Appendix 5: Laboratory Research Facilities

Name of Laboratory: Anthropometry Scanning Laboratory

Site/Location: H 1502

Description (narrative):

This laboratory is a 28 by 20 by 9 foot facility for the development of anthropometric databases of the working population. Research is focused on improving the ergonomic performance of safety equipment and industrial tools. Three laser scanning systems and a halogen-based system, as described below, are available for use in a wide variety of research applications.

The whole body scanner captures the shape and color of the entire human body. This scanner uses four scanning instruments mounted on two vertical towers to capture the intricacies of the human body. A platform structure supports the subject, while a separate frame provides alignment for the towers. A primary goal of the whole body scanner is to acquire an accurate computer model of the test subject in one pass. The whole-body scanner has a level of resolution of 3 mm and requires only 17 seconds to complete a whole body scan. The head and face scanner completes a scan of the head and face of live subjects quickly, comfortably, and safely. This scanner's high level of resolution—0.7 mm— provides increased accuracy for representation of facial features. This scan operates with a safe, low-intensity laser to create a lighted profile; a high-quality video sensor then captures the profile from two viewpoints. Because the system moves the digitizer while the subject remains stationary, this system works well in many applications involving subjects that are inconvenient to move during digitizing.

The hand and product scanner is used to produce surface images of hands, hand tools, and any other smaller objects that can fit in the scanner system's field of view. The hand- and product-imaging platform will provide accurate images of safety equipment, tools and tool components for the rapid development of prototypes. The platform adjusts quickly to accommodate subjects such as 1/5-scale automobile models and other objects whose digitized models will be input into CAD/CAM systems. The platform features both linear and cylindrical scan paths plus linear/cylindrical combinations. One motion system moves objects along the length of the motion platform while another motion system rotates the object. By combining scan data from these movements, one can get detailed scans of objects. The software gives the user interactive control of the entire digitizing process. Only moments after the digitizer has scanned the subject, the software allows the user to view the results. The user, therefore, gets immediate feedback on the quality of the digitized model.

The Inspeck scanner is a rapid-scanning, state-of-the-art 3D scanner, which uses a halogen light that is safe for human subjects. At this time, the halogen scanner is being used for hand scanning, to determine the geometry and volume of the hand so that accurate sizing information can be established for protective gloves. Other anticipated uses include tool sizing and scans of other body parts for PPE fit testing.

The hand is generally considered the most complex object for 3D body scans, because of the complex morphometrics and the tendency of the hand to move during scanning. This scanner uses multiple heads to reduce calibration, registration and interpolation problems, and can complete a scan in less than a second, which obviates the need to eliminate minor hand movement during the process. Specialized software is used to eliminate any spurious data points, as well as to generate a polygonal mesh which can be output as a standardized data file. These data files can be imported into CAD/CAM/CAE applications for further analysis, and can then be used as input files for use with computer-numerically controlled machine tools, garment and sewing machinery, and similar applications. Files can also be imported into 3D modeling and compositing software for surfacing, scientific visualization applications, and image rendering. This data can be used in a wide variety of advanced imaging applications to generate animated 3D visualizations of scientific interest.

Research conducted:

Improved Equipment Design Through Applied Anthropometry
Harness Design and Sizing Effectiveness

Research equipment:

Name: Whole body 3-D laser scanner
Description: Cyberware Model WB4
Use: This scanner is used to capture whole-body scans of human subjects

Name: Table laser scanner
Description: Cyberware Model Shop 3-D Table Scanner
Use: This scanner is used to capture 3D scans of objects

Name: Head and face laser scanner
Description: Cyberware Head and Face 3-D Laser Scanner
Use: This scanner is used to capture head and face scans

Name: Traditional anthropometry tools
Description: Various calipers and measuring devices
Use: These tools are used to capture human anthropometric dimensions

Name of Laboratory: NIOSH Mobile Emergency Medical Service (EMS) Work Environment Laboratory

Site/Location:

NIOSH Morgantown
1095 Willowdale Road
Morgantown, West Virginia 26505

Description (narrative):

The NIOSH Mobile Emergency Medical Service (EMS) Work Environment Laboratory is a 2005 Wheeled Coach Type III ambulance mounted on a Ford E-450 cut-away van chassis. The vehicle was specially outfitted to allow its use as a mobile laboratory for the evaluation of mobile occupant restraints, patient compartment ergonomics, and potential design changes intended to improve EMS worker safety during ambulance crashes. The laboratory conforms to the General Services KKK-1822E Specifications for the Star-of-Life Ambulance. The vehicle has been outfitted with a video monitoring system to record human subjects in the patient compartment as they perform various EMS tasks. A Road Safety RS 3000 vehicle monitoring system is installed to record vehicle operating parameters during subject testing while the vehicle is operated over closed driving courses. The patient compartment is also outfitted with additional mounting locations for various occupant restraint systems that allow EMS workers to access patients and equipment while still providing crash protection. A PDA Stat EMS training manikin is part of the vehicle equipment.

Research conducted:

The laboratory is being used in support of research conducted under the NIOSH Division of Safety Research Ambulance Crash Survivability Improvement project. Currently, ambulance patient compartments are equipped with lap belt occupant restraints that inhibit EMS worker mobility within the compartment making it difficult if not impossible for them to access the patient and EMS equipment. Consequently, EMS workers do not use occupant restraints placing them at high risk for vehicle crash-related injury. The vehicle is being used to conduct human subject testing of mobile occupant restraints during simulated patient care scenarios using the training manikin. While conducting the scenarios, the subject data is collected via cameras and time-coded VHS recorded tapes. The tapes are analyzed to yield task completion times using various restraint systems. Subject heart rate is also collected. Comparison of this data from system to system is expected to identify potential areas of system refinement.

Using computer modeling techniques and anthropometry data, the vehicle is also being used to study ergonomic issues of ambulance patient compartments. Results of the study should identify areas where equipment can be relocated to reduce the need for mobility within the patient compartment. Since the laboratory’s compartment is constructed to GSA KKK-1822 E specifications, the study is expected to provide data that can be used to develop recommended revisions to be included in future GSA specifications.

The laboratory also has potential for use as a concept demonstrator at EMS conferences and meetings.

Research equipment:

2005 Wheeled Coach Type III ambulance, video monitoring system, Road Safety RS 3000 vehicle monitoring system, PDA Stat EMS training manikin.

Name of Laboratory: High Bay Laboratory

Site/Location: H B419

Description (narrative):

This laboratory is a specially constructed facility with elevated (37 feet) ceilings and an overhead catwalk, and which is dedicated to research efforts in reducing fall-related injuries, as well as in improving the safety of large equipment used in industrial, construction, and agricultural applications. Overall dimensions of the laboratory are 30 by 36 by 37 feet, which are necessary for accommodating such research efforts as studies of scaffolding systems, ladder stability, tension/compression testing of fabricated protective structures using hydraulic ram pressure, and access/egress safety for construction equipment.

Test equipment in the High Bay Laboratory includes a 5- ton bridge crane, a test bed, hydraulic power supply and actuator system, and a research manikin. The test bed, which is used for securing equipment in place for testing, measures 10 by 15 feet and is 7 inches thick, and is composed of four sections that can be positioned by the overhead crane. T–slots in the bed surface provide anchors for the equipment under test. The hydraulic power system features a 10 g.p.m. pump and two 22,000 lb. actuators. The actuators can be fully controlled through a personal computer to produce loadings, deflections, or vibrations of desired amplitude and frequency.

This lab is also equipped with an advanced research manikin. The manikin was developed in response to the knowledge gained from the U.S. Air Force's tests of biomechanical effects of acceleration forces on aircrews under high-stress conditions such as aircraft ejection. This manikin is known as ADAM, for advanced dynamic anthropomorphic manikin, and is representative of a 95th percentile Air Force male. This research manikin was designed with a high degree of biodynamic fidelity to the human body under conditions of rapid acceleration and deceleration, such as would be experienced in an aircraft crash or fall incident. The manikin has body segments which approximate that of the human body, articulated limbs with a range of motion that also approximates that of the body, and a spinal system that was designed to replicate the human spine's elasticity along the z axis.

The manikin contains a sophisticated and ruggedized onboard data acquisition system and all joints contain sensors. Internal instrumentation includes three triaxial accelerometers, located in the head, the neck, and the chest, and two internal load cells located in the spine. Finally, there are position sensors mounted in the knees, elbows, and shoulders. This equipment has been used in a series of tests on the biodynamic forces that protective equipment and the human body would experience during free-fall and rapid deceleration while wearing fall-restraint equipment.

Research conducted:

Lab Testing of Adjustable Roof Bracket-Safety Rail Assembly
New Technology to Increase ROPS Use on Tractors

Research equipment:

Name: 5- ton overhead bridge crane
Description: Ground controlled overhead crane with cable and winch assembly. Able to tram in horizontal plane the length of the laboratory.
Use: The overhead crane is used for moving large assemblies the length of the laboratory, as well as raising and lowering assemblies within the vertical dimension. It is also used to restrain objects from uncontrolled movement while under pressure with test conditions.

Name: test bed
Description: Floor-mounted experimental platform with multiple points for securing test objects. The bed measures 10 by 15 feet and is 7 inches thick, and is composed of four sections that can be positioned by the overhead crane. T–slots in the bed surface provide anchors for the equipment under test
Use: Platform used to secure and test machinery, fabricated objects or materials for pressure resistance, durability, deformability and failure under various test and load conditions, in various positions and alignments..

Name: hydraulic power supply and actuator system,
Description: Cyclic-pump mechanism for application of hydraulic pressure to test objects.
Use: Hydraulic pressure through ram or other mechanisms is used to subject test objects to measurable load and determine characteristics of failure modes and range of resistance to failure.

Name: research manikin
Description: The research manikin is a jointed model of the human body, with embedded accelerometers and other sensors. It was designed with a high degree of biodynamic fidelity to the human body under conditions of rapid acceleration and deceleration, such as would be experienced in an aircraft crash or fall incident. The manikin has body segments which approximate that of the human body, articulated limbs with a range of motion that also approximates that of the body, and a spinal system that was designed to replicate the human spine's elasticity along the z axis.

The manikin contains an onboard data acquisition system and all joints contain sensors. Internal instrumentation includes three triaxial accelerometers, located in the head, the neck, and the chest, and two internal load cells located in the spine. Finally, there are position sensors mounted in the knees, elbows, and shoulders.
Use: This equipment has been used in a series of tests on the biodynamic forces that protective equipment and the human body would experience during free-fall and rapid deceleration while wearing fall-restraint equipment.

Name of Laboratory: Human Digital Modeling & Hand Scanning Lab

Site/Location: H 1504

Description (narrative):

This laboratory incorporates specialized scanning equipment, computer workstations and software applications for the acquisition and analysis of digitized models of the human form, in a 40 by 28 by 9 foot facility. This facility is designed to work closely with the Anthropometry Research Laboratory in the acquisition, manipulation, and analysis of digitized information on human forms produced by scanning human subjects and recording this morphological data as digital information. To date research has focused on digitization of the human hand and the interface between the hand and protective gloves.

Research has been conducted in a number of areas, including quantification of proper fit of test subject hand dimensions to glove dimensions, and development of a sizing schema for the National Fire Protection Agency efforts to improve protective gloves for fire fighters.

Research conducted:

Improved Equipment Design through Applied Anthropometry

Research equipment:

Name: A. 3-D Hand Scanner System, manufactured by InSpeck, Inc.
Description: Three dimensional scanner
Use: Obtain 3D scans of hand data

Name: HandScan Flatbed Scanner System, manufactured by VisImage, Inc.
Description: Flatbed scanner for 3D image capture
Use: Acquire 3D image data

Name: Three HP XW500 Windows-based Workstations:
With the following Engineering Software Platforms: INTEGRATE, CYSCAN/ARN, 3D Studio Max, JACK
Description: Workstations with dedicated software
Use: Applications for capturing and manipulating anthropometric data

Name: Jamar Dynamometer
Description: Dynamometer
Use: Test equipment used for grip strength analysis

Name of Laboratory: Human Factors Laboratory

Site/Location: H B413

Description (narrative):

This laboratory is a unique facility for research in the areas of biomechanics, applied physiology, and industrial psychology. The 30- by 40-foot laboratory has a 17-foot-high ceiling to permit the study of a variety of work practices. The lab supports studies of postural stability, human motor and mental responses, machine safety, acute musculoskeletal injuries, and heat stress evaluations.

This laboratory is equipped with three core systems, an environmental control unit (ECU), two types of motion measurement systems, and two force platforms. An electromyography (EMG) measurement system and various physical signal measurement devices are also available, and can be synchronized with the core systems. The ECU can control temperature and lighting with a high degree of precision; temperature can be controlled in a range of 35-degree F to 95-degree F, 30% to 90% humidity, and 0.1 to 100 foot candles lighting. The motion measurement systems use six cameras, which are located in each corner of the room. One system uses an infrared camera which automatically calculates body-position velocities, accelerations, and interfaces directly to software programs which then calculate joint forces. These features make the system optimal for the rapid analysis of motions when all the body markers are visible throughout the range of movement being studied. For movements in which some markers may be hidden at certain times, the second type of measurement system offers a manual digitizing capacity to recover the hidden data points. This video-based system, which is controlled by the Peak Motus software application, can objectively collect, quantify, and document motion in two- and three-dimensional space. These systems are interchangeable within the high bay lab. The last major items of research equipment are two force platforms, which are used to capture data such as the amount of force distribution and direction in workers' feet during walking, as well as the amount of sway in a worker's standing posture, as a predictor of stability and fall potential. These platforms rest on a sunken concrete pad so that the plate surface is level with the floor surface. The supporting pad is isolated from the rest of the floor to reduce the effects of building vibration.

Research within this laboratory will focus, or has focused, on the human factors associated with the use of fire fighters boots, tribologic data collection on the interface between shoes and shoe surfaces in healthcare settings, kinematic data collection for workers performing tasks on the platform of an aerial lift, data collection for studies of gait and joint loadings for workers who use stilts, and the forces imposed on the human body during the lifting and movement of drywall sheeting in construction tasks.

Research conducted:

Fall Prevention for Aerial Lifts in the Construction Industry
Biological and Physiological Study of Firefighter Boots
A Study of Ergonomic Interventions in the Dry Wall Industry

Research equipment:

Name: Variable Incidence Tribometer (VIT), also known as English XL slipmeter
Description: The VIT is a portable device used to measure the slipperiness of floors.
Use: This device is driven by pneumatic pressure using the methodology described in ASTM standards F1679-00 2001. It is a useful tool for determining the tribologic characteristics of flooring material, which may contribute to slip-and-fall incidents.

Name: Portable Inclinable Articulated Strut Tribometer (PIAST), also known as the Brungraber Mark II,
Description: This device is an inclined-strut slipmeter driven by gravity.
Use: This device is cited by ASTM standards F1677-05 2005 as a valid device for measuring floor and shoe slipperiness. This device has a relatively large sensor (58 cm2), compared to English XL (7.9 cm2) which is a better device for measuring shoe slipperiness, which can contribute to loss of balance and slip-and-fall incidents.

Name of Laboratory: NIOSH Lake Lynn Laboratory

Site/Location: Fairchance, PA

Description (narrative): The Lake Lynn Laboratory, an experimental hard-rock mine operated by the NIOSH Pittsburgh Research Laboratory, served as a resource in conducting the "Evaluating Roadway Construction Work Zone Interventions" project, which is evaluating interventions that are intended to prevent ground workers from being struck by construction equipment. In defining the data collection methods for this project, it was necessary to develop blind area diagrams of road construction equipment. These diagrams were used to describe areas around equipment that are hazardous to ground workers. The Lake Lynn facility was utilized in developing diagrams for six pieces of equipment.

Research conducted:

A fenced-in area with a concrete surface at the Lake Lynn facility was utilized in diagramming blind areas for the following equipment, which were provided by a contractor except as noted: Ford F-800 Dump Truck (typical type of two-axle dump truck used to haul asphalt to a paving site); Caterpillar 672 CH Motorgrader (used to develop road grade); Ford F-250 Super Duty Crew Cab Pickup Truck (NIOSH provided; typical of vehicles used by company foreman and quality control personnel); Chevy Astrovan (NIOSH provided; typical of vehicles used to transport construction workers); Clark 75C Wheeled Loader (used to move earth, rocks, and other materials); and Caterpillar 426C Backhoe Loader (used to move material and dig).

The blind area diagramming activity requires that a polar grid be transferred, usually with paint, on to a flat ground surface. The grid consists of 12 meter-long lines radiating from the center of the grid at 10 degree intervals and a series of concentric circles that are centered on the grid at 2 meter intervals. The outer circle has a radius of 12 meters. The equipment being mapped is moved to and held stationary at the center of the polar grid. A mapping crew consists of an equipment operator, an observer, a recorder, and two measurers. The operator and observer communicate to define the border of the blind area; that is, the area in which the operator cannot see the observer who is traversing step-wise around the equipment. The observer marks the grid with defining points of the blind area that are then measured. These measurements are recorded and developed into the blind area diagram. The resulting diagrams were critical in developing the project data collection methodology.

Research equipment: The process used at the Lake Lynn Laboratory facility to develop blind area diagrams of equipment is manual with no specialized research equipment requirements.

Name of Laboratory: NIOSH Pittsburgh Research Laboratory

Site/Location: Bruceton, PA

Description (narrative):

The Pittsburgh Research Laboratory (PRL), a extensive facility located on approximately 180 acres, served as a resource in conducting the "Evaluating Roadway Construction Work Zone Interventions" project, which is evaluating interventions that are intended to prevent ground workers from being struck by construction equipment. In defining the data collection methods for this project, it was necessary to develop blind area diagrams of road construction equipment. These diagrams were used to describe areas around equipment that are hazardous to ground workers. The PRL facility was utilized in developing diagrams for four pieces of equipment. In addition, the PRL facility was utilized in a pilot study to evaluate the project data collection techniques on an active asphalt paving operation.

Research conducted:

The surface of an empty parking area at the PRL facility was utilized in diagramming blind areas for the following equipment, which were all provided by a contractor: CMI Rotomill PR-525-7 (used to mill existing asphalt and prepare the road to be resurfaced); I-R Bobcat 763 with Broom (used to clear debris off of roads prior to paving); Peterbilt 357 Dual Axle Dump Truck (typical type of dual-axle dump truck used to haul asphalt to a paving site); and Mack RD688S Triaxle Dump Truck (typical type of tri-axle dump truck used to haul asphalt to a paving site).

The blind area diagramming activity requires that a polar grid be transferred, usually with paint, on to a flat ground surface. The grid consists of 12 meter-long lines radiating from the center of the grid at 10 degree intervals and a series of concentric circles that are centered on the grid at 2 meter intervals. The outer circle has a radius of 12 meters. The equipment being mapped is moved to and held stationary at the center of the polar grid. A mapping crew consists of an equipment operator, an observer, a recorder, and two measurers. The operator and observer communicate to define the border of the blind area; that is, the area in which the operator cannot see the observer who is traversing step-wise around the equipment. The observer marks the grid with defining points of the blind area that are then measured. These measurements are recorded and developed into the blind area diagram. The resulting diagrams were critical in developing the project data collection methodology.

When a company was contracted to pave an access road at the PRL facility, project researchers took advantage of the opportunity to pilot test the data collection techniques. During the milling and paving operations, ground worker exposure to moving dump trucks and equipment were simultaneously recorded using three methods: direct observation, video recording, and positional logging using global positioning system (GPS) receivers. Positional data were recorded for the following: seven ground workers; dump trucks backing towards the milling machine; a tractor placing geotextile material; a roller; and the paver. Results from this pilot study at PRL enabled researchers to refine data collection methods to better capture ground worker exposures to hazardous areas around road construction equipment.

Research equipment:

Work Zone Data Collection Trailer – Described in a follow-on "Laboratory Research Facilities" form.

Portable Hand Held Video Cameras – Used in the pilot study to record video footage of the paving operation. This footage was used to validate direct observation recordings of ground worker exposures to equipment.

Global Positioning System (GPS) Receivers – These receivers monitored the movement of dump trucks, equipment, and workers for the pilot study. This information was post-processed to calculate exposures of ground workers to equipment.

Name of Laboratory: Protective Systems Laboratory

Site/Location: H 1520

Description (narrative):

This laboratory is a 40 by 28 by 9 foot facility that is equipped with tools for the development of various items of control technology related to the transmission of electrical energy to the human body, as well as items of control technology to serve as warning or protective systems for the control of the transmission of mechanical energy to the human body. In addition, this laboratory includes various sensor-system development tools for developing biomedical instrumentation for workplace hazard exposures and work stressors. Test equipment includes digitizing oscilloscopes, RF phase generators, function generators, digital multimeters, computer workstations and various other items of test equipment for the generation, analysis and modification of items of electronic control technology. The laboratory is also used to develop electronic circuits and sensors to support in-house human subject studies. Current products developed from this laboratory include an EMG-video timecode synchronization unit, ROPS activation sensors, and electronic circuitry for detecting capacitance differential between wood products and humans in the signal path.

Research conducted:

Electrical Injury Protection System

Research equipment:

Name: Electronic signal generator
Description: Agilent 8648B Signal generator
Use: Common item of electronic test equipment used to create stimulus signals and capture responses.

Name: Oscilloscope
Description: Agilent 54832B Digital Oscilloscope
Use: Allows signal voltages and characteristics to be viewed and analyzed. Used in development and testing of electronic circuits.

Name: Electronic Phase Analyzer
Description: Hewlett Packard 4396B Network/Spectrum Analyzer
Use: Test equipment used to analyze phase noise, frequency, phase and transients for electronic devices used in electronic warning and signaling applications.

Name of Laboratory: Safety Engineering Laboratory

Site/Location: H 1610

Description (narrative):

This laboratory houses an array of electronics equipment and sensor-system development instrumentation in a 28 by 14 foot facility. This lab's efforts focus on developing improved designs for agricultural, construction, and industrial equipment. Current research is focused on assessing the safe and efficient operating envelope that equipment operators occupy. This research area focuses on the human factors and design factors of the interface between a truck driver or equipment operator and the operating environment or cab space in which he operates. The Safety Engineering Laboratory is equipped with motion capture Systems, digital measuring devices, foot pressure sensors, dynamic strength simulators, fabricated test bucks for determining the effective volume and space envelope around commercial drivers and equipment operators, and Unix-based workstations for simulations.

Research conducted:

U.S. Truck Driver Anthropometry and Cab Work Space
Evaluation of Fire Fighter Apparel on the Operation of Fire Response Vehicle

Research equipment:

Name: Digital point measurement system
Description: FaroArm, Bronze series
Use: This precision measuring device is used to assign data points to items in 3D space for use in determining effective volume and dimensional envelope around drivers and equipment operators.

Name: Test Bucks
Description: Motor Vehicle Anthropometry and Motion Capture Test Bucks
Use: Test bucks are fabricated mockups of drivers' and operators' seat and equipment space, and are used to model operators' safe and effective operational space, for use in truck and heavy-equipment design.

Name: Motion Capture System
Description: ProReflex Motion Capture System by Qualsys
Use: This technology is used for non-contact, accurate human motion measurement.

Name: Lido Lift
Description: LidoWorkset with dedicated data-capture workstation
Use: This equipment allows measurement of range of motion. The machine, using isokinetic and isotonic principles, responds to the level of strength the test subject to measure limb mobility, stretching capacity and muscle resistance.

Name of Laboratory: NIOSH Spokane Research Laboratory

Site/Location: Spokane Research Laboratory, Spokane, WA

Description (narrative): Preliminary evaluations of tag-based proximity warning systems for construction equipment.

Research conducted:

Evaluations were conducted to determine the detection characteristics and other operating parameters for two systems that are designed to protect workers on foot from being struck by construction equipment. The first system consisted of electronic tags worn by workers that transmit a pulsed radio frequency signal that is detected by tag readers mounted on mobile equipment. Time of flight signal measurements are used to determine distance to the tag. This system, developed by Tag Safety Systems, progressed to proof of concept, but was not far enough in development to progress to field trials. The second system tested was the TramGuard proximity warning system marketed by GeoSteering, Inc. for underground mining. This system uses tags on workers that detect a magnetic marker field generated by a loop antenna mounted on mobile equipment. Tests revealed modifications that were needed in order to use this system on construction equipment. Suggested modifications have been implemented on a new system called Hazardavert that will be tested at roadway and building construction sites.

Research equipment:

Several pieces of electronic test equipment were used during the development and evaluation of these systems: radio spectrum analyzer, oscilloscope, electronic test meter, and a laptop computer.

Name of Laboratory: Virtual Reality Laboratory

Site/Location: H B 209

Description (narrative):

This laboratory contains a virtual-reality-simulation space, which is a computer-generated projection that gives a user the illusion of being fully immersed in a three-dimensional world. The user wears special eyewear that synchronizes and filters the projected images to create a realistic impression of 3D space. At present, this 28- by 35- by 14-foot laboratory is being utilized to understand human behavior, physical response, and decision-making skills under simulated conditions of elevated work; findings are validated and compared with measurements taken under non-simulated work conditions. In addition, investigations of fall risk factors, injury processes, and fall prevention technologies are ongoing.

The Virtual Reality Laboratory is equipped with four projection systems, an image generator, head tracking system, stereo eyewear and a 3-wall-1-floor screen. The projection systems and image generator function as an integrated system, controlling the projected images as well as the software application. The motion tracking system continuously adjusts the stereo projection to the current position of the user, tracking the subject's position and updating the stereo projection in real time to that position. The stereo eyewear is integral to the 3D experience, creating the illusion of depth so that the user can walk through the surrounding virtual environment, experiencing the sights and sensation of elevation.

Various research projects are underway or have been conducted in this innovative and advanced laboratory, including basic research to determine and validate the overall usefulness of SSVR technology in assessing occupational safety issues, research on scaffolding safety, research on maintaining stability while on sloped roof surfaces, and similar research related to falls from elevation and safety while working at heights.

Research conducted:

Evaluation of Sensory-Enhancing Technology for Improving Balance Control at Elevated Workplaces

Research equipment:

Name: CAVE Surround Screen Virtual Reality (SSVR) system
Description: The SSVR is the system used to generate the VR environment
Use: This facility is used to generate virtual imagery for use in testing human subjects under circumstances that would be too dangerous for field studies or laboratory-based tests.

Name of Laboratory: Work Zone Data Collection Trailer

Site/Location: Mobile, currently located at a remote data collection site

Description (narrative):

The Work Zone Data Collection Trailer was designed and constructed to enhance data collection and analysis capabilities for the "Evaluating Roadway Construction Work Zone Interventions" project, which is evaluating interventions that are intended to prevent ground workers from being struck by construction equipment.

Research conducted:

The Work Zone Data Collection Trailer primarily serves as the operational platform for video footage that is recorded as part of the "Evaluating Roadway Construction Work Zone Interventions" project data collection activities. The trailer, powered by a five kilowatt gas generator, is setup alongside active paving operations that are participating in this project. The trailer is equipped with two pan/tilt/zoom cameras positioned on a mast capable of being raised 58 feet. A joystick located inside the trailer controls both of the mast-mounted cameras, allowing for simultaneous views from multiple angles. The trailer is also equipped with three desktop computers that are networked together by a local area network (LAN). All three computers are capable of accessing the internet via the broadband satellite internet connection. Two of the computers control two wireless video cameras that are mounted on separate portable trailers. Through a video splitter, a four-way split image of all video inputs is displayed on one monitor. This video image, in addition to the four independent video inputs, is recorded by VHS video cassette recorders. Time code generators embed a global positioning system (GPS) time code onto all video images.

To date, the trailer has been used in seven pilot sites and eight research sites. The trailer is currently located on the ninth of sixteen scheduled research sites. The study sites have been located in North Carolina, South Carolina, Pennsylvania, West Virginia, Indiana, and Idaho.

Research equipment:

Spectra Mast Camera System – Two pan/tilt/zoom cameras located on top of a telescoping mast that is mounted on the trailer. The cameras are remotely controlled from within the trailer to record video footage of the work site. This video footage can then be analyzed at a later time.

Portable Trailer Mounted Camera System – Two pan/tilt/zoom cameras located on masts that are mounted on two separate portable trailers. These two cameras are controlled wirelessly from the Work Zone Data Collection Trailer to record video footage of the work site. This video footage can then be analyzed at a later time.

Desktop Personal Computer (PC) – Three desktop PCs are located in the trailer. Two wirelessly control the two portable trailer mounted camera systems. One controls the internet connection via the satellite. All three are on a local area network (LAN) for information sharing capability.

Broadband Satellite Internet – Provides the PCs within the trailer with broadband internet access.