Science and Engineering Integrated Research Facility for Human Factors in Rural Traffic Safety

by

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A final report prepared for the

M. J. Murdock Charitable Trust

703 Broadway, Suite 710

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FINAL REPORT FORM AND CERTIFICATION OF FUNI
RECEIVED AND GRANT EXPENDITURES
FOR RESEARCH GRANTS

Complete this form and return with required attachments. This form, containing the signed certification at the bottom of this page, is required before closing the file on this grant. This form should be submitted after all Trust funds have been received and expended.

Grantee: Montana State University-Western Transportation Institute **Reference No.:** 2008090

Grant Title: **Science and Engineering Integrated Research Facility for Human Factors in Rural Traffic Safe**

NARRATIVE REPORT OF RESULTS

Attach, on ten pages or less, a complete description of progress made on this project since project inception or date grant was aw (This report should be comprehensive, and not reference any previous Progress Reports.) Items to address include:

1. The time frame on which this report is based
2. Equipment purchase(s) and installation schedule(s), if appropriate
3. Brief summary of results of research accomplished, if appropriate
4. Impact of research project(s) on your department, researchers, students
5. Any leveraging effect this award had on obtaining other grant support
6. Probable future of the research program(s) with potential source(s) of support
7. List of papers in preparation, in press, or published that acknowledge this award

FINANCIAL ACCOUNTING OF GRANT EXPENDITURES

Attach, on one page, the following three columns: 1) The major components of the project budget upon which this award was ba (indicate any approved budget amendments), 2) How Trust funds were applied to the budget categories, and 3) Amounts and sou of other funds that were received and applied to this project budget.

CERTIFICATION OF TRUST FUNDS RECEIVED AND GRANT EXPENDITURES

Total grant awarded: $495,000 **Total project cost:** $534,500

Total of grant funds received to date from Trust: $495,000

Signature of person responsible for submitting report and certifying expenditure of funds:

With this signature, I certify that all funds received from the M. J. Murdock Charitable Trust were directly applied to the app budget as indicated above and on the attached sheet (also sign attached financial sheet).

Name ***(Printed):*** Laura Stanley **Title:** Assistant Professor

Name ***(Signed):*** [signature] **Date:** December 17, 2013

INTRODUCTION

This final report summarizes the M. J. Murdock Charitable Trust Grant expenditures for the purchase and instrumentation of equipment for the Western Transportation Institute's (WTI) Human Factors in Rural Traffic Safety research program between May 2009 and December 2013. The M. J. Murdock Charitable Trust provided a total of $495,000 in funds and the College of Engineering (COE) provided matching funds in the amount of $39,500. The equipment installed at WTI secured $558,590 in research funding from sponsors such as the National Science Foundation and the Federal Highway Safety Administration. An additional $499,523 is pending from a grant written to the National Science Foundation; additional funding is anticipated in the future. This project, in turn, created funding opportunities for 18 graduate and undergraduate students and was part of several science and math outreach programs that included over 600 Science, Technology, Engineering, and Math (STEM) students. Table 1 provides the financial accounting of the grant expenditures including the project budget and the Murdock Charitable Trust and College of Engineering matching funds.

Table 1. Grant Expenditures

Budget Item:	**Project Budget**	**Murdock Funds**	**COE Matching Funds**
Computer Lab Equipment & Misc. Software	17,073	20,549	6,646
Data Acquisition Systems and Installations	106,407	110,708	2,062
Psychophysical System	22,292	20,318	567
Simulator Tuning/Software Development	19,874	26,012	7,521
Server	3,899	3,899	-
Vehicles, Maintenance, Data Acquisition Equip.	31,299	43,998	10,290
Eye Tracker Head Mounted & Maintenance	25,000	25,655	-
Eye Tracker Naturalistic & Maintenance	60,000	78,646	6,221
Experimenter Interface	74,500	59,093	-
Driving Health Inventory	500	1,000	-
Cogstate Software	500	500	-
Observer XT Software	18,155	13,810	-
VII Portable Trailers	155,000	91,560	-

EQUIPMENT PURCHASED

The Murdock research grant funded the purchase of two instrumented vehicles, three Digital Acquisition Systems (DAS), two eye tracking systems and two physiology monitoring devices based on the timeline show in Figure 1. In addition to the vehicles' dedicated instrumentation, the peripheral equipment (eye trackers and physiology devices) allows researchers to study behaviors and eye movements of drivers operating a fleet vehicle or a driving simulator at WTI. The Impala instrumented vehicle was purchased May 5, 2010. The SmartEye eye tracking system was purchased and installed by October 2011 and the DAS was purchased and installed by February 6, 2012. The Sierra instrumented vehicle was purchased on October 11, 2011. The DAS was installed by September 21, 2012. The TranScecurity DAS is portable between vehicles and was purchased September 25, 2009, and has been installed and removed for EMS research. Physiological monitoring equipment was purchased November 3, 2009 (BIOPAC), and October 17, 2011 (BioHarness). The other eye tracking system, ASL Mobile Eye, was purchased November 23, 2010.

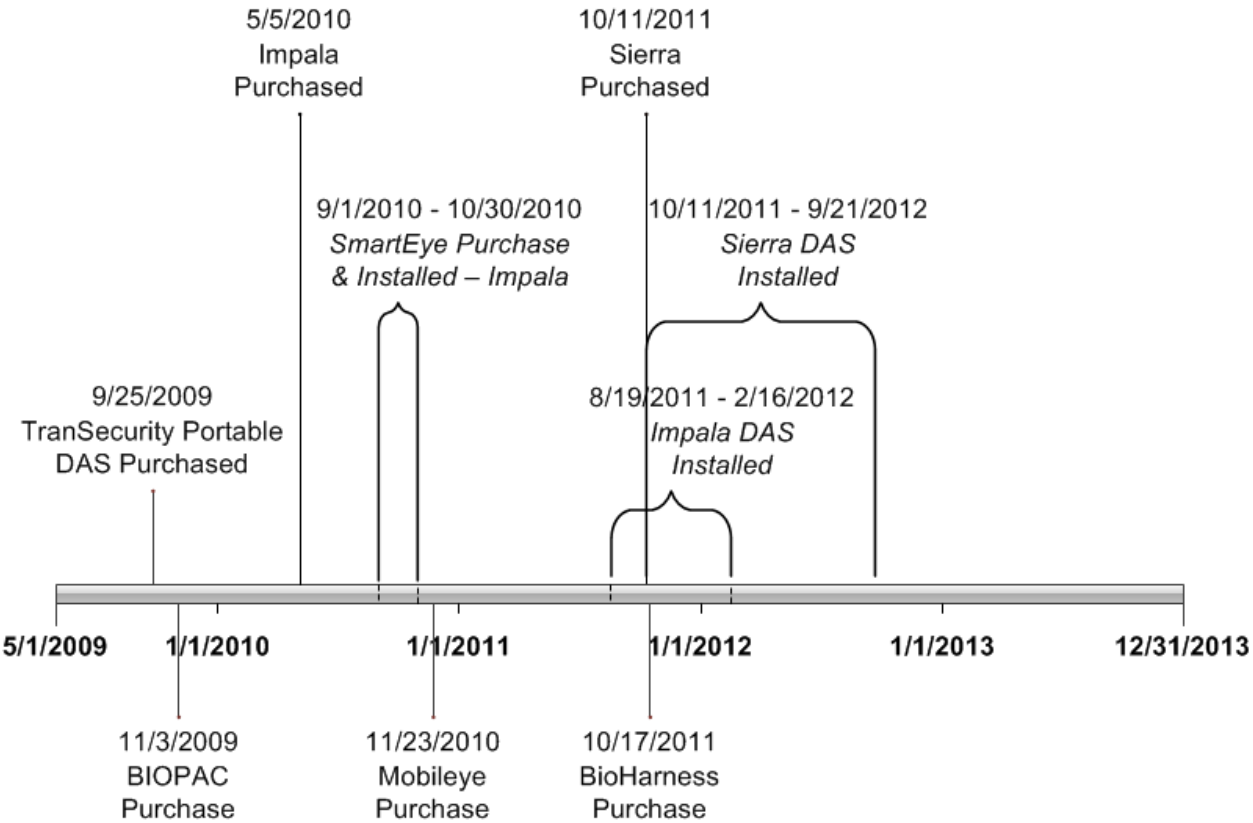

Figure 1. Equipment Purchase and Installation Schedule, May 2009 through December 2013

INSTRUMENTED VEHICLES

Two fleet vehicles, a 2009 Chevrolet Impala sedan and a 2008 GMC Sierra pickup (Figure 2), were purchased and equipped with DAS that record data from video cameras, vehicle controls, integrated sensors, and the vehicle diagnostic (OBDII) system. Also installed was a dual brake on the passenger side (also known as a driving instructor's brake).

Figure 2. Instrumented Fleet Vehicles: 2008 GMC Sierra (left) and 2009 Chevrolet Impala (right)

DIGITAL ACQUISITION SYSTEMS

The DAS in the Impala and Sierra collect information about driver behavior and driving performance through nine dedicated equipment components: radar, accelerometer, global positioning system, light meter, data acquisition board, video cameras (inside and outside the vehicle cabin), cabin microphone, Bluetooth and the vehicle's controller area network bus (CAN bus). A list of equipment that makes up the instrumented vehicle DAS components is available in Appendix A.

Driver performance is based on human perceptual and physical capabilities and limitations. The way a driver performs is measured and recorded with all of the DAS components. Researchers can then determine driving tasks and actions that affect safe driving.

Figure 3. Digital Acquisition System Locations in the GMC Sierra (left) and Chevrolet Impala (right)

Speed is a key indicator of driver behavior and performance. Though it is not the only variable of interest, it will be used to explain the research function of the equipment in the vehicles. Drivers tend to reduce speed as workload increases, and the way drivers adjust their speed is indicative of a number of factors. Adjusting speed can relate to motivation level, including motivations other than those that are transportation related, or subjective risk perception. The DAS record vehicle speed (CAN bus), changes in speed (accelerometers) and distance from other vehicles (radar) using different pieces of equipment.

Data about vehicle speed is collected using the CAN bus. The CAN bus is connected to sensors and systems that are part of the On-Board Diagnostic System. Data about the vehicle's gear, speed, engine revolutions per minute, engine throttle position, throttle pedal position, brake lamp and turn signal indicators, cruise control status, high beam status and ambient air temperature is collected. The pedal positions are relevant to learning about how drivers choose to control their speed. While the CAN bus tells researchers when the brake light is illuminated, the amount of pressure applied to the brake pedal better characterizes driver behavior. Brake pedal pressure is determined by using load cells under the rubber on the brake pedal, which convert the force from the driver's foot into electrical signals that are sent to the data acquisition board and provides force values in the DAS (Figure 4).

Figure 4. Data acquisition board that converts electrical signals from the brake pedal into measures of applied force

Accelerometers measure how quickly drivers change their speed. Abrupt decelerations tend to indicate late recognition of a situation or insufficient monitoring of speed and distance. The accelerometers installed in the Impala and Sierra provide information about the forces on the vehicles in the longitudinal, lateral and vertical directions. The accelerometer is located at the centermost point in the vehicles longitudinally and laterally.

Knowledge about other vehicle behaviors is gathered using a radar device located at the front license plate level in each vehicle. It tracks the angle, distance, velocity, lateral velocity, acceleration, and strength of up to 64 environmental objects around the vehicle. Driver reactions to other vehicles and obstacles, detected by the radar, can be measured using pedal responses and or steering responses.

The DAS records information from seven video cameras and one microphone (Figure 5). One of the seven video cameras in the vehicle is pointed at the steering wheel. Steering wheel angles are determined in the vehicle with a post-processing algorithm (developed by Entropy Control, Inc.) using video of the steering wheel. Pieces of tape placed at points around the wheel allow the software to measure the steering wheel angle, providing useful information regarding a driver's behavior in relation to vehicle speed.

Other cameras point at the driver's upper body and the driver's feet. Cameras also provide a forward view and rear view (Figure 5). The vehicle cabin microphone, above the rearview mirror, can be assigned to record audio with any one of the seven video streams but is usually attached to the camera providing video of the drivers face. The final two cameras are placed at the bottom of the side mirrors to monitor lateral lane position.

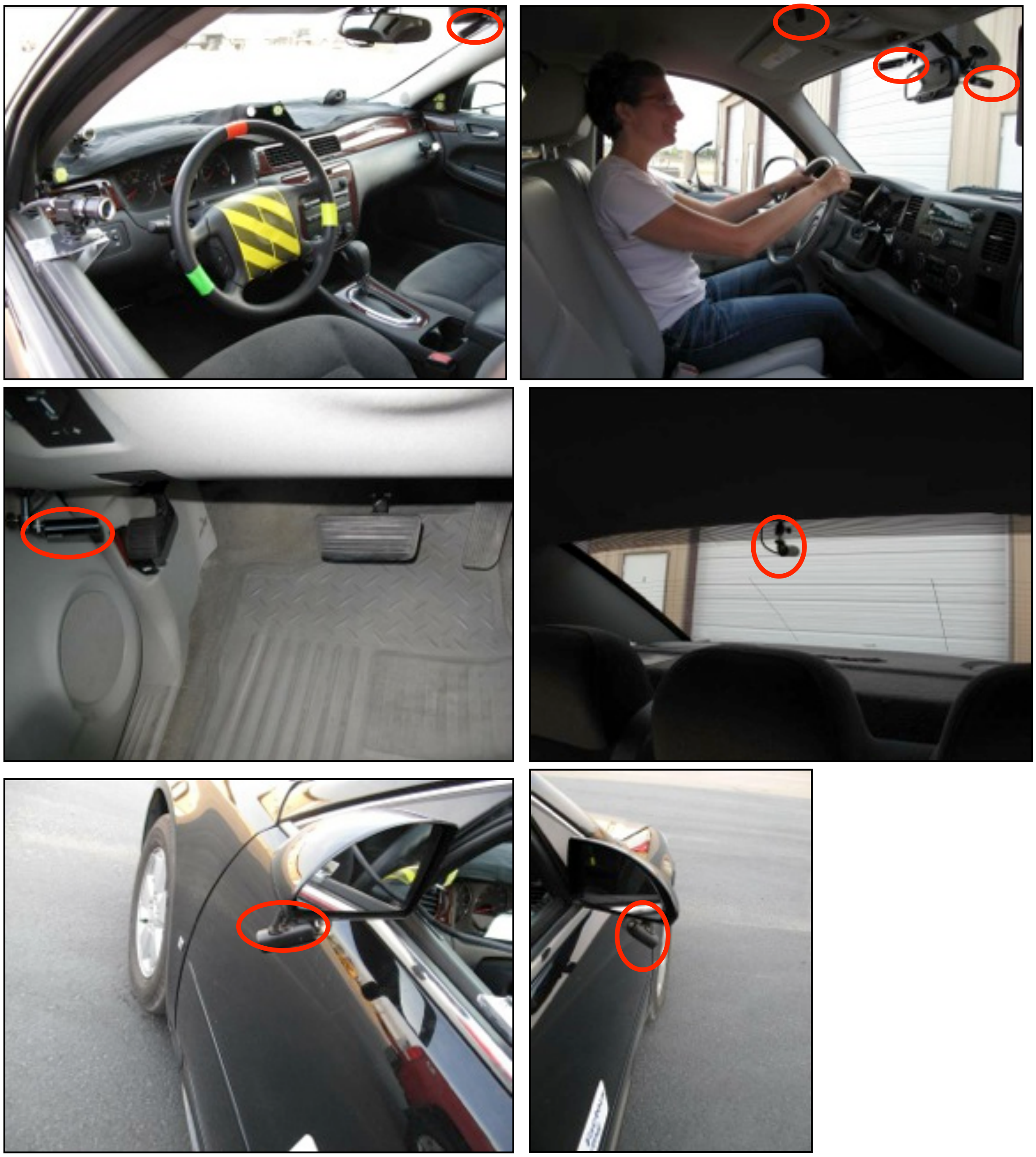

Figure 5. DAS video cameras: (top left) Impala steering wheel with markings used for Entropy Control Inc post-processing algorithms and steering wheel camera; (top right: left to right) steering wheel, driver upper body, and forward cameras; (center left) foot pedal camera; (center right) rear facing camera; (bottom left) left side lane position camera; (bottom right) right side lane position camera.

The vehicle's lateral lane position is determined using a post-processing algorithm developed by Entropy Control, Inc. The algorithm uses the vehicle's side camera videos (see screenshots in Figure 6), which can view up to 18 feet from the side of the vehicle to the lane markings (or edge of the road) in order to measure the lateral roadway position.

Figure 6. DAS "Quad View" Video File Output combines four cameras in one video file. The rear (top left), foot (top right), left side (bottom left) and right side cameras (bottom right). Lateral lane position can also be determined using roadway edges (right quad view) instead of pavement markings (left quad view).

The global positioning system (GPS) records the number of satellites that the system is using to determine the quality of the latitude, longitude, vehicle heading, speed and elevation data. A failure flag will appear if the GPS cannot collect data at a specific point in time. The vehicle's location in the real world can be displayed during post-processing on a digital map using the coordinates collected by the GPS. The changes in elevation can explain why vehicle speed may have changed, as well as a driver's decision to change speeds on inclines or declines.

The Bluetooth dongle is connected via a three-USB hub located in the center console (Figure 7). This location allows connection to the BioHarness (discussed in the next section) and has the capability to work with any other peripheral equipment that sends information via Bluetooth. Also in the center console is the experimenter button. The button can be used by the researcher or participant to mark specific points in time.

Figure 7. Center consoles of the Impala (left) and Sierra (right)

The light meter (orange rectangle attached to the outside of the DAS in Figure 3) measures the intensity of illumination at the rear of the vehicle's cabin. This aids researchers in determining the lighting conditions along the experimental routes.

A third DAS, the TranSecurity DAS, is a small, portable computer device that syncs and records all accessory and onboard vehicle data (Figure 8). The TranSecurity DAS connects to a vehicle's CAN bus and can record variables such as speed, brake force and steering angle. A locking dock for two interchangeable removable hard drives (75 GB each) allow manual data transfer from the TranSecurity DAS to the data storage and processing facilities. Accessory devices such as a head unit, video cameras and accelerometers can also be connected to the DAS unit.

Figure 8. TranSecurity DAS hardware (not attached to vehicle)

The equipment first synced all data collected to ensure an accurate assessment, but the equipment was also used as a validation metric. For example, whole body vibration the medics experience during their trips was of interest in one research study and by using the accelerometers researchers were able to exclude those portions of ambulance trips when the vehicle was parked or still by examining the onboard vehicle data. The DAS was placed in a cabinet in order to be out of the way of EMTs.

A head unit device attaches to the windshield of a vehicle, usually between the rearview mirror and the windshield so it does not obstruct the driver's vision (Figure 9). The head unit is composed of a wide-angle forward-facing camera that captures a forward view of the driving environment, a rear-facing camera to capture video of the driver and his behaviors, a GPS unit, a light meter, an alcohol sensor, and a tri-axial accelerometer. The accelerometer in the head unit can be used to verify motion and characteristics of vehicle movement.

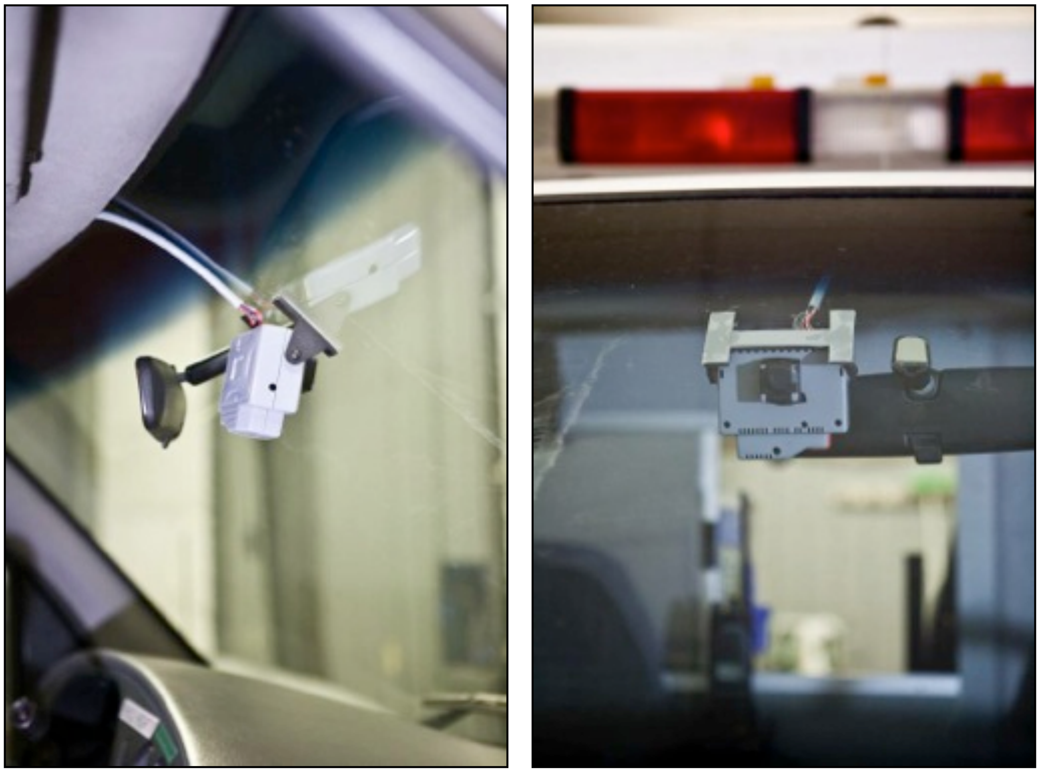

Figure 9. Head Unit from the front passenger seat (left) and the unit's forward-facing camera from the hood (right)

Two tri-axial accelerometers were installed in the ambulance rear patient compartment, near the two locations that EMS workers reported sitting in the most (Figure 10). The accelerometers were used to assess the whole-body vibration that EMS workers typically experience during patient transport. One accelerometer was placed near the bench seat where the EMS workers primarily sit. The other was placed underneath the side "jump seat" where secondary medics occasionally sit.

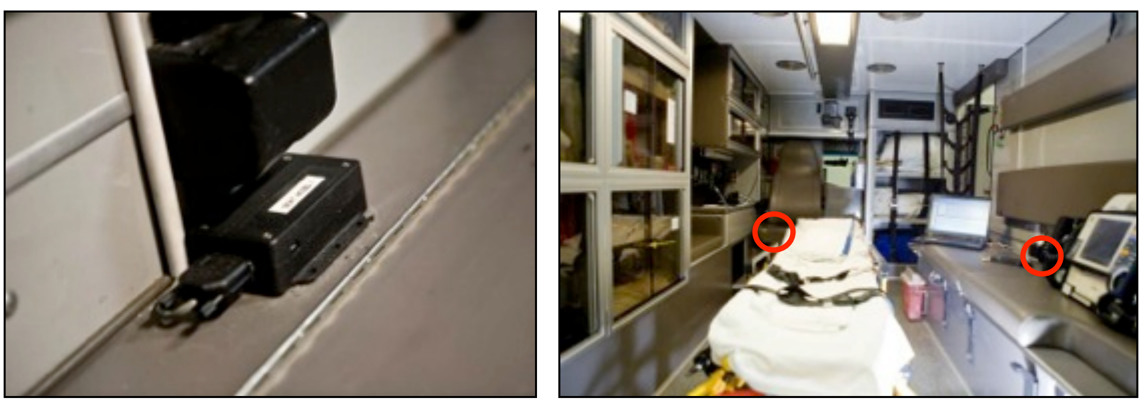

Figure 10. Accelerometer close up (left) and placement in ambulance (right)

Two cameras were placed in the ambulance rear patient compartment, one at each end of the cabin (Figure 11). They were placed to capture the behaviors of the EMS workers in the cabin. Due to the confidential nature of the data collected involving patients who were unable to provide their consent to be recorded, the DAS automatically applied a solid black polygon mask over the areas where the patient was most likely to be seen while entering or exiting the ambulance and during transport. Both cameras were equipped with infra-red lights and recording capability so that video could be captured in all lighting conditions.

Figure 11. Camera used with the TranSecurity DAS (left) and camera location in ambulance study (right)

The cameras were used to observe EMS worker behaviors during transport. EMS posture (seated or standing), back angle, location within the ambulance, specific reaches for equipment, seatbelt usage, and presence in the ambulance were coded for all eligible trips using ObserverXT data reduction software. This information was used to assess postural and behavioral patterns displayed by the EMS workers during transport with the goal of providing recommendations in cabin design that could make these behaviors safer for EMS workers.

PERIPHERAL EQUIPMENT

The DAS also collects information about drivers through peripherally connected equipment. Currently, there are four pieces that can be integrated into the DAS data stream. They are the BioHarness, BioPAC and eye tracking equipment (2 systems). The DAS software can be programmed to handle up to four additional pieces of equipment at a time.

Purchased with Murdock Charitable Trust funds were the BioHarness and BioPac physiological measurement devices. The BioHarness fits around a person's chest like a heart rate monitor and sends signals via a Bluetooth connection to the DAS. The BioHarness measures heart rate, skin conductance, skin temperature, breathing rate, and heart rate variability. The BioPAC system is a larger system of equipment and has a variety of configurations allowing recording and analysis of muscle tension (EMG), neuronal activity (EEG), blood pressure, heart rate variability (HRV), electrodermal activity (EDA), and eye movement (EOG). Measuring a driver's physiological responses provides objective measures about a driver's state, including their level of stress, arousal and mental workload. These objective measurements can be more precise and useful than responses to survey questions asking a driver to describe his or her mental and physical state.

The SmartEye eye tracking system is currently installed in the Chevrolet Impala (Figure 12). There are five eye tracking cameras that record driver eye and head movements. Eye and head position data is combined from the eye tracking cameras to produce a gaze vector, which indicates the direction that a driver is looking. Three panoramic scene cameras capture what the driver sees to the front and sides of the vehicle. SmartEye software stitches the three videos of the roadway together then superimposes the eye gaze vector from the eye tracking cameras on that panoramic video. The result is one video recording of the roadway with a green circle representing the gaze vector moving about the screen. This indicates what a driver is looking at while driving. The SmartEye eye tracking system performs well in daytime driving environments—something that is an issue for most outdoor eye trackers. In direct sunlight, this system loses very little eye gaze data. Researchers are interested in the objects and areas that drivers fixate on, both on and off the road. The duration of a gaze, as well as the number of times an object or area are fixated on reflects the driver's visual attention to the object or area. Distracted driving is often calculated by the amount of time a driver spends looking away from the roadway, or the frequency with which they look away. This information is obtained using MAPPS software to post-process the video information, automating a process that researchers used to perform by frame-by-frame observation.

Figure 12. SmartEye Eye Tracking System: Computer (left), Eye Tracking Cameras (center), and Panoramic Cameras in Rooftop Enclosure (right)

The ASL Mobile Eye is a portable eye tracking system consisting of eye glasses and a small video recording box. This is a lightweight and portable system that gathers eye position information, which is then placed on a video of a person's view of their environment. This eye tracker was used in in a distracted driving assessment study on the effects of voice-activated texting while driving. Mobile Eye data was post-processed using MAPPS software in the Murdock computer laboratory to determine the amount of time drivers spend looking at cell phones while texting as opposed to at the roadway. This provides an indication of the amount of time a driver is attending to the driving task.

An iPad application allows researchers to annotate a map while the instrumented vehicle is moving. The researchers can specify a set of selectable labels with unique markers that are placed on the map when a button is tapped. The information is stored in a database together with GPS and route information for use in post processing. If an odd event occurs while a participant is driving, the researcher can note its location and event type. This will help explore what occurred during a drive in order to explain outliers in a data set.

DATA PROCESSING AND SYSTEM TEST PLATFORM EQUIPMENT

MAPPS is a software program that automates some of the video data analysis from the SmartEye eye tracking system. MAPPS can produce gaze variables such as crosshairs, gaze trails, number of fixations, durations of fixations, as well as video overlays of colored and shadow heatmaps (frequently gazed areas) and gaze cones. It can also produce summary graphs of processed data, such as pie charts of fixations in certain regions of interest.

Observational data is analyzed using ObserverXT data reduction software. It is used for activities, postures, movements, positions, social interactions or any other aspect of human behavior. It is a manual event recorder for the collection, management, analysis and presentation of observational data and allows analysis at a higher level of detail with the automated system.

Statistical software such as SAS and SPSS provide researchers a way to communicate the patterns or trends of driving data as well as the significance of these patterns. This can be useful in predicting what behaviors drivers may exhibit in the future. Both are established, reliable statistical software programs that reduce the processing time for large data sets and provide complex statistical procedures for data analysis.

The Digital Artefacts proprietary data visualization software tool takes the information from the data recorded on the Sierra and Impala DAS and provides visual outputs for all of the variables gathered. This allows researchers to visually determine patterns or trends in driving data.

The project also obtained mobile communication equipment to provide future vehicle-to-vehicle and vehicle-to-infrastructure research. This will allow for the integration of data about the behavior of surrounding vehicles and the local road network (weather conditions etc). This research capability will support the development, evaluation, and demonstration of Intelligent Transportation Systems (ITS) in terms of both Vehicle-to-Vehicle and Vehicle-to-Infrastructure applications. However, during the period of this program, no naturalistic studies in this area were awarded that could provide staff funds to integrate the equipment.

INTEGRATION OF THE SIMULATION AND MURDOCK NATURALISTIC LABS

As noted in the original proposal, the aim of the Murdock grant was to provide an integrated suite of research facilities for WTI to investigate rural traffic safety and develop interventions. This integrated suite was to include the existing advanced driving simulator and the addition of data instrumentation for a fleet of two dedicated vehicles to support test track and naturalistic studies. In this way, research could be supported with controlled experimentation to test conceptual hypotheses in the driving simulator, to partial-controlled experimentation to evaluate conclusions with real world driving in test track scenarios, to naturalistic observation of drivers in their normal driving situations to provide basic data to guide hypothesis development and evaluate intervention effectiveness.

This integration included a two-phase project conducted with the Foundation's permission by Entropy Control Systems. During phase one of the integration, WTI embarked on a systematic program to optimize and tune its advanced driving simulator so that it provides a realistic research and testing environment capable of yielding results that are transferable to the real world. This tuning and optimization work was completed by Dr. Erwin R. Boer (Entropy Control Inc.) who is an international expert in modeling and optimizing perceptual cues in driving simulators. This involved comparing the response of the simulator including its motion base to driver input (steering, throttle, and braking) with the response of an instrumented vehicle that matched the type of vehicle used to develop the simulator dynamic model (Chevrolet Impala). The following press releases summarize the results via their respective hyperlinks.

- Motion Delays
- Motion Filters
- Sound and Vibration
- Pedal Control Cues
- Motion Steering Cues

The second integration phase included the use of our currently National Science Foundation (NFS) funded study and make them more generalizable to future studies. Utilizing these funds, software development by Entropy Control, enabled the researchers to turn the activities for this NSF project into reusable pieces of scenarios and code. This software included the development of scenarios and analysis in a general fashion such that they can be easily reused for future projects, e.g. hazard perception scenarios for assessing and training novice drivers in the simulator and the instrumented vehicles. This allows us the additional versatility to collect data as part of naturalistic and simulated-based studies. Moreover, to ensure and demonstrate the integration of the research facilities, to help use in demonstrating the validity of relating driving simulators to real vehicles as part of an integrated suite of research facilities. As a result, this novel software is enabling the research team to write follow-on grants to the currently funded NSF grant. As part of the NSF's and the Murdock Charitable Trust Foundation's mission, dissemination of the scenarios' code will be available to the research community at the close of the project (expected September, 2014), to be housed on the following website http://www.coe.montana.edu/ie/faculty/stanley/research/NSF%20Project.html.

RESEARCH IMPACT

RESEARCH CONDUCTED/DEPARTMENTAL IMPACT

Research publications and summaries conducted from the use of Murdock purchased equipment are listed in Appendix B. Below provides a summary of past and current grants and the specific utilization of Murdock equipment.

Current Research Awards

Modeling the Validity and Transfer of Eye-scanning Patterns for Hazard Perception from Virtual Reality Training Environments to Reality, National Science Foundation, 2011-2014, $499,610. 4W3706, http://www.montana.edu/cpa/news/nwview.php?article=10639.

> Visual search skills for hazard perception are critical in many domains. They are used by pilots to maintain situation awareness, by doctors reviewing screen images to diagnose health disorders, and by security screeners inspecting for hazardous materials. They are also critical to a novice driver's ability to detect roadway hazards. For novice drivers, poor visual search skills can increase the risk for traffic fatalities, which are the leading cause of death for teenagers nationwide.
>
> Virtual reality can be used to provide visual search training during driver education. However, the success of these training programs depends on the validity of eye-scanning

patterns in the virtual environment and on the simulation parameters employed to elicit those patterns. The overall objective of the research is to assess the validity of search patterns in the virtual world as they apply to the physical realm, and then to identify which simulation parameters are critical for successful simulator-based hazard perception training.

Intellectual merit: The project will integrate theory and data to advance our knowledge of which parameters of virtual reality-based hazard perception training promote the greatest transfer of training to real world driving. Specifically, the project will (a) examine the relationship between visual search in driving simulators vs. that in the real world, using specially equipped vehicles; (b) test which aspects of the driving simulator lead to the best training and transfer of learning; and (c) examine how age and experience influence hazard perception skills.

Broader impacts: The findings from the project will advance scientific understanding of how virtual reality training simulations can be used to improve driver education, thereby leading to better drivers and fewer traffic accidents. The results will also be applicable to other areas in which virtual reality training can be valuable, such as medical diagnosis and security screening. In addition, the project will enable a number of disadvantaged students to take part in engineering and technology research and includes a high school outreach component to engage students in research at an early age.

Past Research Awards

Naturalistic Safety Evaluation of the Medic's Work Environment, Federal Highway Safety Administration, October 2009-Dec 2011, $58,980, 4W2879, http://www.westerntransportationinstitute.org/research/4W2879.aspx

In this study the TranSecurity DAS was installed in a Type III Ambulance in Bozeman, Montana, on August 23-25, 2009, and removed after the completion of data collection on January 19, 2011. The purpose of this study was to gain a better understanding of emergency medical service working conditions, and to develop recommendations to aid in minimizing harmful actions and behaviors inherent in EMS work. The naturalistic data collected in this study allowed researchers to perform analysis in a rural emergency driving environment to identify contributing factors to attending medic behavior, severity of biomechanical forces experienced in the driver and patient compartment, and an evaluation of emergency medical response safety culture. Based upon research findings, the project includes development of a series of environmental, ergonomic, policy, or training recommendations to mitigate circumstances that cause potentially unsafe operations in the driver's and patient's compartment of the ambulance. This study used naturalistic data and video, survey responses, focus groups, and agency patient care records to analyze the rural medics' working environment during emergency patient transportation. Accelerometer data was analyzed for 102 separate emergency transports to provide descriptive statistics relevant to whole-body vibration experienced by the medics during patient care. Five years of patient care records were analyzed to identify specific patient illnesses and medical procedures associated with traveling in emergency response mode. Restraint compliance rates were collected for both self-reported (21.5% restrained) and observed (2.6% restrained) data collection methods. Focus groups identified factors influencing medics' choice to be unrestrained, characterized by a reduced ability to provide patient care, the belief that restraint devices will cause harm to the medics, and the belief that the restraint devices are ineffective in a crash situation. Finally, reach analysis was conducted to highlight the procedures and equipment retrieval which require the medics to assume positions resulting in awkward and unstable postures during transport. The results of this study will add to the growing body of knowledge surrounding the behaviors of EMS workers in a real work setting, will aid in understanding the complexities of EMS safety culture, and can be applied toward different aspects of EMS work such as driver or medic training.

Voice-Activate Texting - Is it Safe? - Research Experience for Undergraduates. Federal Highway Administration US Department of Transportation**.** October 2010 – May 2011, $15,000, 4W1365-URE.

In this student lead study, the ASL Mobile Eye tracker was used in conjunction with the mid simulator to determine if voice-activated texting methods are a safer alternative to manual texting methods. It was concluded that voice-activated texting does provide drivers better control of their vehicles and may improve the safety of roadways as new technology becomes prevalent in society.

Student Awards from those Utilizing the Murdock Laboratory Resources

Since the inception of the Murdock grant in 2010, several awards have been won by students using the laboratory resources garnered via this grant (Table 1). A total of eighteen students have worked in the lab (Appendix C).

Table 1. List of Awards Won by Students Using Murdock Laboratory Resources

Name	Award	Date
Jessica Mueller	MSU College of Engineering Benjamin Fellowship ($25,000, dissertation will be using Murdock resources)	2013
Kaysha Young	National Science Foundation Graduate Research Fellowship ($120,000 over three years)	2013
Jessica Mueller	Montana Academy of Sciences Student Research Grant Award ($500, using Murdock resources)	2013
Jessica Mueller & Tawny Hoyt	Semi-finalists: NHTSA Enhanced Safety of Vehicles International Collegiate Student Safety Technology Design Competition, $2,000	2011
Tawny Hoyt	Best Student Technical Paper, Industrial Engineering Western Regional Conference	2011
Jessica Mueller	3rd Place: National Rural Intelligent Transportation System Student Paper Competition	2010
Jessica Mueller	MSU University Transportation Center Student of the Year	2009

OUTREACH ACTIVITIES

The instrumented vehicles have been showcased as part of several engineering based outreach events to the community, examples include: Expanding Your Horizons to excite girls to the field of engineering; tours as part of Industrial Engineering courses at Montana State University; teen advisory board to Denise Juneau, State Superintendent for Montana's Office of Public Instruction; and the Montana Apprenticeship Program for Montana's Native American youth. During two summers a team of undergraduates completed a study that utilized both the simulator and instrumented vehicle as part of their work sponsored by the National Science Foundation program entitled *Research Experience for Undergraduates*. The outreach activities to date have included 36 interactive demonstrations of the simulator and instrumented vehicles to at least 480 students in grades 6 through 12, parents, college freshmen, researchers and Industrial Advisory Board members. In the summer of 2013 the vehicle was demonstrated at a free public music festival in Bozeman.

While the groups in these demonstrations typically consist of both sexes, 20 presentations (in 2013) were made to a total of 50 female 7th grade students who were part of the *Gaining Early Awareness and Readiness for Undergraduate Programs* from the Browning Middle School in the Blackfeet Indian Reservation, Montana. Continuing the PI's support for the Expanding Your Horizons workshop the PI and her research students created a workshop focused on virtual reality with an emphasis on teen driver hazards. In the past three years approximately 150 girls (ages 11–14) participated in the interactive demonstration of the driving simulators and the girls were encouraged to consider careers in science, technology, engineering and math.

The demonstrations, primarily conducted by the students working on current research projects, increase awareness and stimulate interest in engineering concepts and professions as well as introduce students, parents, advisory board members and the general public to the current research projects conducted at the Western Transportation Institute. An example table of Murdock related outreach efforts starting in 2011 are shown below.

Table 2. Outreach Events Utilizing the Murdock Equipment

Date	Group	Group's Location	Age	Sex	Number of Session(s)	Approximate Number of Participants
1-Apr-11	Expanding your Horizons	Montana	6-8th grade	Female	3	45
1-Jun-11	Summer Transportation Institute (STI)	Montana	High School	Mixed	1	24
1-Jun-11	Native American Group (Montana Apprenticeship Program)	Montana	High School	Mixed	1	15
27-Oct-11	STEM	Sleeping Giant Middle School Livingston MT	8th Grade	Mixed	2	30

27-Feb-12	Shadow an Engineer Day (Hosted by Society of Women Engineers [SWE])	Montana High Schools	10-12 grade & College Students	Mixed	1	25
22-Mar-12	STEM	Sleeping Giant Middle School Livingston MT	8th Grade	Mixed	2	12
29-Mar-12	EIND142	MSU	IE Freshmen	Mixed	1	
10-Apr-12	Superintendent of Schools Tour	Montana	High School	Mixed	1	20
21-Apr-12	Expanding your Horizons	Montana	6-8th grade	Female	4	50
22-May-12	STEM	Sleeping Giant Middle School Livingston MT	8th Grade	Mixed	3	19
11-Jun-12	STI	Montana	High School	Mixed	1	24
July 16-19	Montana Apprenticeship Program (MAP)	Montana	High School	Mixed	4	3
June - Aug 2012	Research Experience for Undergraduates (REU)	New York, Oregon	Undergrad	Mixed	Many	2
9-Oct-12	Industrial Advisory Board	MSU	Engineering Professionals	Mixed	1	25
1-Nov-12	EIND 413	MSU	Undergrad	Mixed	1	21
15-Nov-12	Livingston high school Physics Class	Livingston, Montana	17-18	Mixed	2	15
30-Nov-12	Gear Up Program - Browning School District	Montana	7th grade	Female	20	50
15-Feb-13	Shadow an Engineer Day (Hosted by SWE)	Montana	10-12 grade & College Students	Mixed	1	College - 2 High School - 12
23-Mar-13	MSU Friday	MSU	High School & Parents	Mixed	1	120

28-Mar-13	EIND 142	MSU	Undergra d	Mixed	1	25
11-Apr-13	Sleeping Giant Middle School	Livingston, Montana	8th Grade	Mixed	2	25
18-Apr-13	Bozeman High School	Bozeman, MT	High School Students	22-M, 5-F	1	27
26-Apr-13	Livingston high school	Livingston, Montana	Junior and Senior High School Students	Mixed	1	9
12-Jun-13	MAPPS	Montana	Junior and Senior High School Students	Mixed	1	3
June - Aug 2013	Research Experience for Undergraduates (REU)	Florida, Virginia	Undergra d	Mixed	Many	2
25-Jun-13	Transportation Research Board Visit	Washington	Engineeri ng Profession als	Male	1	2
18-Jul-13	Music On Main	Montana	General Public	Mixed	1	Many

RESEARCH LEVERAGE/FUTURE RESEARCH PROGRAM

The NSF award would not have been possible without the generosity of this grant. Because of the procured equipment the research team is currently collaborating on NIH, NSF, and NIOSH grants with other agencies (Claremont College, Entropy Controls Systems, Virginia Tech) and additional publications are expected.

APPENDIX A: DATA ACQUISITION SYSTEM EQUIPMENT LIST

Component	Draft Specification
PC OS Software	Windows 7 Pro
Computer Case	Opus Solutions ATX Vehicle PC
Case Mount	OPUS Anti-Vibration Mount
Processor	Intel Core i3-2120 Sandy Bridge 3.3GHz
Hard Drive	HITACHI Deskstar 7K3000 2TB 7200 RPM 64MB Cache SATA 6.0Gb/s 3.5"
Solid State Disk Drive	Crucial M4 CT128M4SSD2CCA 2.5" 128GB SATA III MLC Internal Solid State Drive (SSD) with Transfer Kit
Memory	Mushkin Enhanced Silverline 4GB 240-Pin DDR3 SDRAM DDR3 1333 (PC3 10666)
Mother Board	ASUS P8H67-M EVO
Power Supply	M4-ATX 250W Intelligent DC-DC PSU
Video Camera	Sony Super HAD CCD Super High Resolution Weatherproof Color Camera
Quad Processor	EverFocus EP4QC 4 Channel Color Quad Processor
USB Adapter	StarTech.com 4 Port USB A Female Slot Plate Adapter
Video Capture Card	Osprey 460e Video Capture Card
Monitor/Display	Xenarc 1210YR 12.1" TFT LCD Roof Mount Monitor w/ VGA & AV inputs
Wireless Keyboard & Mouse	GMC-IOGEAR GKM681R Black USB RF Wireless Mini Keyboard with Optical Trackball and Scroll Wheel; Chevrolet–ADESSO WKB-3200UB Wireless Media Center Keyboard with Optical Mouse
GPS	u-blox 6 ROM-based GPS receiver LEA-6T module with Precision Timing
Light Meter	Extech HD450
USB Isolator	Olimex LTD. USB-ISO
Dual Brake	TS Instructor's Brake System
Microphone	Electret Condenser Stereo Microphone
Load Cells	Transducer Techniques MPL-200-C, 200lb compression. Requires Plug and Play
Signal Conditioner-Load Cells	TMO-1 LOAD CELL SIGNAL CONDITIONER
Accelerometer	Gecko USB Accelerometer / Tilt Meter
USB connected data acquisition board (DAQ)	Data Translations DT9803, USB, 16bit, 16SE/8DI, 16 DI/O, SDK included
CAN bus interface	NI PCI-8512 1-Port High-Speed NI-XNET CAN Interface, PCI
Deep Cell Battery	Optima Yellow Top Deep Cycling AGM Battery
Table Computer	iPad 2
SATA Dock for Lab	Startech eSATA USB to SATA Hard Drive Docking Station for Dual 2.5 or 3.5-Inch HDD SATADOCK22UE
USB Extension	USB Gold A/a Extension Cable 12 Feet
Belkin USB Hub	Belkin USB 2.0 4-Port Ultra-Mini Hub (F5U407)
Bluetooth Dongle	IOGEAR USB 2.1 Bluetooth Micro Adapter (GBU421)

Component	**Draft Specification**
DC Regulator	CarNetix CNX-P2140 185W Dual Output Intelligent DC-DC Regulator
Inverter	GMC Sierra - Cobra CPI 1575 1500 Watt 12 Volt DC to 120 Volt AC
	Chevrolet Impala - Xantrex Prowatt SW1000 1000W True Sinewave Inverter
KVM Switch	IOGEAR GCS632UW6 MiniView Micro USB PLUS 2-Port KVM Switch
Voltage Regulator	Power Stream PST-DC292 DC/DC Converter - Adjustable
Audio Cable Extension	Cables To Go 40408 3.5 mm Male/Female Stereo Audio Extension Cable, Black (12ft)
WIFI Router	WL ROUTER D-LINK| DIR-655 R
Button	Vetco Electronics
Radar	http://www.autonomoustuff.com/delphi-automotive-radar.html
Can-USB Interface	NI USB-8473

APPENDIX B: PUBLICATIONS USING MURDOCK EQUIPMENT

JOURNAL PUBLICATIONS

Young, K., Stanley, L., & Mueller, J. Voice-Activated Texting and Driving—Is it Safer? *Accident Analysis & Prevention*, under revision.

Mueller, J. & Stanley, L. Contributors toward Ambulance Use of Lights and Sirens from Patient Records. *Open Journal of Safety Science and Technology*, Vol 3., No. 3, 2013, pp 63-68, www.scirp.org/journal/PaperInformation.aspx?PaperID=37092.

Sanddal T., Sanddal N., Ward N. & Stanley L. Ambulance Crash Characteristics in the U.S. Defined by the Popular Press: A Retrospective Analysis. Emergency Medicine International, vol. 2010, Article ID 525979, 7 pages, 2010. http://www.hindawi.com/journals/emi/2010/525979/

Hoyt, T., Stanley, L., and Sanddal, N. Rural EMS Worker Restraint Usage and Feasibility in Emergency Response Vehicles, Annals of Advances in Automotive Medicine, 2010.

CONFERENCE PROCEEDINGS

Mueller, J & Stanley, L. *A Naturalistic Approach to Improving Patient Safety During EMS Transport.* HFES 2014 International Symposium on Human Factors and Ergonomics in Health Care, Chicago, March, 2014.

Mueller, J & Stanley, L. Emergency Medical Services: A Naturalistic Posture Evaluation While Providing Patient Care during Patient Transport. Accepted to Human Factors and Ergonomics Society Annual Meeting Proceedings, San Diego, CA, October 2013.

Stanley, L. Complexity of Instrumentation in Assessing Virtual vs Real World Hazard Perception Environments. *Proceedings 1st Annual International Conference on Industrial & Systems Engineering,* June 24-27, 2013 Athens, Greece.

Mueller, J., Hoyt, T. & Stanley, L. *Improving Restraint Feasibility through Ambulance Layout Redesign*. 7th Annual Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, Bolton Landing, NY, June 17-20, 2013.

Results Summary:
Restraint feasibility was significantly increased for the 5th percentile female, 50th percentile male, and 95th percentile male anthropometric populations. The proposed patient compartment design increased overall restraint feasibility from 47 percent to 90 percent. The proposed design would increase safety for medics and patients during patient transports by increasing the number of tasks that could be performed from a belted and seated position.

Mueller, J., Stanley, L., Azamian, T., & Mercer, D. Assessing Physiological Response Validity in Simulated and Real Driving Environments. *Proceedings of the Industrial and Systems Engineering Research Conference,* Puerto Rico, 2013.

Results Summary:
There was no difference in participant heart rate or breathing rate at the hazardous events in the driving simulator and instrumented vehicle. However, drivers in the simulator showed a significant increase in breathing rate over the baseline at the hazardous scenario. This study gave researchers an understanding of drivers' physiological responses to hazardous scenarios in a driving simulator relative to on-road driving. Initial validity is implied by these findings; however, the higher breathing rate measured in the simulator should be explored to understand its underlying cause.

Young, K. & Stanley, L. *Driver's Attitudes and Behaviors Regarding Voice Activated Texting Technology and Distracted Driving*. Proceedings of the Industrial and Systems Engineering Research Conference, Puerto Rico, 2013.

Mueller, J., Marley, R. & Stanley, L. *Whole-Body Vibration in Emergency Medical Transportation.* Accepted to National Institute for Occupational Safety and Health (NIOSH)'s National Occupational Research Agenda (NORA) Proceedings. Salt Lake City, UT, April 2013.

Results Summary:
WBV values were not found to be dangerous pertaining to ISO 2361 health guidance caution thresholds, but the vibration exposure fell in the "very uncomfortable" range. Peak acceleration values may be substantial enough to pose a danger to unrestrained medics, and the discomfort associated with the vibration exposure can directly impact the EMS worker's ability to perform patient care in certain procedures (intubation, IV sticks). While not conclusive, data suggest that vibration energy may not be sufficient to cause injury on its own, but may aggravate existing injury already commonly found in EMS workers, or impair motor control abilities; further study is recommended.

Page, L., Stanley, L., & Sharma, J. Teen drivers' hazard perception – are we using crash-representative testing scenarios? *Proceedings of the Industrial and Systems Engineering Research Conference,* Orlando, FL, 2012.

Results Summary:
The purpose of the study was to use 2009 crash databases — the General Estimates System and the Fatality Accident Reporting System — to determine whether the hazardous scenarios in recent research remain the most problematic, in terms of teen driver (16 and 17 years old) crashes. Crash data show the scenarios used for teen drivers generally reflect the estimated crashes in the United States but not fatal crashes. While this study shows hazard scenarios align better with the General Estimates System crash characteristics than the Fatality Accident Reporting System crashes, it also expands the analysis to take into account what is not present in the scenarios by looking at variables other than what is shown in the hazard scenarios. The lack of pedestrians in teen driver crash circumstances

suggests that a focus on scenarios where crashes with single vehicles (FARS) or two vehicles (FARS and GES) may be of more relevance than scenarios containing pedestrian hazards. Improvements in scenario characteristics, based on the crash data, could be made by including scenarios with speed limits of 35 mph and 55 mph, single- and two-vehicle crashes, and developing a scenario that relates more specifically to fatal crashes.

Mueller, J. (2010*). Naturalistic Data Collection in Rural Emergency Medical Services transportation.* National Rural Intelligent Transportation System (NRITS) Annual Conference, August 2010.

Results Summary:

The study used an advanced naturalistic data collection system to record visual, vehicle, and accessory parameters associated with each ambulance trip. Visual data was analyzed to look at restraint characteristics, position within the ambulance data, and posture data to identify areas where medics are subject to poor working conditions. This paper was more of a description of how naturalistic data collection can be used in mobile workplaces, instead of an actual workplace assessment.

Mueller, J & Stanley, L. *Emergency Medical Services: A Naturalistic Posture Evaluation While Providing Patient Care during Patient Transport*. Accepted to Human Factors and Ergonomics Society Annual Meeting Proceedings, October 2013.

Results Summary:
Data showed that EMS workers display intermediate (between 20° and 60°) and severe (larger than 60°) back angles while standing compared to sitting, and are standing and displaying potentially harmful postures while providing patient care. These findings indicate that there is a relationship between the EMS worker's ability to adequately provide patient care and his inability to do so from a neutral seated posture in an ambulance layout that is currently used in many ambulances used throughout the world.

PAPERS IN PROGRESS

Mueller, J. & Stanley, L. Simulator Comparison to Real-World Driving with Different Scenario Complexity. This project will assess driver response to scenarios of varying levels of complexity in both an advanced motion-capable simulator and in the real world in Western Transportation Institute's instrumented Impala. Data collection is scheduled to begin August 2013. Results will be presented at the Montana Academy of Sciences annual meeting in April 2014 and at J. Mueller's dissertation defense in February 2015. Will submit to Journal of Safety Research in May 2015.

Mueller, J. & Stanley, L. Simulator Comparison to Real-World Driving with Different Scenario Complexity. This paper is comparing driver response to scenarios in the real world to the same driver response to the same scenarios modeled in the Western Transportation Institute's Advanced Driving Simulator using different levels of horizontal field of view, graphics resolution, and graphics contrast in the simulator. Driver response will be assessed comparing physiological response, behavioral responses, and subjective measures of driver workload. Data collection will be finished in October 2013, and results are expected to be

presented at J. Mueller's dissertation defense in February 2015. Will submit to Accident Analysis and Prevention in May 2015.

Mueller, J. & Stanley, L. Simulator Comparison to Real-World Driving with Individual Driver Differences. This paper will look at how drivers with different levels of risk acceptance and with different emotionally elicited states compare when driving particular scenarios in the Western Transportation Institute's Advanced Driving Simulator and the same scenarios in the real world. Data collection will be finished in October 2014, and results are expected to be presented at J. Mueller's dissertation defense in February 2015. Will submit to Human Factors in May 2015.

DISSERTATIONS/THESIS

Mueller, J. (2011). *Safety evaluation of a medic's work environment during rural emergency response.* Master's Thesis, Montana State University.

POSTER PRESENTATIONS

Young, K., Primly, E., Borden, K., and Stanley, L. *Teenage Traffic Safety Awareness –A Peer to Peer Approach*. MSU Student Research Celebration-Montana State University, 2013, Poster Presentation.

Young, K. *Hands Free Texting While Driving - Is It Safer than Conventional Texting While Driving?* MSU Student Research Celebration – Montana State University, April 19, 2012, Poster Presentation. http://www.montana.edu/usp/pages/documents/2012ResearchCelebrationProgram.pdf

Young, K., & Stanley, L. *Voice Activated Texting-Is It Safer than Conventional Texting While Driving?* National Council for Undergraduate Research Annual Conference, Ogden, Utah 2012, Poster Presentation. https://ncur.weber.edu/ncur/search/Display_NCUR.aspx?id=62324

Young, K. & Stanley, L. *Hands Free Texting While Driving-Is it Safer than Conventional Texting While Driving?* MSU Student Research Celebration-Montana State University, April 11, 2011, Poster Presentation.

WEBSITES

- Murdock Naturalistic Fleet/Lab Dedicated Website - http://www.westerntransportationinstitute.org/laboratories/fleet
- NSF study utilizing the equipment - http://www.coe.montana.edu/ie/faculty/stanley/research/NSF%2520Project.html

PUBLIC MEDIA

- Safer Roads: A Montana State University study focuses on the training of young drivers. Montana State University News Service. Video http://vimeo.com/63782471.

- MSU study focuses on young drivers (May 6, 2013). Bozeman Daily Chronicle.

- MSU study focuses on young drivers (April, 26, 2013). Montana State University News Service.
- Bozeman Daily Chronicle (January 27, 2012) Reach for the Stars.

- WTI lands grant to study hazard perception (December 8, 2011) MSU News Service.

- Cover story for Public Roads on Naturalistic Evaluation of Emergency Medical Service Providers During Emergency Transport – to be published in October 2010.

APPENDIX C: LIST OF STUDENTS USING MURDOCK LABORATORY RESOURCES

Table 3. List of Students Using Murdock Laboratory Resources

Name	Degree Program	Graduation Date
Graduate Students		
Shuchisnigdha Deb	M.S. Industrial Engineering, MSU	expected May 2014
Salman Imtiaz	M.S. Industrial Engineering, MSU	expected May 2014
Taylor Martin	M.S. Human Factors and Systems Engineering, Embry-Riddle Aeronautical University	expected May 2014
Jessica Mueller	Ph.D. Engineering, MSU	expected May 2015
Lenore Page	Ph.D. Engineering, MSU	expected May 2014
Cheryl Polacek	Ed. D. Education, MSU	expected May 2015
Chris Runquist	M.S. Industrial Engineering, MSU M.S. Accounting, MSU	expected December 2014
Kaysha Young	M.S. Industrial Engineering, MSU	expected May 2014
Undergraduate Students		
Tara Azamian	Biomechanical Engineering, Cornell University	May 2013
Kelly Borden	Health & Human Development, MSU	expected May 2014
Laura Frazee	Agriculture Education & Social Studies Broadfield Education, MSU	expected May 2015
Conor Gallagher	Industrial & Systems Engineering, Virginia Polytechnic Institute	expected May 2015
Tawny Hoyt	Industrial Engineering, MSU	December 2010
John McIntosh	Computer Science, MSU	expected May 2016
Daniel Mercer	Mechanical Engineering, Portland State University	expected May 2014
Michael Nguyen	Industrial Engineering, MSU	expected May 2014
Erica Pimley	Industrial Engineering, MSU	expected May 2014
Jyoti Sharma	Industrial Engineering, MSU	May 2013