Auditory Systems Laboratory at Virginia Tech: Research Capabilities, Hearing Protection Test Facility, and Standard Report Forms

by

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SCOPE OF SERVICES

Virginia Tech's Auditory System Laboratory is equipped to provide versatile research and testing services for a wide variety of acoustics- and human factors-related applications. In this facility, principles and methods of engineering, ergonomics, behavioral science, and acoustics are applied to solve problems and answer technical questions concerning human hearing conservation, auditory information display, and product design. The laboratory exists in the Human Factors Engineering and Ergonomics Center within the Grado Department of Industrial and Systems Engineering. It provides independent research and testing services for a variety of government, military, and industrial clients on a contract or grant basis. Laboratory personnel can also be retained to consult on short-term projects outside the University.

Previous clients, which encompass research supporters and those requesting testing or consulting services, include: National Institutes of Health, NIOSH, NPPTL, U.S. Bureau of Mines, U.S. Army, U.S. Navy, USAARL, Federal Highway Administration (FHWA), Peltor AB and Bilsom AB of Sweden, North Health Care, Bose Corporation, UPS, Toyota, Adaptive Technologies, Inc., Noise Cancellation Technologies, Willson Safety Products, ALCOA, General Motors, Battelle, AEARO Corp., (formerly Cabot Safety Corporation), DeGil Safety, Bilsom International, Advanced Intelligent Communications, Virginia Center for Innovative Technology, Shure Corp., Turman Lumber, Jefferson Mills, Johnson Controls, Sonomax, Custom Protect Ear, and various attorneys and city/county governments involved in noise and safety related litigation and legislation. The facility is equipped to support industrial and community in-field investigations as well as controlled laboratory experiments employing human subject (psychophysical) or physical (microphone-based) acoustical measurements.

Instrumentation, acoustic test chambers, and personnel provide a wide range of research and analysis capabilities, exemplified by the following:

Attenuation testing and Noise Reduction Rating (NRR) of hearing protection devices per ANSI, ISO, and military standards and EPA labeling requirements. Compression force and application pressure measurements for earmuff protectors.

1) Evaluation of Active Noise Cancellation hearing protectors and communications headsets for attenuation and speech intelligibility, using acoustic manikin and real-ear testing protocols.

2) Development and/or improvement of hearing protector designs. Experimentation on all types of hearing protectors and headsets, including active noise cancellation, amplitude-sensitive, and frequency-selective devices, using miniature microphones with acoustic manikins and acoustical test fixtures or with human subjects.

3) Design, development, and assessment of auditory displays and warning signals. Human performance evaluation of displays in various acoustic environments.

4) Empirical assessment of speech intelligibility with headset, ear microphone, or sound field electronic communications systems using ANSI Standard methods.

5) Investigation of signal detection, interpretation, and perceived urgency under various environmental (e.g., heat chamber, in-vehicle) conditions using custom-designed, validated protocols and rating scales.

6) Analytical evaluation of signal detection and speech intelligibility per standardized ISO and ANSI procedures.

7) Evaluation of personal protection product comfort and wearability using validated rating scales and behavioral test protocols.

8) Development of instruction and training materials for use with products, especially hearing protectors and noise measurement instruments.

9) Assessment of industrial noise exposure, community noise, and noise sources using dosimetry, real-time spectral analysis, and FFT analysis.

10) Design of industrial hearing conservation programs.

11) Pure-tone, extended frequency, masking, speech, and bone conduction audiometry for determination of hearing level and acuity of candidate subjects in research.

12) Psychoacoustic laboratory experimentation concerning issues in auditory perception and hearing loss research.

13) Usability testing of products from a human factors engineering perspective.

14) Evaluation of pilot performance under standard and non-standard operating conditions using existing and conceptual aircraft displays to investigate and promote pilot safety in the current and future national airspace system.

15) Evaluation of the current Federal hearing-level requirement for commercial vehicle operators.

16) Quantification of the noise exposure of long-haul commercial vehicle operators.

17) Quantification of noise emissions from consumer products, in-situ or in acoustic chambers.

18) Evaluation of in-vehicle auditory displays in simulated and on-road scenarios and quantify their impact on driver performance.

19) Determination of driver brake response time under various simulated and on-the-road conditions.

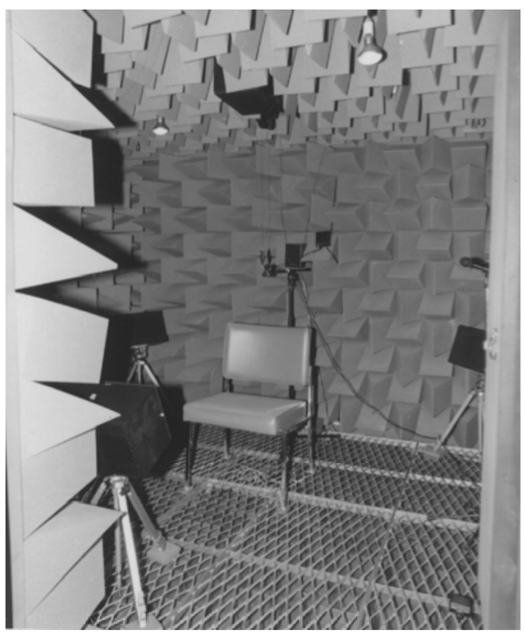
FACILITIES

The laboratory occupies over 2500 ft^2 in Whittemore Hall on the Virginia Tech campus. Two sound chambers (an anechoic chamber and a reverberant room) are housed within a sound-isolated room with double exterior walls and an acoustic door. These chambers are shown in Figures 1 and 2. A second room can be configured for experiments that do not require the restrictive sound fields exemplified by the two test chambers. In addition, driving and flight simulators, shown in Figures 3 and 4, are available in the Vehicle and Aircraft Research Simulation Laboratory (of which Dr. Casali is co-Director) for conducting transportation-related display and control research. Access to additional test space can be gained as necessary on a project-by-project basis. Furthermore, portable equipment housed within the Laboratory allows on-site tests and data collection in the field.

Major Laboratory Equipment

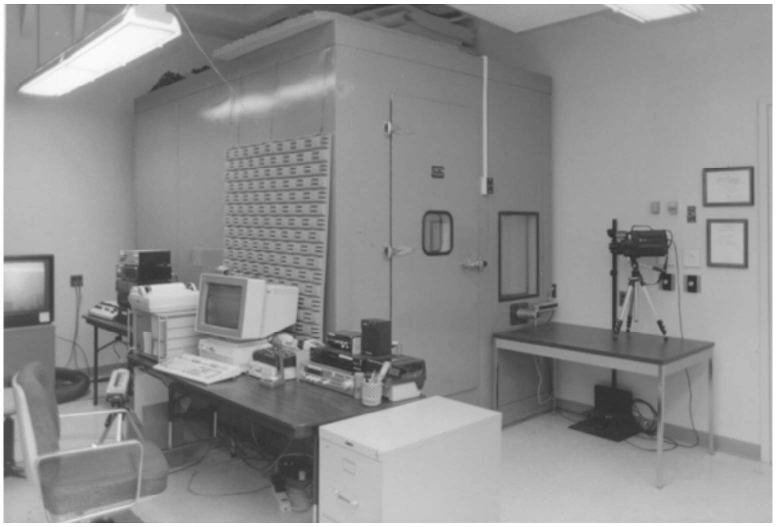
Research and test/evaluation efforts in the laboratory are supported by an array of versatile instrumentation and special sound chambers. In addition to the fixed-site facilities pictured in Figures 1 through 4, the Auditory Systems Laboratory also houses a portable audiometric booth, Figure 5, for on-site screening and data collection purposes. A variety of acoustical measurement instruments, test fixtures, analog and digital sound recording and reproduction equipment, and computer resources provides the Laboratory with the flexibility necessary to perform a wide range of research. A few of these resources are shown in Figure 6 while a partial listing of available equipment follows:

Exterior view of the anechoic chamber



Interior view of the anechoic chamber

Figure 1. Anechoic chamber located in the Auditory Systems Laboratory.

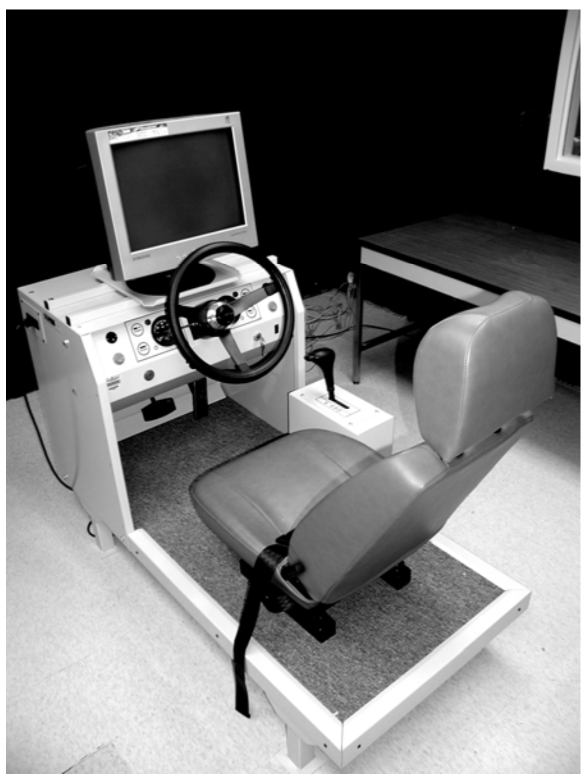


Exterior view of the reverberant room showing the experimenter's station

Interior view of reverberant room

Figure 2. Reverberant room located in the Auditory Systems Laboratory.

Commercial driving simulator driver's position



Passenger vehicle driving simulator driver’s position

Figure 3. Virginia Tech Driving Simulators.

i-Gate simulator control console

Flight simulator experimenter’s station

Figure 4. Virginia Tech i-Gate Flight Simulator

Figure 5. Portable audiometric test booth.

Experimental Chambers:

- Eckel Anechoic Room, 2,000-ft^3, 150 Hz cutoff, foam wedge system, <13 dBA interior noise level
- IAC Reverberant Room, 600-ft^3, reverberation time at 1,000 Hz: 1.21 sec, <16 dBA interior noise level
- IAC LP-250 portable audiometric test booth

Instrumentation:

- Larson-Davis 3200 Real-Time and FFT Spectrum Analyzer, dual-channel, with full through 1/24 octave filters
- Larson-Davis 2800 Real-Time and FFT Spectrum Analyzer, with full and 1/3 octave filters
- Larson-Davis 824 RTA/SLM, with full and 1/3 octave filters
- Larson-Davis 800B Precision Sound Level Meter and One-Third Octave Band Analyzer
- KEMAR (Knowles Electronic Manikin for Acoustic Research)
- B&K Type 4227 mouth simulator
- Rion NA-29E Portable Real-Time Octave Band Spectrum Analyzer/Sound Level Meter

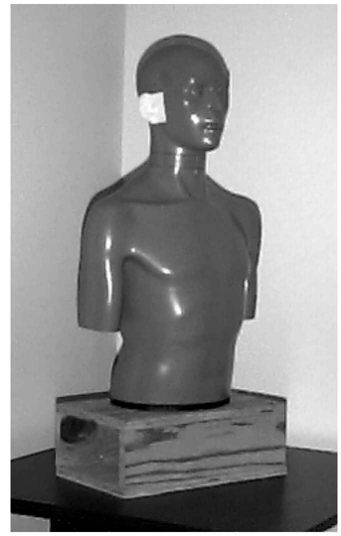
- Rion SA-27 Portable One-Third Octave Band Spectrum Analyzer
- Rion SA-77 Portable FFT Analyzer
- Quest 2200 Sound Level Meter
- Quest M-27 (4) and Q-300 (5) Noise-Logging Dosimeters and Larson-Davis 710 Dosimeter for field use
- Quest M-28 Community Noise Analyzer
- Quest, B&K, and RION Standard Source Sound Level Calibrators
- ACO, Larson-Davis, Rion, AKG, and Shure Measurement and Recording Microphones
- Norwegian-Electronics Type 828 Hearing Protector Test System and Signal Generator/Attenuator with custom software for conducting attenuation tests per ANSI and ISO Standards
- MLSSA Acoustical Measurement System for performing computer-based room acoustics and speech intelligibility testing
- Custom Miniature Microphone Systems (based on Knowles microphones), with belt-pack mounts, for physical HPD attenuation testing
- INSPEC Earmuff Headband Force Measurement Rig (as required by ANSI and ISO Standards)
- INSPEC Earmuff Cycling Rig (as required by ANSI and ISO Standards)
- Beltone 2000 Clinical, Masking, Speech, and Bone Conduction Audiometer with high frequency test capability to 20,000 Hz
- Beltone 114 Clinical Audiometer
- Beltone 119 Portable Audiometers (2 for on-site tests)
- Micro Audiometrics MicroLab Portable Audiometer (for on-site tests)
- Norsonic TEP-2 Frequency-Matched Loudspeakers (2 sets of 4 each)
- Infinity RS9 (2 pair), RS6 (2 pair) and SM-155 (2 pair) Loudspeakers
- Bose 802 Series II Loudspeakers (2 pair) and 502B Bass Unit
- JBL SP215-6 Full Range Loudspeakers (4) and SP128S Subwoofer
- Parasound, NAD, ADCOM, Bose, QSC, and OCM Preamplifiers and Power Amplifiers (up to 1100 w/ch)
- Yamaha, AudioControl, and Ross Equalizers
- Fostex, Sony, and Teac Magnetic Audio Tape Recorders (both analog and digital)
- Digital and analog video recording systems

Computing equipment:

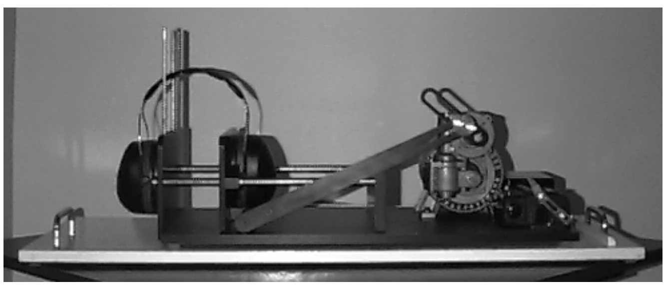
- Power Macintosh and Pentium-based computers used for sound generation and editing, equipment control, and data acquisition
- Digital sound editing software for both Mac and PC platforms
- Gateway, Dell, and Apple Macintosh portable computers for in-field data acquisition

Two distinct sound environments, each equipped with closed circuit TV so that human subjects can be monitored, are used to conduct attenuation tests. For EPA product labeling purposes and NRR determination, real-ear attenuation tests (REAT) are conducted per ANSI S3.19-1974 using a trained panel of subjects in an IAC reverberant chamber, which provides room noise levels of less than 16 dBA. REAT tests can also be conducted in an Eckel anechoic chamber, which provides interior levels of less than 13 dBA, and houses instrumentation that meets ANSI S12.6-1997 as well as certain European standards. The test signal generation, presentation, and recording system for these tests is a modified Norwegian-Electronics Type 828 unit, which is fully computer-controlled and can provide data at the required frequencies from 125 to 8,000 Hz plus extended range testing down to 64 Hz and up to 16,000 Hz. All audiogram recording and calculation is performed via dedicated computer so that the subjectivity inherent in human scoring of audiometric data is removed. Three detailed technical reports describing each facility, its calibration data to verify standard compliance, and a laboratory policies and procedures manual are listed in the reference list at the end of this report and are available for inspection by interested parties (Casali, Robinson, and Hankins, 2000a; 2000b; Hankins, Robinson, and Casali, 2000).

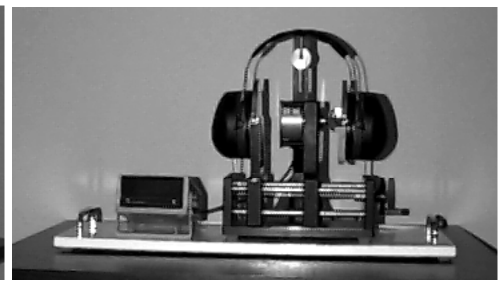
Audiometric and Tympanometry Equipment



KEMAR (Acoustic Manikin)



Earmuff Cycling Rig



Earmuff Headband Force Rig

Sound Level Measurement Equipment

Figure 6. Examples of the support equipment available in the Auditory Systems Laboratory.

In addition to the real-ear attenuation tests, physical measurements of earmuffs or earphones using acoustical test fixtures can be obtained to meet the physical methods of ANSI S3.19-1974 or ISO/TR 4869-3, or using miniature microphone in human ears to meet Military Standard MIL-STD-912, ANSI S12.42-1995, or similar standards. Laboratory personnel have extensive experience in conducting microphone-in-real-ear tests and have developed a custom miniature microphone system to provide *noise reduction* or *insertion loss* measurements on two earmuff cups simultaneously through a Larson-Davis 3200 real-time analyzer. This system is particularly helpful in providing quick results of changes in design when prototyping hearing protectors. It also supports the determination of active and passive attenuation for Active Noise Cancellation devices. Also, a KEMAR manikin and various acoustical test fixtures are available as alternatives to human head approaches. Special needs outside the standardized test requirements can usually be accommodated on request.

Attenuation test results from the ANSI-standardized test are provided to the client in the form of a formal technical report. An example of a standard test report form appears in Appendix 1. Included in the report are attenuation data by trial for each individual subject, mean and standard deviation attenuation by frequency, the NRR and its stepwise calculations, physical measurements (e.g., earmuff compression force) as appropriate, test conditions and procedures for fitting the protectors. Special testing procedures may be requested by the client for non-labeling purposes; if so, these will be specified on the test report.

Vehicle Driving Simulator Facility

The Virginia Tech Vehicle Driving Simulator Facility (see Figure 3) was developed to examine issues related to the use of auditory displays and display modality allocation in motor vehicles. Example topics include the intelligibility of synthetic speech in truck noise, the utility of directional auditory displays for the presentation of navigational information, the utility and potential performance enhancements available from the use of auditory icons (representational sounds with stereotypical meanings), the effect of visual display type (e.g., head-mounted display [HMD] vs. plasma panel) on driving performance, quantification of the acoustic environment in which commercial vehicle operators work, and simulator sickness investigations. Such issues are becoming increasingly important as Intelligent Transportation Systems (ITS) technology matures. Since driving is a visually intensive manual control-tracking task, ITS information display systems must be designed in such a way as to minimize additional burdens on the driver's already heavily loaded visual sensory channel. If not, the added workload could exacerbate current workload-related problems, possibly diverting the driver's attention away from the primary task of vehicle control. Alternative sensory channels, especially hearing, must be investigated as a means of presenting ITS information whenever appropriate.

The commercial vehicle simulator is a fixed-base, driver-in-the-loop simulator based on the STISIM Driving Simulator marketed by Systems Technology. Inc. The STISIM simulation software is installed on an Intel-based computer equipped with a 400 MHz Pentium II processor and 128 MB of memory. The driving scene is presented on an IBM 21-inch Trinitron display. Steering wheel, brake, and accelerator pedal position are obtained via optical encoders to ensure the maximum possible resolution in the driving performance measures obtained during an experiment. A list of potential driving performance measurements (dependent measures) that can be obtained in an experiment are presented in Table 1. The Open Module software option allows customization of the simulation software over and above that allowed by the scenario scripting language. The digital I/O card installed in the computer allows rudimentary two-way communication between the computer running the simulation and one or more additional computers to coordinate secondary tasks (i.e., present auditory prompts or control the presentation of a navigational display) or monitor and obtain driver response data not supported directly by the simulation software (i.e., raw pedal position or secondary-task response time).

To maximize the fidelity of the simulations, a pneumatic air-suspension seat was obtained from the Volvo Heavy Truck manufacturing facility in Dublin, Virginia and the original 12-inch diameter steering wheel was replaced by a 21-inch diameter unit taken from a White cabover tractor. The cab buck was constructed so that the seat, steering wheel, and pedal assembly were positioned as they would be in a typical long-haul truck cab. Finally, the dynamic response variables in the simulation software were changed so that the acceleration, deceleration, braking, and steering responses mimic those of a real class-8 truck.

The system described above allows a high degree of flexibility in the type and complexity of the experimental scenarios utilized. This flexibility is best illustrated by an example. The schematic diagram shown in Figure 7 illustrates an experiment developed for the simulator. This experiment was designed to: a) compare the utility of auditory displays and visual displays in warning truck drivers of impending front-to-rear and side collisions and b) measure their brake response times in such situations. The Pentium-based computer running the simulation controls the presentation of the visual displays via digital I/O. The first Macintosh computer collects raw pedal position data from the optical encoders from which reaction time can be calculated. The second Macintosh computer controls the presentation of all of the auditory displays. Events controlled by both of the Macintosh computers are triggered via digital I/O by the PC running the simulation.

A second STI driving simulator and console has recently been acquired that allows for research investigations into passenger vehicle simulation. The main structural component of the newer simulator is the Advance Therapy Products (ATP) Model No. 300VT, which is based on the ATP WT-2000 driving console.

Table 1. Dependent measures directly obtainable via the STISIM simulation software.

Driver-based performance measures:	
Number of off-road accidents	Number of speed limit exceedances
Number of collisions	Response time (seconds)
Number of pedestrians hit	Number of correct responses
Number of speeding tickets	Number of incorrect responses
Number of red lights run	Number of non-responses
Vehicle-based performance measures:	
Lane position (feet)	Throttle input (g's/second)
Steering wheel rate (degrees/second)	Longitudinal acceleration (g's)
Road heading error (radians)	Longitudinal speed (miles/hour)
Curvature error (1/feet)	

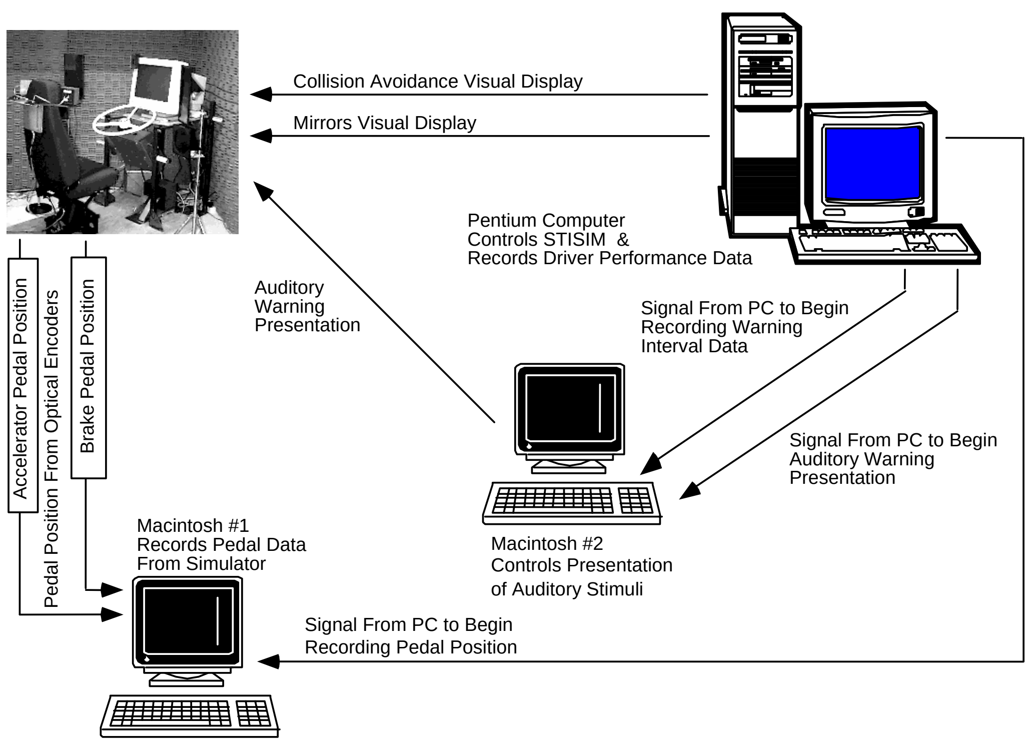


Figure 7. Schematic diagram illustrating a recent simulator-based display modality allocation study.

The ATP console serves as a platform for several seat options, allows the driver to reach and operate the fixed controls, and provides space for a CRT or flat-panel display behind the steering wheel. The overall dimensions and weight of the console made it an ideal candidate for the simulator because it is able to fit through a standard doorway. This satisfies, for example, requirements for such entities as the Department of Motor Vehicles (DMV), who may wish to place such a system in existing DMV offices (e.g., for substitution of the on-road driving test) without altering existing doorways. The spring-centered steering wheel is equipped with a computer-controlled torque motor that provides realistic, velocity-dependent force feedback. Optical encoders are used to sense steering wheel and pedal position. The console is equipped with a speedometer and tachometer mounted in the dash, both of which are linked to the simulator computer through an interface panel. Virginia Tech modified the console to provide visual and aural realism when the turn signals are activated by adding relays that provide a ticking sound, and by enabling the blinking dashboard indicators. The console is also equipped with a generic automatic transmission gearshift selector that, although not currently enabled, can be used to provide realistic functionality when desired.

Based on the VT-ISE simulator design requirements, ATP provided a custom seat configuration, including a vibration generator that provides haptic sensation to the driver when the vehicle passes over rumble strips. To correlate vehicle speed with seat vibration, it was necessary to determine the vibration frequencies caused by rumble strips at various highway speeds. Preliminary measurements were taken in a 1998 Dodge Ram pickup truck traveling over rumble strips at various speeds on Interstate-81 near Blacksburg, Virginia. In-cab noise measurements were performed using the lab's Larson-Davis 1/2-inch microphone and 3200 series real-time spectrum analyzer. The theoretical vibration frequencies produced by a vehicle traveling over rumble strips at various speeds was then calculated for several different designs of rumble strips. This was done by converting vehicle speed in miles-per-hour to millimeters-per-second and dividing by the center-to-center distance in mm for the rumble strip. The resulting frequencies were then used as a baseline for the seat vibration frequency of the simulator.

In order to provide a realistic driving experience, haptic foot pedal sensation similar to an actual vehicle is important to replicate. The VT-ISE simulator provides this sensation through the use of the ATP WC-220 foot pedal assembly. The spring-loaded WC-220 provides an increasing level of resistance as the pedals are depressed. Since the simulator has an automatic transmission, the WC-220 contains only gas and brake pedals. The foot pedals are independently connected to the simulator computer via the console interface. Optical encoders sense the position of the pedals during driving operations.

The steering wheel is connected to a torque motor assembly and provides velocity-dependent, active force-feedback to the driver. Optical encoders sense the position of the steering wheel during vehicle operation and relay the position to the computer. Steering wheel velocity and position information are relayed through a quadrature card (digital input/output interface) to the torque motor. The steering wheel can operate in three independent modes: free-rotation, spring-centering, and active resistance through the torque-motor.

The software controlling the simulation allows for the manipulation of a host of variables related to driving performance. For example, the driving surface can be widened or narrowed to present a decreased or an increased workload situation, respectively. Traffic densities, weather conditions, and road conditions (e.g., rough vs. paved) can be varied as well. The experimenter's computer (along with controlling the simulation) has the capability to collect and store data with respect to dependent variables of interest for transfer into spreadsheets and/or statistical programs for subsequent analysis.

Flight Simulator Facility

The Simulation facility also houses a flight simulator called the 'iGATE', which is an acronym for 'integrated General Aviation Training Environment.' The iGATE is certified by the Federal Aviation Administration (FAA) for Instrument Flight Rules (IFR) instruction, and licensed pilots can actually gain flight hours through its use (with a certified flight instructor present). Additionally, the simulator has the desirable ability to be configured for various testing conditions (such as weather and glideslope), it measures and stores objective data on over 40 variables related to flight (e.g., vertical speed, indicated airspeed, yaw rate), and can be configured to simulate up to nine different general aviation (GA) aircraft (e.g., Cessna 172R, King Air). An experimenter controller's station monitors and controls all aspects of the simulation, with researchers having the ability to manipulate several indices, such as weather conditions, day/night operations, and equipment failures.

The iGATE is a technically advanced digital training system designed around the widely used ELITE (ELectronic IFR Training Environment) software and incorporates a 'smart' panel upon which all of the instrumentation as well as the outside view from the aircraft are rendered. The panel design was a result of a NASA-sponsored scientific research study of human factors and optimum ergonomics for personal and professional use, and the panel is actually being used in many high performance aircraft today. The simulator is integrated, meaning that all required digital devices, hardware components, and software interface as an integral part of one system. This is not a new concept as older analog electromechanical trainers manufactured in the 70's and 80's were powered by a single electrical source. The uniqueness of this system is that the iGATE, with its digital components, combines all-new technologies to provide a simulator with state-of-the flight dynamics for several types of aircraft as well as other training capabilities at a single training station, one that can be used on a desktop or used in an enclosed cockpit environment.

Several research projects have been completed using the iGATE system. Topics have included: comparing pilot performance as measured in the simulator with that as measured in a real aircraft from a macroergonomic perspective, investigating pilot performance using mixed-modality simulated data link, comparisons of voice synthesis systems outputting air traffic control (ATC) directives for speech intelligibility within aircraft cockpit engine noise, and comparisons of various modern aviation communication headsets within several flight conditions for performance and workload evaluations.

Dr. John G. Casali, Laboratory Director

The Laboratory's Director, Dr. John G. Casali, is a Board-Certified Professional Ergonomist (registration number 222) who has served on the faculty at Virginia Tech since 1982. He is currently the John Grado Professor in the Grado Department of Industrial and Systems Engineering, and served as Department Head from 1996 to 2002. He received a B.S. in Psychology (1977) and M.S. (1979) and Ph.D. (1982) degrees in Industrial Engineering with concentrations in Human Factors Engineering at Virginia Tech. He joined the faculty in 1982 and was promoted to Associate Professor with tenure in 1986, to Full Professor in 1991, and received the Grado Professorship in 1996.

Dr. Casali's research interests lie in human factors and ergonomics, and he has conducted experiments concerning noise control and hearing protection, active noise cancellation, truck safety, driver-vehicle interaction and vehicular displays, warning signal design, and operator communications in noise and under workload. He also currently directs the Virginia Tech Vehicle Driving Simulator Facility, and together with Dr. Gary Robinson, has developed both a truck and an automobile simulator. His research, spanning over 60 separate projects, has been funded to a total of over $5 million by a variety of government and military agencies (e.g., FHWA, NIOSH-CDC, NPPTL, USAARL, U.S. Army Human Engineering Laboratory, Naval Training Systems Center, U.S. Bureau of Mines), as well as industrial corporations (e.g., Alcoa, General Motors, Carilion Health Care Systems, Peltor AB and Bilsom AB of Sweden, Bose Corp., Cabot Safety, AEARO Corp.). A large portion of his work on hearing protection has been supported by the National Institutes of Health.

Dr. Casali founded and developed the Auditory Systems Laboratory, which is unique among U.S. academic institutions in that it is equipped to conduct experimentation on hearing protection as per ANSI Standards S3.19-1974, S12.6-1984, and S12.6-1997, as well as several ISO and military standards. This facility houses both anechoic and reverberant acoustical chambers as well as a variety of acoustical and audiometric instrumentation. Many of the publications emanating from the laboratory concern hearing protection, auditory signal detection, and in-vehicle displays; Dr. Casali is considered to be a leading expert in these research areas.

Dr. Casali became a *Fellow* of the Institute of Industrial Engineers (IIE) in 2001, and a *Fellow* of the Human Factors and Ergonomics Society in 1994. He is also a member and former President of the National Hearing Conservation Association, and a member of

Sigma Xi, Alpha Pi Mu, Psi Chi, and Phi Kappa Phi. He is an Editorial Board member of *Human Factors* and serves as reviewer for several other journals. He is active on several ANSI and ISO Standards committees dealing with hearing protection and human engineering standards.

Dr. Casali has received several research and teaching awards from the Human Factors and Ergonomics Society (HFES), including the *Paul M. Fitts Award* (September, 1997) for outstanding contributions to the education and training of human factors specialists, and the *Jack A. Kraft Award* (September, 1991) for his efforts to extend or diversify the application of human factors to hearing loss prevention. In May of 1999, he received the *Institute of Industrial Engineers David Baker Award*, the premier industrial engineering research award. He also received the *American Psychological Association Briggs Award* for the Outstanding Dissertation in Engineering Psychology for 1982. From the National Hearing Conservation Association (NHCA) he twice received the *Outstanding Lecture Award* based on audience ratings for his papers at the 1991and 2008 NHCA Conferences and the 1994 *Media Award* for television and newspaper interviews he gave on the problems of noise exposure. In September, 1994 he was interviewed and the Virginia Tech Auditory Systems Lab featured on three national Cable News Network (CNN) TV shows: World News Tonight, Headline News, and Science and Technology Week. In May, 1998, Virginia Tech awarded him the *Dean's Award for Excellence in Research* while he is serving as Department Head of Industrial and Systems Engineering. In September, 2002, Virginia Tech awarded him its highest research award, the *Alumni Award for Research Excellence.*

Dr. Casali has also served a number of organizations in leadership capacities outside the the university, and for these efforts, Virginia Tech awarded him the 2006 College of Engineering Outreach Excellence Award. For instance, he currently serves on the Scientific Advisory Boards of the Oxford Research Institute, Personics, Inc., and Custom Protect Ear, Inc., and was President of the National Hearing Conservation Association in 2007.

Dr. Casali has been a versatile teacher, and has received five commendations for his classroom performance. Under Casali's chairmanship, 26 M.S. and 17 Ph.D. students have completed degree requirements to date. He credits much of his laboratory's research accomplishments to the work of these students.

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As a consultant, Dr. Casali has served over 60 organizations and companies nationally concerning acoustics and hearing protection, ergonomics, industrial safety, community noise, and forensic human factors and has completed some 70 consulting projects. He and a graduate student are co-holders of two U.S. Patents (#'s 5,333,622 and 5,131,411) for custom hearing protection and in-ear couplers. Dr. Casali has another U.S. patent (# 5,651,422) for a detachable power drive/steer attachment for folding wheelchairs. He has other patent applications under review in the areas of hearing aids and ear-insert technologies. Dr. Casali has authored noise ordinance legislation adopted by a small city and participated in numerous public hearings on zoning and community noise annoyance issues.

As Department Head (1996-2002), Dr. Casali recruited over 15 faculty and played a significant role in procuring over $7.2 million in donations and scholarships/fellowships including a major endowment which resulted in the permanent naming of the ISE department for the benefactor. Under his leadership, in 2000 the ISE department was named as one of three "Exemplary Departments" at Virginia Tech for accomplishments toward diversity and multiculturalism. In 2002, the ISE department also rose to become the 7th-ranked department nationally in *U.S. News and World Report* rankings for undergraduate programs and 8th-ranked for graduate programs, and it is one of the top-ranked programs at Virginia Tech.

In the human factors engineering and acoustics literature, Dr. Casali has authored over 160 publications, including over 100 refereed papers. He has also given over 140 technical presentations, workshops, and seminars, including plenary or invited speeches at conferences in South America, Canada, NATO-AGARD in Belgium, Germany, and Denmark, as well as in the U.S.

LABORATORY CONTACT AND CONTRACTUAL ARRANGEMENTS

Inquiries regarding research, testing, or consulting efforts should be directed to Dr. John G. Casali at jcasali @vt.edu or 540-231-5073.

In addition to the standard services, laboratory personnel perform design consulting and maintain an interest in pursuing new areas of research and assisting in technology development efforts. Inquiries into acoustics and ergonomics issues which may not be addressed in this report are welcomed. Research and testing work is usually conducted through grants or contracts administered by the Virginia Tech Research Division, and short-term consulting projects are negotiated individually with the faculty member desired. Research projects can be structured on a fixed-cost or cost-reimbursable basis. Testing projects are usually performed on a fixed-cost basis. All projects culminate in a final technical report that is provided to the sponsor. The scope and term of projects varies considerably, ranging from tests which encompass only a few days to long-term research projects of several year's duration.

MANUALS AND REPRINTS

The aforementioned ANSI verification and policies and procedures manuals for the HPD test facilities are available for inspection by interested parties. Also, over 100 articles and reports have been generated by laboratory personnel since 1983. Most of these reports are available in the open literature. A list of available articles as well as reprints of them can be requested through the Laboratory Director's Office.

Sponsors may also participate in the Auditory Systems Laboratory's Graduate Internship Program. While interns, graduate students from the laboratory serve at the sponsor's site for 4.5 months each year and conduct thesis or dissertation research on a topic of interest to the sponsor while on campus the remainder of the year. A proposal describing the structure and cost of this program is available from Dr. Casali.

Laboratory Manuals

Hankins, S. E., Robinson, G. S. and Casali, J. G. (2000). *Quality manual: Virginia Tech Hearing Protection Research and Testing Facility re: ANSI S3.19-1974 and ANSI S12.6-1997*, (ISE Report Number 20001, Audio Lab Number 4/01/00-1-HP). Blacksburg, VA: Virginia Tech, Department of Industrial and Systems Engineering.

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Casali, J. G., Robinson, G. S. and Hankins, S. E. (2000b). *A computer-controlled facility for hearing protection research and attenuation testing: Verification re ANSI S12.6-1997* (ISE Report No. 20003, Audio Lab Number 4/14/00-3-HP). Blacksburg, VA: Virginia Tech, Department of Industrial and Systems Engineering.

Selected Laboratory Research Publications (Reprints available upon request)

Casali, J. G. (2006) Sound and noise. Chapter 24 in Salvendy, G. (Ed.) Handbook of Human Factors, 3rd Ed., New York: John Wiley, 2006, Chapter 24, 612-642.

Casali, J. G. (2006). Protection and enhancement of hearing in noise. Chapter 7 in Williges, R. C. (Ed.) Reviews of Human Factors and Ergonomics, Volume 2, Santa Monica, CA: Human Factors and Ergonomics Society, 195-240.

Casali, J. G., Robinson, G. S., Dabney, E. C., and Gauger, D. (2004). Effect of electronic ANR and conventional hearing protectors on vehicle backup alarm detection in noise. *Human Factors*, 46(1), 1-10.

Belz, S. M., Robinson, G. S., and Casali, J. G. 2004). Temporal separation and self-rating of alertness as indicators of driver fatigue in commercial motor vehicle operators. *Human Factor*s, 46(1), 154-169.

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Lee, S. E., Robinson, G. S., and Casali, J. G. (1999). Safety implications of the FHWA hearing requirement for truck drivers. *Proceedings of the Second International Truck and Bus Safety Symposium,* Knoxville, Tennessee: The University of Tennessee Transportation Center, October 6-8, 331-342.

MANUALS AND REPRINTS

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Belz, S. M., Robinson, G. S., and Casali, J. G. 2004). Temporal separation and self-rating of alertness as indicators of driver fatigue in commercial motor vehicle operators. *Human Factor*s, 46(1), 154-169.

Casali, J. G. and Robinson, G. S. (2002) Industrial warning signal detection under augmented hearing protection devices. *Journal of the Acoustical Society of America*, Vol. 112(5), Pt. 2, 22.94.

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Casali, J. G. and Park, M. Y. (1990). Attenuation performance of four hearing protectors under dynamic movement and different user fitting conditions. *Human Factors*, *32*(1), 9-25.

APPENDIX 1

Hearing Protection Device
Attenuation Test Report Form
(for tests conducted under ANSI S3.19-1974)

AUDITORY SYSTEMS LABORATORY
HEARING PROTECTION DEVICE
ATTENUATION TEST REPORT

AUDITORY SYSTEMS LABORATORY
Dr. John G. Casali, Grado Professor & Director
Office Phone: (540) 231-5073
Facsimile: (540) 231-3322
WWW: http://hfec.vt.edu/asl/

GRADO DEPT. OF INDUSTRIAL & SYSTEMS ENGINEERING
COLLEGE OF ENGINEERING
VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY
***Blacksburg, Virginia* 24061**

Test Report Date: zzz

Client: zzz
zzz
zzz

Test Report Number: zzz

The client may not use this report to claim product endorsement by Virginia Polytechnic Institute and State University (Virginia Tech).

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VIRGINIA TECH AUDITORY SYSTEMS LABORATORY

HEARING PROTECTOR ATTENUATION TEST REPORT*

HEARING PROTECTOR: zzz

PROTECTOR TYPE: zzz

MANUFACTURER: zzz

TEST DATE: zzz

TEST STANDARD USED: ANSI S3.19 - 1974

FITTING METHOD: Experimenter Fit[5]

NO. OF SAMPLES TESTED: zz

NO. & SEX OF SUBJECTS TESTED: zz M, zz F

SUBJECT AGE RANGE/MEAN: zzz yrs; zzz yrs

HEADBAND FORCE: zz N

TEST POSITION: zzz

COMMENTS:

TESTER: ______________________ ______________________ __________
Name Signature Date

APPROVED SIGNATORY: John G. Casali, Ph.D., CPE ______________________ __________
Name Signature Date

NOISE-REDUCTION RATING (NRR) per EPA (1990[5]): **zzz**
(calculations on page 3)

ATTENUATION MEANS AND STANDARD DEVIATIONS (from 30 trials)

1/3 octave band center (Hz)	125	250	500	1000	2000	3150	4000	6300	8000
mean attenuation (dB)									
standard deviation (dB)									

*Test report data relate only to those protector units and subject sample tested. The client may not use this report to claim product endorsement by Virginia Tech.

For labeling purposes, only the following statement may be used in regard to testing in the Virginia Tech facility; no other references to the university or to personnel may be used.

"These attenuation data were obtained in accordance with ANSI Standard S3.19-1974 in an independent university testing laboratory."

HEARING PROTECTOR ATTENUATION TEST REPORT

PROCEDURES USED

a) Test subjects were randomly selected from a pool of qualified listeners maintained by the Auditory Systems Laboratory. All listeners were empirically qualified as per the requirements of ANSI S3.19-1974[1] or ANSI S12.6-1997[3], according to the particular standard specified for testing.

b) Where ANSI S3.19-1974[1] was the test method, experimenter-fit was used, according to section 3.3.3.1 (2) of the standard, as per EPA (1990)[5] requirements. Where ANSI S12.6-1997[3] was the test method, experimenter-supervised fit (section 8 of the standard) or subject fit (section 9 of the standard) was used, as requested by the client and as indicated on page 1 of this report.

c) Room ambient noise levels were continuously monitored during the tests using a real-time spectrum analyzer to verify that allowable levels of the standards[1,3] were not exceeded during threshold determination.

d) The psychophysical procedure used in the tests was Békésy tracking, presented and scored on-line by computer. The scoring criteria programmed on the computer met the requirements of section 3.3.1.4 of ANSI S12.6-1997[3]. Detail concerning the implementation of this psychophysical procedure appears in Casali, Robinson and Hankins (2000a, 2000b)[2,4].

e) Where the protector under test was an earmuff or semi-insert device, headband compression force values were obtained from the test samples before attenuation testing commenced. Measurements were arithmetically averaged across the samples and the result (in Newtons, N) reported on page 1 of this report. The measurements were obtained using a Headband Force Rig Model 3.02.B manufactured by INSPEC Laboratories, Ltd, Manchester, England. The force measurements were obtained at a separation of 14.35 cm and a 13.08 cm headband height for tests conducted under S3.19-1974 and at a separation of 145 mm and a 130 mm headband height for tests conducted under S12.6-1997.

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[2] Casali, J. G., Robinson, G. S. and Hankins, S. E. (2000a). *A reverberant computer-controlled facility for hearing protection research and attenuation testing: Verification re ANSI S3.19-1974* (Report No. 20002). Blacksburg, VA: Virginia Tech, Department of Industrial and Systems Engineering.

[3] ANSI S12.6-1997. *Methods for the measurement of the real-ear attenuation of hearing protectors.* New York, NY: American National Standards Institute, 1997.

[4] Casali, J. G., Robinson, G. S. and Hankins, S. E. (2000b). *A computer-controlled facility for hearing protection research and attenuation testing: Verification re ANSI S12.6-1997* (Report No. 20003). Blacksburg, VA: Virginia Tech, Department of Industrial and Systems Engineering.

[5] Environmental Protection Agency. Product noise labeling. *Code of Federal Regulations*, 40 CFR Part 211, 128-144, July 1, 1990. (Requires ANSI S3.19-1974 and "Experimenter-Fit" protocol of section 3.3.3.1 (2).)

HEARING PROTECTOR: Protector Name

NOISE REDUCTION RATING (NRR) CALCULATION (per EPA, 1990)

1/3 octave band center (Hz)	125	250	500	1000	2000	4000	8000		
1. assumed pink noise (dB)†	100.0	100.0	100.0	100.0	100.0	100.0	100.0		
2. C-weighting corrections (dB)†	-0.2	0.0	0.0	0.0	-0.2	-0.8	-0.3		
3. unprotected ear C-weighted level (dB)†	99.8	100.0	100.0	100.0	99.8	99.2	97.0	107.9	Logarithmic Sum (log base 10)
4. A-weighted corrections (dB)†	-16.1	-8.6	-3.2	0.0	1.2	1.0	-1.1		
5. unprotected ear A-weighted level (dB) (step 1 + step 4)†	83.9	91.4	96.8	100.0	101.2	101.0	98.9		
6. mean attenuation at frequency (dB)†									
7. standard deviation at frequency (x2) (dB)†									
8. protected ear A-weighted sound levels (dB) (step 5-step6+step7)									Logarithmic Sum (log base 10)
9. NRR = (step 3 log sum) – (step 8 log sum) – (3dB correction factor) = **NRR =** Fitting Procedure: Experimenter-Fit									

†All values/calculations in rows 1-5 are from EPA (1990)

*4000 Hz values are mean of 3150 Hz and 4000 Hz data.

8000 Hz values are mean of 6300 Hz and 8000 Hz data.

Protector Name FREQUENCY (Hz)	125	250	500	1000	2000	3150	4000	6300	8000
attenuation mean									
attenuation std. dev.									

ATTENUATION DATA (in dB) BY TRIAL BY INDIVDUAL SUBJECT

		1/3 octave band center (Hz)								
subject	trial	125	250	500	1000	2000	3150	4000	6300	8000
1	1									
1	2									
1	3									
2	1									
2	2									
2	3									
3	1									
3	2									
3	3									
4	1									
4	2									
4	3									
5	1									
5	2									
5	3									
6	1									
6	2									
6	3									
7	1									
7	2									
7	3									
8	1									
8	2									
8	3									
9	1									
9	2									
9	3									
10	1									
10	2									
10	3									

attenuation mean	
attenuation std. dev.	