pilot tested to assess whether differences are likely to be measurable.

3.2.1 Measures

VTTI proposes to investigate driver performance with HUDs using known measures of distraction, notably visual scanning behavior, longitudinal vehicle control, lateral vehicle control, and response time to surprise events. It is believed that these metrics are sensitive to potential distractions resulting from using a HUD versus a HDD. However, investigating driver performance with these measures may also generate insight on new measures of driver interaction with HUDs.

3.2.1.1 Visual Scanning Behavior

For the public road component, drivers will be asked to interact with the display at the experimenter's command. A close up video recording of the drivers' eyes will be used to assess when drivers look slightly down from the forward roadway at the HUD (Figure 8). The experimenter's cue to begin the task will help flag the onset of glances to the display. This approach is needed because the reliability of equipment capable of measuring driver accommodation inside a moving vehicle is questionable. Personal communication with augmented reality experts, vision experts, eye-tracking equipment manufacturers, and ophthalmologists stated that measuring accommodation inside a vehicle is not entirely possible without significant challenges, notably being that measurement requires the driver's head to remain still, ambient light can generate detrimental measurement noise, and the resolution is not great enough to precisely measure focal depths. As such, the amount of time spent looking down at the display until the driver says aloud the information shown will be measured. It should be noted that VTTI became aware of Sensomotoric Instruments' eye tracking equipment that can measure convergence of the left and right eye during the late stages of preparing this proposal. This equipment is not able to precisely measure accommodation, but it may be able to roughly differentiate glances to the OEM or aftermarket HUD and the roadway. If NHTSA desires to pursue the use of this equipment, VTTI proposes to borrow the equipment from SMI to evaluate its capabilities (note that SMI offered to lend the equipment to VTTI). If the evaluation proves successful, the project's scope could be changed to include either the leasing or purchasing of the eye tracker. If the eye tracking data does not allow convergence to be measured, VTTI will use the existing measures in this proposal.

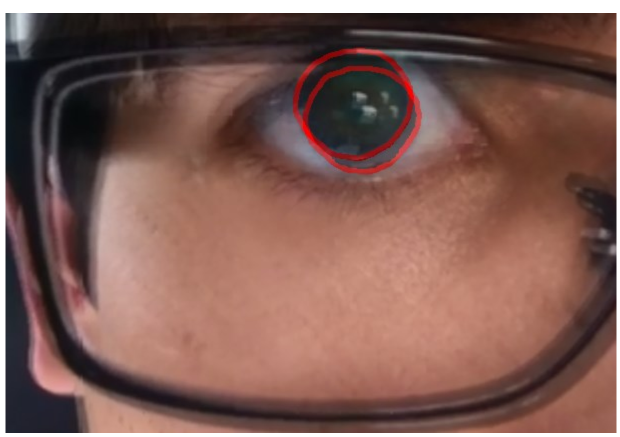


Figure 8. Video stills outlining the drivers' gaze to the road and the OEM HUD in Red. The motion from one glance location to the next is more evident when viewing the video.

To investigate the unintended consequences of continuously displaying HUD images, segments of driving where the driver is not specifically asked to interact with the HUD will undergo an eye glance reduction. Some segments will be recorded when the HUD is disabled during the HDD condition. The probability of looking at the roadway when a HUD is available versus when it is not available will be investigated.

For the Smart Road testing component, the experimenter will issue a command that will encourage drivers to look down at the display. The amount of time drivers take to return their eyes to the road once the surprise event is presented will be measured.

3.2.1.2 Reading Task Performance

Whether drivers accurately read the display will be scored to motivate drivers to actually accommodate to view the display. The data will also be helpful in determining whether driver's read the display.

3.2.1.3 Longitudinal Vehicle Control

For the public road testing component, drivers' longitudinal vehicle control will be measured in terms of how well they maintain their position relative to the lead pickup truck. Their mean headway, standard deviation of headway, mean speed, and standard deviation of speed will be measured as drivers are asked to engage with the displays at specific points on the course.

For the Smart Road testing component, driver's headway to the lead pickup truck will be measured to assess whether drivers' experience similar conditions prior to the first surprise event.

3.2.1.4 Lateral Vehicle Control

For the public road testing component, drivers' lateral vehicle control will be measured in terms of how well they maintain their position. Drivers' standard deviation of lane position will be measured as drivers are asked to engage with the displays at specific points on the course.

3.2.1.5 Response Time to surprise Events

For the Smart Road testing component, driver's response time to the first surprise event (i.e., the muffler drop) will be measured in terms of their gaze response time (i.e., how long drivers take to look back at the road), their throttle response time, their brake response time, and their swerve response time (i.e., how much time transpires before a measurable change in yaw is detected if the driver swerves). The same measures will be used to assess drivers' response time to the second surprise event (i.e., the intersection phase change). It should be noted that no surprise events will be presented to drivers in the public road testing component.

3.2.1.6 Additional Measures

VTTI will characterize the HUD luminance and contrast ratio so that this information can be used to help explain any performance differences that may be found. VTTI will also record the nominal digit height for the HUD and HDD in terms of visual angle. The HUD will be set at 4.6 degrees below horizon for each driver. However, drivers will be allowed to adjust the HUD such that the display appears just above the driver's front hood. Where the top of the HUD superimposes the road will be measured.

3.2.2 Potential Measurement Issues

- Eye glances to the HUD may be missed if the driver has a shorter stature and the OME HUD is positioned high in the windshield. This issue can be resolved by having the OEM HUD moved down per the recommendation of the manufacturer.
- Some of the driver performance measures, including standard deviation of headway, standard deviation of lane position, and standard deviation of speed require data to be analyzed over a window of time to produce a stable measurement. Because the HUD tasks may be too short (i.e., 1-5 s), there is a concern that the measurements may need to extend beyond the HUD task. A potential solution is to use a longer window (e.g., a 10 s) that begins when the HUD task begins and extends past the end of the task.
- Measuring drivers' eye accommodation to the display inside a moving vehicle in daytime is not possible with the equipment currently proposed. VTTI will continue to investigate possible measurement technology. Candidate technologies will be brought to NHTSA's attention and a discussion will be held to determine whether the study's scope should be changed to include them.
- Drivers between the ages of 50 and 60 years old may be unable to accommodate to the HUD or HDD without corrective vision. The impact of corrective vision on drivers' interaction with HUDs, or the study's ability to assess glances to the displays needs to be pilot tested. If too many complications arise from using this subject pool, VTTI will work with NHTSA to select an alternative driving population.

3.2.3 Equipment

3.2.3.1 Data Acquisition System

The VTTI data acquisition system (DAS) will be the same DAS that served as the collection platform in the SHRP 2 naturalistic driving study. The following data elements are captured by the DAS.

- *Video,* captured using four in-vehicle cameras, record the driver's face and torso, a wide-angle view of the forward roadway, a close-up view of the driver's eyes, and the driver's vantage point using a camera mounted to the driver's head via a headband.
- *Accelerometers* in the vehicle are used to detect longitudinal and lateral forces.
- *Forward Radar* is used to monitor the headway to a lead vehicle.
- *Lane Tracker Machine Vision* is used to estimate the vehicle's distance to existing lane markings.
- *Vehicle network data from the On-Board Diagnostics (OBD-II) port* are used to monitor vehicle measures such as vehicle speed, throttle application, and brake application.
- *Global Positioning System (GPS)* technology indicates the vehicle's location.

3.2.3.2 Displays

The OEM HUD will be the HUD equipped on a 2010 Buick Lacrosse (Figure 9). This vehicle is a part of the VTTI vehicle fleet. The 2D image is optically focused at 2.5 m, which is just beyond the vehicle's hood. A button to the left of the steering wheel can control the HUD brightness and disengage the HUD altogether. Drivers can press a menu button on a left lever to cycle through four displays. Each display presents various information and arrangements. The content presented includes the following:

- Vehicle speed

- Distance to next turn
- Street name of next turn
- Next turn direction
- Engine RPM
- Radio Channel

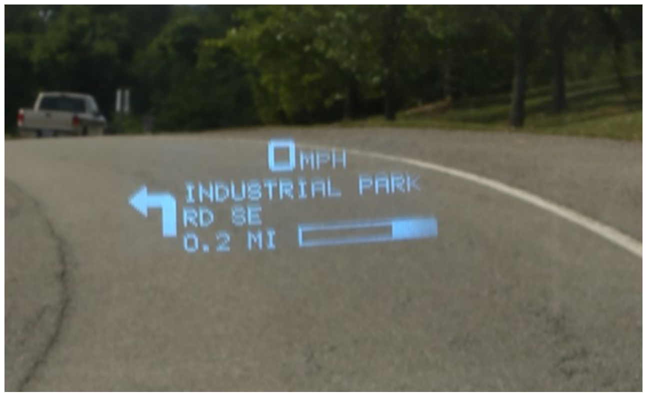


Figure 9. 2010 Buick Lacrosse HUD

The OEM HDD will also be the HDD equipped in the 2010 Buick Lacrosse (Figure 10). The 2D image is presented in the instrument cluster behind the steering wheel. Drivers can press a menu button to cycle through the type of information displayed. The content presented includes the following:

- Vehicle speed
- Distance to next turn
- Street name of next turn
- Next turn direction
- Engine RPM

Figure 10. 2010 Buick Lacrosse HDD

The aftermarket HUD will be the Garmin Navigation HUD (Figure 11). This unit sits on the dash and reflects the HUD images off the windshield or a plastic screen mounted to the device. The device connects to a smartphone and is operated by the Garmin Streetview app. VTTI is in possession of a smartphone, but would need to purchase the Streetview app. The HUD only displays information related to navigation, including:

- Vehicle speed
- Distance to next turn
- Street name of next turn
- Next turn direction
- Estimated time of arrival
- Current speed limit
- Over speed limit indicator
- Lane assist arrows
- Safety camera indicator
- Traffic delay indicator

Figure 11. Garmin Navigational HUD

It should be noted that if NHTSA desires to enlarge the proposed project's scope to use more advanced HUD technology and measurement equipment, VTTI is willing and able to modify its experimental approach.

3.3 DATA ANALYSIS

Inferential statistical tests will be performed to investigate whether drivers' visual scanning behavior, longitudinal vehicle control, lateral vehicle control, and response to a surprise event significantly differ when they interact with an OEM HUD, an aftermarket HUD, or an OEM HDD. The analyses will be performed to identify the main visual distraction issues with HUDs vs. HDDs. For the within-subject public road testing component, repeated measures ANOVAs will be used to investigate how driver performance differs across the three display conditions. Whether the HUD obstructs the view of objects on the road will also be assessed across the two HUD conditions. Nonparametric tests will be used to assess how drivers' ratings differ across the three display conditions. For the between-subjects Virginia

Smart Road testing component, one-way ANOVAs will be used to investigate how driver response performance differs across the three display conditions and a fourth baseline condition. Whether the HUD obstructs the view of objects on the road will also be assessed by counting the number of trials that this occurs across the two HUD conditions. Appropriate nonparametric tests will be performed to investigate difference in drivers' subjective opinions across the conditions.

3.4 INTERPRETING RESULTS

Overall, this study will allow an investigation of how drivers' interaction with HUDs of different focal depths and HDDs differ. The public road component will allow the investigation of drivers' visual scanning behavior and whether HUDs generate any unintended disruptions in this behavior. The Virginia Smart Road component will allow the investigation of potential delays in response performance to surprise events, which can provide insight on the distraction potential of HUDs and their impact on transportation safety. It is believed that the performance measures selected for this study will be sensitive to driver interaction with the displays, particularly for the surprise event response task. However, the meaning of the findings will need to be carefully interpreted. Statistical differences in driving performance do not necessarily translate into changes in crash risk. VTTI is aware of this relationship and has a demonstrated ability to not generalize beyond what the data show. Although, VTTI will interpret the data to help NHTSA develop potential minimum performance specifications for HUD systems. VTTI has an extensive track record in supporting NHTSA in this regard and firmly believes it will be successful in this regard.

3.5 EXPERIMENTAL APPROACH SUMMARY

The following summary is provided to clearly state how the VTTI team will address the objectives of the RFP.

- Identify the main visual distraction issues involved with using HUD versus HDD HMI.
    - Accomplished by comparing driver visual behavior, longitudinal vehicle control, lateral vehicle control, and response performance to surprise events when using HUDs and a HDD.
- Identify metric(s) that are sensitive to potential distractions resulting from using a HUD versus a HDD.
    - Accomplished by assessing which dependent measures produced measurable differences across the display condition and providing an interpretation for the observations.
- Determine whether a surrogate measure of distraction increases when drivers use candidate HUD systems (i.e., when a driver is viewing the HUD and road with a potential target or road and HUD with a target).
    - The surrogate measures will consist of those listed to study drivers' visual behavior, longitudinal vehicle control, lateral vehicle control, and response performance to surprise events. The study will identify any measures that show marked performance differences when using a HUD compared to baseline.
- Identify a method to determine or manipulate the driver's focal distance to near or far displays.
    - Drivers' focal distance will be manipulated by assessing their performance with an OEM HUD focused at 2.5 m, an aftermarket HUD focused on the windshield, and the HDD. Eye tracking equipment to potentially measure a driver's focal distance was identified,

but was not scoped into the study as it has yet to be validated. The VTTI team is able to pilot test this equipment if NHTSA desires.

- Identify any unintended consequences associated with HUD systems.
  - Unintended consequences in visual scanning behavior will be determined by assessing whether drivers show a tendency to overly concentrate on the HUD when it is available compared to how often they focus on a HDD while driving on public roads. The identification of any other performance measures that show marked decrements relative to when drivers use a HDD may also uncover unintended consequences.
- Describe potential minimum performance specifications for HUD systems and their advantages/disadvantages.
  - Minimum performance specifications will be presented if it is found that drivers perform substantially worse with one HUD versus the other in this study. However, the follow-on research described below may be necessary to develop the performance specifications NHTSA seeks for HUDs.

3.6 FOLLOW-ON RESEARCH

It is envisioned that the work proposed in this document would fit into a phased research program. There are numerous factors that stand to affect the distraction potential of HUDs. Many of these factors were not included in this proposal in order to keep the scope reasonable. Future research could consider investigations of the following:

3.6.1 Size of HUD Image

The size of the HUD image can impact the degree to which the HUD clutters the view of the road. Research should be performed to assess whether the image's size should be bound to a limit. Texas Instruments has developed a prototype HUD capable of projecting up to 20 degrees along the horizon (most HUDs currently project out 5 degrees) (Figure 12). Their prototype could be used to control the size of the horizontal image to see if driver performance (such as response to surprise event) decreases when the images increase in size.

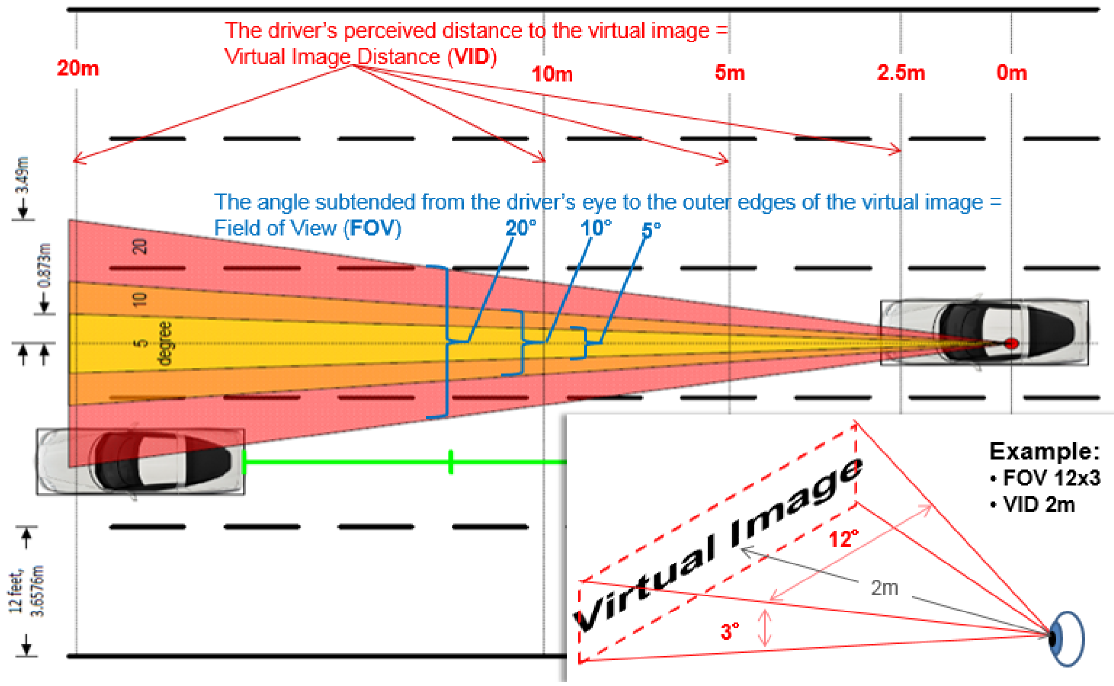


Figure 12. Texas Instruments' Protoype HUD capable of projecting out 20 degrees along the horizon (figure Courtesy of Texas Instruments)

3.6.2 Location of HUD Image

The HUD images proposed in this study are all centrally located along the bottom of the windshield. However, the degree to which graphics clutter the road scene or capture drivers' attention when located on the left, right, or along the top of the windshield should be studied. Dropdown visors that reflect HUD graphics, such as the Pioneer Cyber Navi display (Figure 13), could serve such an investigation.

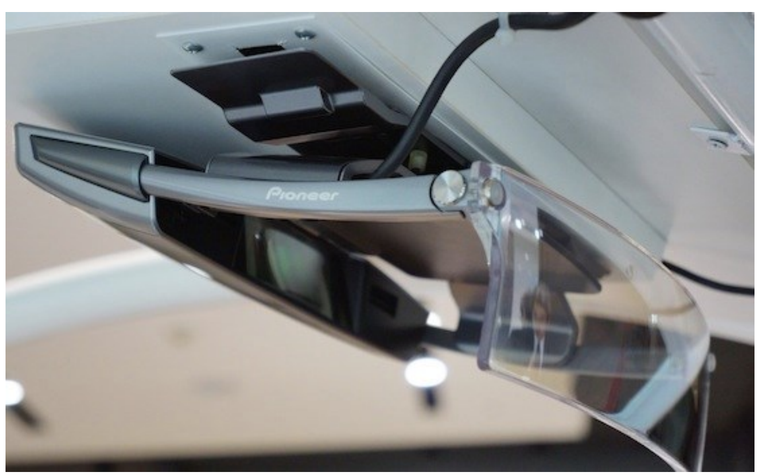


Figure 1. Pioneer Cyber Navi Drop-Down visor

3.6.3 Number of HUD Image

Whether clutter becomes too great if more than one HUD image is projected stands to be investigated. It is foreseeable that future displays are conceived to project onto both the left and right side of the windshield (an extreme example is shown in Figure 14). Whether this affects the perception of peripheral targets should be assessed.

Figure 2. Hypothetical HUD Displaying Numerous Images

3.6.4 HUD Image Brightness

The role of HUD brightness on impacting drivers' perception of the road, particularly at night, should be well understood. It is foreseeable that a maximum brightness should be specified to minimize the impact on drivers' darkness adaptation.

3.6.5 Moving vs. Static Images

Whether moving HUD imagery distracts or does not distract drivers should be investigated. This is because technology to display moving maps on a HUD already exists. It is possible that such imagery needlessly captures drivers' attention and makes them less attentive of the road.

3.6.6 Driving Scene

The role of driving scene's visual complexity in the perception and processing of HUD images merits investigation. The HUD's signal to noise ratio can be expected to substantially drop when travelling in urban environments with many moving objects.

Overall, VTTI is ready to develop these future research ideas into more formal experimental designs. VTTI can also work with NHTSA to select aspects of the proposed ideas into the current study.

4 PART III: QUALIFICATIONS OF PERSONNEL

VTTI has assembled an impressive team of key personnel with the objective of providing NHTSA with the most qualified, comprehensive, and experienced project staff possible at the best value to the government. The Principal Investigator and Senior Technical Program Manager for this proposal will be

Dr. Gregory Fitch. Dr. Fitch is experienced overseeing transportation studies and has the expertise and personnel in place to facilitate this project. He has extensively applied human factors to the study of transportation safety, notably in the areas of driver distraction and driver performance with technology. Dr. Fitch was the lead investigator for the NHTSA study titled *The Impact of Hand-held and Hands-free Cell Phone Use on Driving Performance and Safety-Critical Event Risk* (Fitch et al., 2013). This study investigated driver distraction resulting from cell phone use using multiple analyses that investigated an often contentious issue using a fair and balanced approach. He is intimately familiar with the NHTSA Phase I Distraction Guidelines and the underlying research. He is also currently supporting NHTSA on various driver distraction projects and is aware of how the project requirements relate to one another. Dr. Fitch has the technical and managerial skill set required to lead this effort. He has managed major projects for the U.S. DOT/NHTSA as a primary investigator. In his role as Senior Technical Program Manager, Dr. Fitch will be aware of, understand, and abide by U.S. DOT/NHTSA established policies, regulations, and safety practices, and will have full authority to act relative to the performance of services under this contract. He will be available to answer questions and will assist and serve as the primary point of contact for the COTR. Dr. Fitch will also serve as the project manager. Dr. Fitch will manage daily operations pertaining to research planning, reviewing literature, data collection, data reduction, analysis, and reporting.

Dr. Nicholas Ward is a Professor of Mechanical and Industrial Engineering at Montana State University and the Director of the Center for Health and Safety Culture (Western Transportation Institute). He will serve as a Co-PI for this investigation. Professor Ward has led interdisciplinary and international research consortia to study traffic safety research including intelligent transportation systems and advanced information displays including HUD. The work has included the design and implementation of evaluation methods to examine the effect of vehicle displays on driver visual, cognitive, emotional, and behavioral performance. These research methodologies have used driving simulators, test tracks, and naturalistic driving approaches. This work includes European Union funded research (PROMETHEUS) and recent work for NHTSA on connected vehicle systems. Professor Ward is a national leader in the definition and advancement of traffic safety culture as a new traffic safety paradigm. Professor Ward's research and outreach in this area has contributed to the development of the National TZD Strategy to transform traffic safety culture.

Mr. Kevin Grove is an Associate Researcher in the User Experience Group in the Center for Automated Vehicle Systems at VTTI. He has worked at VTTI since 2013. Prior to that, he worked in the field of system safety since 2005. He has worked in both transportation safety and construction safety research. Mr. Grove has contributed to the analysis of driver compensatory behavior of commercial motor vehicle drivers when conversing on a cell phone. He has also heavily worked on the NHTSA study titled *Field Study of Heavy-Vehicle Crash Avoidance Systems*. Through this project, he has focused on commercial driver safety and automated systems for improving driver awareness and response. Prior to joining VTTI, his previous projects included research with UPS delivery drivers to improve driving safety and designing new training courses.

Mr. Andy Petersen is a Senior Instrumentation Engineer and the Direction of the Center for Technology Development at VTTI. He will oversee the data acquisition system installation for this study. He will also oversee the creation of the study database to facilitate data reduction and analysis on a secure server at

VTTI. Mr. Petersen has 25 years of experience in developing equipment to support transportation research.

Other key personnel include: 1) Mr. Carl Cospel, an Electrical Engineer who will help oversee the data acquisition system installation; 2) Mrs. Tammy Russell, a Program Associate in the Center for Technology Development, who will serve as the Center for Technology Development's project manager and will help coordinate this study's installation requirements amongst other studies at VTTI, and 3) Mr. John Lilostolen, a Computer/Software Technician in the Center for Technology Development, who will be the primary technician installing the data acquisition system.

Finally, Dr. Suzie Lee, a Project Director in the Center for Data Reduction and Analysis Support at VTTI, will direct efforts towards Institutional Review Board (IRB) compliance and data access policies and procedures. Dr. Lee recently directed the coordination of IRB efforts for the Second Strategic Highway Research Program (SHRP 2) Naturalistic Driving Study and has the experience and skills to serve in the proposed role.

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6 APPENDIX: PERSONNEL RESUMES

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Research Scientist, User Experience Group Leader
Center for Automated Vehicle Systems
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Education

Ph.D., Industrial and Systems Engineering, Virginia Tech, 2009

M.S., Industrial and Systems Engineering, Virginia Tech, 2005

B.A.Sc., Industrial Engineering, University of Toronto, 2002

Key Qualifications

Dr. Gregory Fitch is a Research Scientist and User Experience Group Leader in the Center for Automated Vehicle Systems at the Virginia Tech Transportation Institute, where he has been conducting human factors research pertaining to transportation safety since 2002. He received his Ph.D. from the Grado Department of Industrial and Systems Engineering at Virginia Tech in 2009. Dr. Fitch has formal training in human factors/industrial engineering, systems design, human-computer interface design for complex systems, experimental design, and inferential statistics. He is an experienced researcher of driver performance with technology. Dr. Fitch specializes in driver distraction (with a focus on the risk of mobile device use and driver interaction with wearable technology), collision-avoidance system driver vehicle interfaces and algorithms, driver performance leading to improper lane changes and rear-end conflicts, haptic/auditory/visual displays, indirect visibility systems, driver drowsiness, and the collection and analysis of naturalistic driving data.

Dr. Fitch is currently the Chair of the Human Factors and Ergonomics Society Surface Transportation Technical Group (HFES STTG), the Chair of the ITS America Human Interaction with Intelligent Transportation Systems Committee, the Secretary of the Transportation Research Board (TRB) of the National Academies Vehicle User Characteristics Committee, the Communication Coordinator of the TRB Cyber Security Subcommittee, and the Past Program Chair of the HFES STTG. Dr. Fitch is a reviewer for the *Human Factors Journal*, the *Applied Ergonomics Journal*, the *Journal of Experimental Brain Research*, the *IEEE Transactions on Instrumentation and Measurement Journal*, the TRB Vehicle User Characteristics Committee, and the HFES Surface Transportation Technical Group. Dr. Fitch is an experienced manager of large-scale projects, and has a proven track record of efficiently using labor, time, and technology to successfully complete a project on schedule within an allocated budget.

Professional Experience

Research Scientist and User Experience Group Leader, Center for Automated Vehicle Systems, VTTI (July 2014 Present)

Senior Research Associate, Automated Vehicle Systems, VTTI (August 2013- June 2014)

Senior Research Associate, Center for Truck and Bus Safety, VTTI (January 2010 – July 2013)

Research Associate, Center for Truck and Bus Safety, VTTI (January 2006 – December 2009)

Graduate Research Assistant, Center for Advanced Safety Systems, VTTI (December 2002 – December 2005)

User Interface Designer, Cognos, Ottawa, ON (May 2000 – August 2001)

Assistant, Human Factors North, Toronto, ON (January 1999 – August 1999)

Assistant, Cognitive Engineering Lab, University of Toronto, Toronto, ON (May 1999 – October 1999)

Selected Publications

Fitch, G. M., Hanowski, R. J., & Guo, F. (2014). The Risk of a Safety-Critical Event Associated with Mobile Device Use in Specific Driving Contexts. *Traffic Injury Prevention*, 1-34. 10.1080/15389588.2014.923566.

Fitch, G. M., Bowman, D. S., & Llaneras, R. E. (2014). Distracted Driver Performance to Multiple Alerts in a Multiple-Conflict Scenario. Human Factors.

Gabbard, J. L., **Fitch, G. M.**, & Kim, H. (2014). Behind the Glass: Driver Challenges and Opportunities for AR Automotive Applications. Proceedings of the IEEE, 102(2), 124-136. 10.1109/JPROC.2013.2294642.

Fitch, G.M., Grove, K., Hanowski, R., & Perez, M. (2014). Investigating Light Vehicle and Commercial Motor Vehicle Driver Compensatory Behavior when Conversing on a Cell Phone Using Naturalistic Driving Data. *Transportation Research Record*.

Fitch, G.M., Soccolich, S.A., Guo, F., McClafferty, J., Fang, Y., Olson, R.L., Perez, M.A., Hanowski, R.J., Hankey, J.M., & Dingus, T.A. (2013). *The Impact of Hand-held and Hands-free Cell Phone Use on Driving Performance and Safety-Critical Event Risk. (Report No. DOT HS 811 757)*. Washington, D.C.: National Highway Traffic Safety Administration.

Fitch, G.M. & Hankey, J.M. (2012). Investigating Improper Lane Changes: Driver Performance Contributing to Lane Change Near-Crashes. Proceedings of the 56th Annual Meeting of the Human Factors and Ergonomics Society.

Fitch, G.M. & Hanowski, R.J. (2011). The risk of a safety-critical event associated with mobile device use as a function of driving task demands. *Proceedings of the 2nd International Conference on Driver Distraction and Inattention*.

Fitch, G.M., Hankey, J.M., Kleiner, B.M., & Dingus, T.A. (2011). Driver comprehension of multiple haptic seat alerts intended for use in an integrated collision avoidance system. *Transportation Research Part F: Traffic Psychology and Behaviour, 14*(4), 278-290.

Fitch, G.M., Schaudt, W.A., Wierwille, W.W., Blanco, M., & Hanowski, R.J. (2011). Human factors and systems engineering of a camera/video imaging system. *Proceedings of the 18th World Congress on Intelligent Transportation Systems*, Washington, D.C.

Fitch, G.M., Blanco, M., Camden, M.C., & Hanowski, R.J. (2011). Field demonstration of a camera/video imaging system for heavy vehicles. *Society of Automotive Engineers International Journal of Commercial Vehicles, 4*(1), 171 - 184. doi: 10.4271/2011-01-2245.

Fitch, G.M., Blanco, M., Morgan, J.F., & Wharton, A.E. (2010). *Driver Braking Performance to Surprise and Expected Events*. Paper presented at the Human Factors and Ergonomics Society 54th Annual Meeting, San Francisco, California.

Fitch, G.M., Blanco, M., Morgan, J.F., Wierwille, W.W., & Hanowski, R.J. (2010). *Human Performance Evaluation of Light Vehicle Brake Assist Systems.* Paper presented at the Transportation Research Board (TRB) 89th Annual Meeting, Washington, D.C.

Fitch, G.M., Kiefer, R.J., Hankey, J.M., & Kleiner, B.M. (2007). Toward developing an approach for alerting drivers to the direction of a crash threat. Human Factors.

Rakha, H., **Fitch, G.**, Arafeh, M., Blanco, M., and Hanowski, R. (2010). Safety Benefit Evaluation of a Heavy Vehicle Forward Collision Warning System. Transportation Research Record: Journal of the Transportation Research Board.

Nicholas Ward, Ph.D.

Western Transportation Institute

Education

Ph.D., Human Factors, Organizational Psychology, Queen's University, 1993

M.S., Psychology (Human Factors, Organizational Psychology), Queen's University, 1990

B.S., Psychology (Social Psychology, Statistics), Simon Fraser University, 1987

Technical Qualifications

Professor Nicholas Ward (F. Erg. S) obtained his Ph.D. in Human Factors psychology from Queen's University (Canada). He is currently a Professor of Mechanical and Industrial Engineering at Montana State University and the Director of the Center for Health and Safety Culture (Western Transportation Institute). Professor Ward has led interdisciplinary and international research consortia to study traffic safety research including intelligent transportation systems and advanced information displays including **head up displays** (HUD). The work has included the design and implementation of **evaluation methods** to examine the effect of vehicle displays on driver visual, cognitive, emotional, and behavioral performance. These research methodologies have used driving simulators, test tracks, and naturalistic driving. This work includes European Union funded research (PROMETHEUS) and recent work for NHTSA on connected vehicle systems. Professor Ward is a national leader in the definition and advancement of traffic safety culture as a new traffic safety paradigm. Professors Ward's research and outreach in this area has contributed to the development of the National TZD Strategy to transform traffic safety culture.

Professional Experience

Professor, Mechanical and Industrial Engineering, Montana State University (2007 – present)

Associate Research Professor, Mechanical Engineering, University of Minnesota (2001 – 2007)

Lecturer, Psychology, University of Leeds (1996 – 2001)

Research Fellow, Human Sciences, Loughborough University (1993 -1996)

Publications (Head Up Displays)

Ward, N.J., Parkes, A.M., Crone, P. (1995). The effect of background scene complexity and field dependence on the legibility of Head-Up Displays. Human Factors, 37, 735-745.

Ward, N.J. & Parkes, A.M. (1994). Head-Up Displays and their automotive application: An overview of the Human Factors issues. *Accident Analysis and Prevention*, 26, 703-718.

Ward, N.J., Stapleton, L, & Parkes, A.M. (1994). Behavioral and cognitive impacts of night-time driving with HUD contact analogue infrared imaging. 14th ESV Conference, Munich, Germany (May 23-26).

Stapleton, L., **Ward, N.J.**, & Parkes, A.M. Methodological problems associated with the use of eye movement measuring techniques in evaluation contact analogue Head-Up Displays. Vision in Vehicles 5, Glasgow, Scotland (September 9-11).

Bossi, L.L.M., **Ward, N.J.**, & Parkes, A.M. (1994). The effect of enhanced image Head-Up Displays on driver peripheral visual performance. 12th Congress of the International Ergonomics Association, Toronto, Canada (August 15-19).

Ward, N.J., Parkes, A.M., Crone, P. (1994). The legibility of Head-Up Displays within the driving environment: The effect of background scene complexity. Vehicle and Navigation and Information Systems International Conference, Yokohama, Japan (August 31 - September 2).

Stapleton, L., **Ward, N.J.**, & Parkes, A.M. (1998). Automotive Contact Analogue Head-Up-Display Images and Distance Estimation. In A.G. Gale (Ed.) Vision in Vehicles 6, Amsterdam, The Netherlands: Elsevier Press.

Ward, N.J., Parkes, A.M., & Lindsay, P. (1995). The effect of automotive Head-Up Displays on attention to critical events in traffic. International Conference on Experimental Analysis and Measurement of Situation Awareness, Daytona Beach, Florida (Nov. 1-3).

Ward, N.J. (1997). Cognitive capture with automotive head-up displays. International Seminar: Human Factors in Road Traffic II, Braga, Portugal (April 9-11).

Bossi, L.L.M., **Ward, N.J.**, Parkes, A.M., & Howarth. P.A. (1997). The effect of vision enhancement systems on driver peripheral visual performance. In I. Noy (Ed.) Ergonomics of IVHS, Hillsdale, New Jersey: Lawrence Erlbaum Associates, Inc.

Publications (In)

Ward, N.J., Mueller, J., & Velasquez, M. (2013). Response interference under near-concurrent presentation of safety and non-safety information. Transportation Research Part F: Traffic Psychology and Behaviour, 21, 253 – 266.

Ward, N.J. (2013). The Psychology of Intelligent Vehicles and Traffic Safety. 121st Annual Convention of the American Psychological Association. Honolulu, Hawaii (July 31 to August 4).

Ward, N.J. (2013). More than distraction: The effects of "extraction" and "insertion" by vehicle automation. 2013 Governors Highway Safety Association Annual Meeting, San Diego, CA (August 25 – 28).

Ward, N.J. (2012). Evaluating the effectiveness of driver assistance systems. ITS American 2012 Annual Meeting, Washington, D.C. (May 21 – 23).

Lee, J.D., McGehee, D.V., Brown, J.L., Richard, C.M., Omar, A., **Ward, N.J.**, Hallmark, S., & Lee, J. (2011). Matching simulator characteristics to highway design problems, Transportation Research Record: Journal of the Transportation Research Board, 2248, 53 – 60.

Stanley, L. & **Ward, N.J.** (2010). An evaluation of a cooperative avoidance warning system. *International Journal of Vehicle Safety*, 5, 86 – 99.

Kuge, N., Yamamura, T., Boer, E.R., **Ward, N.J.**, & Manser, M.P. (2007). Study on driver's car following abilities based on an active haptic support function. SAE Transactions Journal of Passenger Cars - Electronic and Electrical Systems, 115(7), 157 – 169.

Creaser, J.I., Rakauskas, M.E., **Ward, N.J.**, Laberge, J.C., & Donath, M. (2007). Concept evaluation of intersection decision support (IDS) systems to support drivers' gap acceptance decisions at rural stop-controlled intersections. Transportation Research Part F: Traffic Psychology, 10, 208 – 228.

Ward, N.J., (2007). "Intelligent technology for safe traffic" – Minnesota state senate committee hearing on Intelligent technology and traffic safety, Minnesota State Senate Transportation Committee, Policy and Budget Division (January 30), St. Paul, MN.

Boer, E.R., **Ward, N.J.**, Manser, M.P., & Kuge, N. (2006). Driver-model-based assessment of behavioural adaptation. Transaction of Society of Engineers of Japan, 37, 21 – 26.

Ward, N.J., Shankwitz, C., Gorgestani, A., Donath, M., de Waard, D., & Boer, E. (2006). Bus Rapid Transit and bus driver stress. Ergonomics, 49, 832-859.

Ward, N. J., Gorgestani, A., Shankwitz, C., & Donath, M. (2004). A preliminary demonstration study of the usability of a vision enhancement system for state patrol vehicles. *Journal of Intelligent Transportation Systems,* 8, 169-185.

Ward, N.J. & Parkes, A.M. (2001). Special edition on car phone design (Preface). *International Journal of Vehicle Design*, 26, 1-3.

Parkes, A.M. & **Ward, N.J.** (2001). Case study: A safety and usability evaluation of two different car phone designs. *International Journal of Vehicle Design*, 25, 12-29.

Ward, N. J. (2000). Automation of task processes: An example of Intelligent Transportation Systems. Human Factors and Ergonomics in Manufacturing, 10, 395-408.

Ward, N.J. & Hirst, S.J. (1998). An exploratory investigation of information attributes of reverse/parking aids. International Journal of Vehicle Design, 19, 41-49.

Ward, N.J. & Hirst, S.J. (1997). The philosophy and function of in-vehicle information systems. Behaviour and Information Technology, 16, 88-97.

Kevin Grove, M.S.
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Education

Ph.D. Candidate, Industrial & Systems Engineering (Management Systems Option), Virginia tech, Blacksburg VA, Expected Graduation 2015

M.S., Industrial & Systems Engineering (Human Factors Option), Virginia Tech, Blacksburg VA, 2008

B.S., Industrial & Systems Engineering, Virginia Tech, Blacksburg VA, 2005

Technical Qualifications

Kevin Grove has been working in the field of system safety since beginning graduate work in 2005 at Virginia Tech. He has worked in both transportation safety and construction safety research. His previous projects include research with UPS delivery drivers to improve driving safety and design a new training course. His current work is focused on tractor trailer safety and automated systems for improving driver awareness and response.

Professional Experience

Research Associate, Automated Vehicle Systems Group, VTTI, Blacksburg VA (2013-Present)

Adjunct Instructor, Grado Department of Industrial & Systems Engineering, Virginia Tech, Blacksburg VA (2010-2013)

Graduate Teaching Assistant Grado Department of Industrial & Systems Engineering, Virginia Tech, Blacksburg VA (2008-2010)

Graduate Research Assistant, Grado Department of Industrial & Systems Engineering, Virginia Tech, Blacksburg VA (2005-2008)

Selected Publications

Fitch, G.M., **Grove, K.**, Hanowski, R., & Perez, M. (2014). Investigating Light Vehicle and Commercial Motor Vehicle Driver Compensatory Behavior when Conversing on a Cell Phone Using Naturalistic Driving Data. Transportation Research Record: Journal of the Transportation Research Board.

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Education

B.S., Electrical Engineering, Iowa State University, Ames, IA, 1991

Technical Qualifications

Mr. Andrew Petersen is the Director of the Center for Technology Development at the Virginia Tech Transportation Institute (VTTI). His current duties include all of the Institute research equipment hardware and software design and implementation. Some of his current design work includes an instrumentation system for the 100-Car Naturalistic Driving Study (experience ranking 1), machine-vision software development, and instrumentation for the Sleeper Berth Study. He has also worked with hardware and software for the Short Haul Trucking Study, multiple data acquisition and force/position control systems designed specifically for controlling the steering wheel, accelerator pedal and brake pedal, and installation of control systems on a variety of vehicles ranging from a Ford Taurus to a Volvo Class 8 semi-tractor.

In 1988, Mr. Petersen became an entrepreneur with Petersen Technology in Iowa City, Iowa. He performed custom digital and analog circuit design, circuit board layout design, and software development, including a complete materials requirement planning system and developmental software for education. Mr. Petersen developed an original instrumented vehicle hardware design and implemented this design into a Ford Taurus wagon. He also developed real-time data collection, user interface, data analysis, and display software to support the instrumented vehicle.

Since 1991, Mr. Petersen has designed a variety of hardware and software products. He currently leads a group of engineers and software specialists at VTTI. He has experience with real-time data acquisition hardware, DSPs, FPGAs, software, firmware, machine-vision programming, algorithmic programming, control, robotics and automation. He has been involved in a variety of human factors studies at VTTI. He is an expert at covert installation of video surveillance, data collection hardware, and in-vehicle displays.

Professional Experience

Director, Center for Technology Development, VTTI, Blacksburg, VA (1996 – Present)

Group Lead, Center for Computer Aided Design, University of Iowa, Ames, IA (1991 – 1996)

Manager, Petersen Technology, Iowa City, IA (1988 – Present)

Selected Publications

Dingus, T. A., Klauer, S. G., Neale, V. L., **Petersen, A.**, Lee, S. E., Sudweeks, J., Perez, M. A., Hankey, J., Ramsey, D., Gupta, S., Bucher, C., Doerzaph, Z. R., Jermeland, J., and Knipling, R.R. (2005). *The 100-Car Naturalistic Driving Study: Phase II – Results of the 100-Car Field Experiment.* (Interim Project Report for DTNH22-00-C-07007, Task Order 6; Report No. TBD). Washington, D.C.: National Highway Traffic Safety Administration.

Neale, V. L., Klauer, S. G., Knipling, R. R., Dingus, T. A., Holbrook, G. T., **Petersen, A. D.** (2002). *The 100 car naturalistic driving study: Phase I – experimental design* (DOT HS 809 536). Washington, D. C.: U.S. Department of Transportation, National Highway Traffic and Safety Administration.

Gellatly, A.W., **Petersen, A.**, Ahmadian, M., and Dingus, T.A. (1997). The Virginia Tech Center for Transportation Research Smart Truck—An Instrumented Heavy Vehicle for Evaluation of Intelligent Transportation Systems*, Proceedings of the 1997 SAE International Truck and Bus Meeting and Exposition,* Cleveland, OH, November 1997.

Carl Cospel, M.B.A
Group Leader, Data Acquisition
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Virginia Polytechnic Institute and State University
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Education

M.B.A., Systems Engineering Management, Virginia Tech, Blacksburg, Virginia, May, 2011

B.S., Computer Engineering, Virginia Tech, Blacksburg, Virginia, 2003

Technical Qualifications

Mr. Carl Cospel is the leader of the Data Acquisition Group at the Virginia Tech Transportation Institute (VTTI). He is the lead designer and programmer of VTTI's data collection software and manages a software development team. He also supervises a group of technicians, programmers, and engineers in the design, manufacturing, and installation of data acquisition systems for automobile, motorcycle, and tractor trailer studies.

Mr. Cospel's engineering experience and job responsibilities include circuit board design, firmware development, and software development. His programming skills include OOD in C++ and Java, application design for embedded systems, Linux driver programming, and microcontroller firmware design in C and assembly. He has experience with the GNU compiler, Visual Studio .net, and JDK. He works with multiple architectures including x86, ARM, and PIC and has significant experience with the GNU/Linux operating system. Many of his designs require interfacing with communication busses including CAN, RS232/485, SPI, I2C, and Ethernet. He also has experience interfacing with vehicle networks, including J1850, J1850/CAN, J1708, and J1939.

Professional Experience

Data Acquisition Group Leader, VTTI (November 2005 - Present)

Electronic Systems and Systems Integration Group Leader, VTTI (September 2003 - November 2005)

Instrumentation Engineer, VTTI (September 2002 - September 2003)

Research Assistant, VTTI (September 2001 - September 2002)

Tammy I. Russell, B.S.
Project Associate, Center for Technology Development
Virginia Tech Transportation Institute
Virginia Polytechnic Institute and State University
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Phone: (540) 231-1099; Email: trussell@vtti.vt.edu

Education

P.M.P Certification, Project Management Institute, 2010

B.S., Management (Marketing), St. John Fisher College, Rochester, NY, 2000

A.S., Business Administration, Finger Lakes Community College, Canandaigua, NY, 1998

Technical Qualifications

Tammy Russell is a project associate with the Virginia Tech Transportation Institute (VTTI) Center for Technology Development. She assists with the management of project budgets and timelines to ensure work can be completed without cost overruns or unwarranted delays using OneNote, SharePoint, Excel, and Project. She tracks and coordinates administrative tasks such as staff training, meetings, facility use, performance appraisals, perspective hiring, labor reporting, and purchasing reporting. She provides research and writing support for technical development, proposals, and other activities and works with the Center's faculty and staff to standardize project documentation procedures.

Professional Experience

Project Associate, Center for Technology Development, VTTI (August 2008 – Current)

511 Virginia/Smart Road Supervisor, VTTI (May 2006 – August 2008)

Project Coordinator, FedEx Kinko's – Christiansburg, VA (January 2001 – January 2008)

Assistant Manager Grocery Department, Wegman's Food Markets – Canandaigua, NY
(March 1994 – December 2000)

Jon Lillestolen, B.S.
Electronics Technician
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Education

B.S., Electrical Engineering, University of Tennessee, Knoxville, TN, 2003

Key Qualifications

Mr. Jon Lillestolen is an electronics technician with the Virginia Tech Transportation Institute (VTTI). His experience includes:

- Programming in Linux and UNIX environments;
- Embedded systems, programming C/C++, and assembly for PIC microcontrollers;
- The design, layout, and production of printed circuit boards;
- The use of major software packages such as AutoCAD, ArcGIS, Adobe Creative Suite, and MS Office; and
- Programming in Perl, HTML/PHP, SQL, and Python.

Professional Experience

Electronics Technician, VTTI, Blacksburg, VA (2011 – Present)

Graduate Research Assistant, University of Tennessee Imaging, Robotics, and Intelligent Systems Laboratory, Knoxville, TN (2003 – 2004)

Suzanne Lee, Ph.D.
Project Director, Center for Data Reduction and Analysis Support
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Virginia Polytechnic Institute and State University
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Education

Ph.D., Industrial and Systems Engineering, Virginia Tech, Blacksburg, Virginia, 1998

M.S., Industrial and Systems Engineering, Virginia Tech, Blacksburg, Virginia, 1995

B.A., English Literature, Louisiana State University, Baton Rouge, Louisiana, 1980

Technical Qualifications

Dr. Suzanne Lee is a Project Director for the Center for Automotive Safety Research at the Virginia Tech Transportation Institute (VTTI) where she directs efforts towards Institutional Review Board (IRB) compliance and data access policies and procedures. Dr. Lee recently directed the coordination of IRB efforts for the Second Strategic Highway Research Program (SHRP 2) Naturalistic Driving Study. This multi-site effort involved eight IRBs (including the IRB of the National Academies of Science) and a successful Certificate of Confidentiality application. Dr. Lee's other areas of expertise include the transportation human factors, design and implementation of on-road research studies, recruitment, focus groups, statistical analysis, and crash database analysis. Her dissertation included measurements and recommendations regarding locomotive whistle loudness and audibility in heavy vehicles. Recent projects in which Dr. Lee has served as a Principal Investigator (PI), Co-PI, or another key role include teen driving research conducted for the National Institutes of Health and the National Highway Traffic Safety Administration, naturalistic driving research conducted for the National Academies of Science, and road noise research conducted for the Virginia Department of Transportation.

Professional Experience

Project Director, Virginia Tech Transportation Institute, Center for Automotive Safety Research, Blacksburg, VA (2011 – Present)

Research Scientist, Virginia Tech Transportation Institute, Center for Automotive Safety Research, Blacksburg, VA (1999 – 2011)

Visiting Assistant Professor, Department of Industrial and Systems Engineering, Virginia Tech, Blacksburg, VA (1998 – 1999)

Selected Publications

Simons-Morton, B. G., Ouimet, M. C., Zhang, Z., Klauer, S. G., **Lee, S. E.**, Wang, J., Chen, R., Albert, P., and Dingus, T. A. (2011, in press). The Effect of Passengers and Risk-Taking Friends on Risky Driving and Crashes/Near Crashes among Novice Teenagers. *Journal of Adolescent Health.*

Simons-Morton, B. G., et al. (2011, in press). Risky Driving among Novice Teenagers and Their Parents. *American Journal of Public Health.*

Lee, S. E., Simons-Morton, B. G., Klauer, S. G., Ouimet, M. C., and Dingus, T. A. (2011). Naturalistic Assessment of Novice Teenage Crash Experience. *Accident Analysis and Prevention 43,* 1472-1479.

Klauer, S. G., Simons-Morton, B. G., **Lee, S. E.**, Ouimet, M. C., Howard, E. H., and Dingus, T. A. (2011). Novice Drivers' Exposure to Known Risk Factors during the First 18 Months of Licensure: The Effect of Vehicle Ownership. *Traffic Injury Prevention 12,* 159-168.

Lee, S.E., Velasquez, S., Flintsch, G., and Peterson, J. (2008). Road Noise Attenuation Study: Traffic Noise, Trees, and Quiet Pavement (Report Performed for the Virginia Department of Transportation under the supervision of the Virginia Transportation Research Council). Richmond, VA: VDOT.

Gibbons, R.B., **Lee, S.E.**, Williams, B., and Miller, C.C. (2008). *Selection and Application of Warning Lights on Roadway Operations Equipment.* (NCHRP Report 624.) Washington, DC: National Cooperative Highway Research Program, Transportation Research Board of the National Academies.

Lee, S. E., Klauer, S. G., Olsen, E. C. B., Simons-Morton, B. G., Dingus, T. A., Ramsey, D. J., and Ouimet, M. C. (2008). Detection of Road Hazards by Novice Teen and Experienced Adult Drivers. *Transportation Research Record: Journal of the Transportation Research Board, No. 2078,* pp. 26–32.

Perez, M. A., Doerzaph, Z. R., **Lee, S. E.**, and Neale, V. L. (2007). Rapid Prototyping Improves Research on Red-Light-Running Behavior. *Ergonomics in Design.* 15(4) 23-27.

Dingus, T. A., Klauer, S. G., Neale, V. L., Petersen, A., **Lee, S. E.**, et al. (2006). *The 100-Car Naturalistic Driving Study: Phase II – Results of the 100-Car Field Experiment.* (Report No. DOT HS 810 593). Washington, D.C.: National Highway Traffic Safety Administration.

Medina, A. L., **Lee, S. E.**, Wierwille, W. W., and Hanowski, R. J. (2004). Relationship Between Infrastructure, Driver Error, and Critical Incidents. *Proceedings of the Human Factors and Ergonomics Society 48th Annual Meeting*, pp. 2075-2079. Santa Monica, CA: HFES.

Lee, S. E., Robinson, G. S., and Casali, J. G. (2003). An analytical look at live and CB speech intelligibility in contemporary commercial truck cabs based on the Articulation Index. *The Ergonomics of Sound* (E. Haas & J. Edworthy, eds.), pp. 146-150. Santa Monica, CA: Human Factors and Ergonomics Society.

Neale, V. L., Dingus, T. A., Garness, S. A., Hanowski, R. J., Keisler, A. S., **Lee, S. E.**, et al. (2002). *Impact of Sleeper Berth Usage on Driver Fatigue.* (Final Report for Federal Motor Carrier Safety Administration contract RT-02-050). Washington, D.C.: Department of Transportation.

Lee, S. E., Robinson, G. S., and Casali, J. G. (2001). Noise: Metrics and Equipment. Entry in *International Encyclopedia of Ergonomics and Human Factors* (W. Karwowski, ed.) pp. 1870-1874. New York: Taylor and Francis.

Lee, S. E. (1998). Role of driver hearing in commercial motor vehicle operation: An evaluation of the FHWA hearing requirement. *Doctoral dissertation*, Virginia Tech, Department of Industrial and Systems Engineering, Blacksburg, VA. (Available at http://scholar.lib.vt.edu/theses/available/etd-72598-154557/unrestricted/etd.pdf)

Robinson, G. S., Casali, J. G., and **Lee, S. E.** (1997). Role of driver hearing in commercial motor vehicle operation: An evaluation of the FHWA hearing requirement. Report for Federal Highway Administration contract DTFH61-95-C-00172 (NTIS Order No. PB98-114606). Washington, D.C.: Federal Highway Administration.