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Development of NASA Glenn Research Center Auditory Demonstration Laboratory facility and operational capabilities

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ABSTRACT

The NASA Glenn Research Center Auditory Demonstration Laboratory (ADL) is a dual purpose facility, constructed in 2007 to support hearing conservation programs across the agency. Configured as a reverberant room, the ADL is an appropriate space for evaluating the performance of personal hearing protectors, using either human subjects or a test fixture. Hearing protector evaluations are conducted using NASA *REATMaster* software, developed in partnership with the National Institute for Occupational Safety and Health. This software is available free on request to qualified laboratories, which are encouraged to participate in a collaborative program to fund continued software development.

The ADL can also be configured as a free-field room to support the development of auditory demonstrations, widely used for a variety of training purposes within NASA and externally. The ADL provides an environment, sound system, and audio engineering tools for presenting and developing calibrated demonstrations of various acoustical and auditory phenomena that include fundamental acoustical and concepts, noise control principles, and simulations of hearing loss. Current work at the ADL will establish the capability of making 3D surround-sound recordings, which will expand the scope of the laboratory's educational products into additional areas of psychoacoustics such as binaural hearing and localization.

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1. INTRODUCTION

The establishment of the NASA Auditory Demonstration Laboratory (ADL) at the Glenn Research Center in Cleveland, Ohio, has provided the agency with a new suite of unique capabilities in support of hearing loss prevention programs for ground-based operations. This represents an intentional shift in focus from the acoustic emission testing services provided for International Space Station science experiment payloads by the Glenn Research Center Acoustical Testing Laboratory (ATL) to a broader program that focuses on the delivery of a broad spectrum of hearing loss prevention services and resources at the agency level, serving all NASA field centers as well as the external community. Much of the hearing-loss-prevention effort formerly managed under the ATL umbrella[1] has been incorporated as the core business of the new Auditory Demonstration Laboratory, which was established to provide an appropriate physical laboratory facility to most effectively support this growing effort and to expand it into two specific areas: 1) the in-house development of a wider variety of technically-sophisticated auditory demonstrations with updated and improved delivery methods for broader accessibility and increased cost efficiency and 2) the on-site evaluation of personal hearing protector attenuation performance, particularly for critical high-noise applications.

1.1 Auditory Demonstration requirements

The Auditory Demonstration Laboratory distributes free and publicly-accessible hearing conservation training resources, including three collections of auditory demonstrations, all of which were developed for NASA by Nelson Acoustics. Historically, these demonstrations, and most other hearing conservation resources distributed by ADL, have been produced in compact disc format and distributed via postal mail (see Figure 1). This approach to production and delivery was appropriate when *Auditory Demonstrations in Acoustics and Hearing Conservation,* the first CD in the series, was released in 1997. Current technology for producing and delivering all-digital resources by means of web-based file downloads now offers sufficient cost-savings in terms of administrative processing labor and postage to warrant the implementation of the necessary technical capabilities to enable an all-digital process. The nearly universal access to powerful computer resources, combined with the reach of the internet and the increasing use of social media communication strategies, particularly among businesses and educational institutions, have elevated public awareness of the ADL's resources and increased demand to the point where managing the "one-per-person" request fulfillment process for free CDs, shipped worldwide, has become unnecessarily unwieldy and prohibitively expensive. New communication technologies, if combined with an all-digital production and delivery system, could make NASA's hearing loss prevention resources available to a vastly expanded constituent population at a fraction of the current cost of producing and shipping CDs via a process that has become outdated and limiting. Furthermore, an in-house capability for developing auditory demonstrations, combined with an expedient all-digital delivery mechanism, represents the potential for easily expanding NASA's library of demonstrations in response to specific requests, current issues in hearing loss prevention, and new areas of focus, such as binaural hearing and localization. Thus, a primary set of requirements for the ADL's new physical facility had as its goals the development of a test chamber suitable for presenting (and developing) auditory demonstrations and a suite of custom software/hardware for recording, processing, presenting, promoting, and delivering acoustical signals and other digital resources in an accessible format and with an interactive and dynamic interface.

1.2 Hearing Protector Evaluation requirements

The development of the ADL was also intended to address the need within NASA to evaluate personal hearing protector attenuation performance for individuals in critical high-noise exposure positions. This capability would provide a desirable and acceptable alternative to the mandatory derating of labeled NRR values when determining personal hearing protector NRR requirements, since calculations that involve derated NRR values can result in required labeled NRRs that are unrealistically high and often unachievable, thus leading to the implementation of inefficient and logistically complex administrative controls in order to reduce exposure to the maximum permitted level while wearing the HPD with maximum achievable NRR. This presents an especially severe limitation in cases where HPD options are reduced by other competing and sometimes incompatible factors such as the requirement for other personal protective equipment or the need to wear a muff-style communications headset. The use of individual attenuation data, properly acquired in a laboratory environment, where the employee has (after training) personally donned the specific personal hearing protector to be worn in field conditions, represents a credible and mutually advantageous alternative to the use of derated labeled NRR values, which have little if any relationship to the actual field performance when donned and worn by a particular employee. Furthermore, the ability to determine and consider individual octave band HPD attenuation data allows NASA hearing conservationists to evaluate candidate HPDs in the context of the spectrum of the intended noise exposure scenario and make a more informed selection of HPD for each case than would be possible using only (derated) labeled NRR values.

Thus, the second primary set of requirements for the ADL arose from the desire to establish a fully-functional, NVLAP-accreditable laboratory facility that would provide the necessary reverberant and low-noise environment and the associated software, hardware, and sound system for evaluating personal hearing protector attenuation in a sound field. This capability existed in a number of hearing protector laboratories in the US, some of which used a system of software/hardware developed and distributed as a publicly-available resource by the National Institute of Occupational Safety and Health (NIOSH). This system represented the state-of-the art in hearing protector evaluation laboratory-based capabilities at the inception of this project, but NIOSH wished to consider an alternative approach that would address some persistent challenges that plagued the current system. NASA desired to contribute to the advancement of the state-of-the-art by funding the development of the desired alternative system as part of a collaborative partnership with NIOSH, and then to make the resulting software application publicly available, free, to qualified laboratories.

2. DEVELOPMENT OF AUDITORY DEMONSTRATION LABORATORY

The requirements for a physical laboratory facility that could serve as a development and presentation environment for auditory demonstrations and as an accreditable facility for evaluating the attenuation performance of personal hearing protectors in a sound field were combined into an initial scope of work for a turnkey hearing protector evaluation facility with dual-use potential. The project was contracted to ViAcoustics, with software development subcontracted to Nelson Acoustics, and the construction of the test chamber was completed in

late 2007[2]. NASA, through ViAcoustics, worked with William Murphy and David Byrne at NIOSH to take advantage of the work already done toward developing a robust, standards-compliant and accurate HPD evaluation process and to accommodate the specific features that NIOSH wished to see incorporated in the NASA system. Subsequent contracts with both ViAcoustics and Nelson Acoustics extended this work to include a number of enhancements for the hearing protector evaluation software as well as the development of the auditory demonstrations capability, which included custom filtering software for developing acoustical demonstrations. A subcontract to Gelfand Design supplied the remaining element of the project: a website with associated social media sites that showcase the ADL's hearing loss prevention resources and facilitate electronic delivery of all-digital of all current and future products.

2.1 Laboratory Facility

The laboratory facility was constructed at the former site of a radiation laboratory, whose walls provided the high transmission loss and integrity needed to meet the low background noise requirements for conducting hearing protector evaluations and presenting auditory demonstrations. The renovated site provided a host space to house an office area and control console from which to operate both laboratory operations as well as a dual-use test chamber, supplied by ETS Lindgren Acoustic Systems (see Figure 2). The reverberant test chamber was fitted with removable absorptive fabric panels, which allowed the space to be configured as a free-field room for presenting and developing auditory demonstrations (see Figure 3). A PC-based system controls dual instrumentation racks and dual speaker systems and supports measurement/data acquisition and signal generation and analysis for both hearing threshold determination and surround-sound audio demonstrations (see Figure 4).

2.2 NASA *REATMaster* Software

NASA ***REATMaster*** (for **R**eal **E**ar **A**ttenuation at **T**hreshold) software, developed by Nelson Acoustics, in collaboration with NIOSH, runs on a LabVIEW platform on National Instruments hardware. The software executable files have been made available to qualified laboratories who own, or are acquiring, the requisite hardware on which to operate the software, in accordance with the conditions of a licensing agreement that preserves NASA ownership and control of the ***REATMaster*** source code and protects Nelson Acoustics' intellectual property rights to proprietary software on which ***REATMaster*** is built. NASA has established a collaborative arrangement that encourages laboratories that request and receive the ***REATMaster*** software to contribute a small amount of funding to continue the development of the software (including the implementation of a specific feature desired by a particular laboratory) and to provide support for its ongoing maintenance and expansion. Each of the participating laboratories has contributed, or has expressed the intention to contribute, funding to this effort; a number of software enhancements have already resulted from this arrangement.

2.3 Filtering Software for Auditory Demonstrations

Custom filtering software developed by Nelson Acoustics (see Figure 5) provides a powerful tool for developing auditory demonstrations, particularly hearing loss simulations,

which are typically constructed as a sequence of progressively filtered signals, consisting of either speech (communication vignettes) or music of various genres. The spectral filters model audiometric configurations that would be statistically likely given a specified history of noise exposure. Simulated hearing loss demonstrations are extremely popular among occupational hearing conservationists who are eternally seeking new and compelling material to include in OSHA-mandated annual hearing conservation training, which must include a fixed (and unchanging) set of topics including "the effects of noise on hearing." The filtering software and associated laboratory capabilities were developed to meet the ongoing and growing demand for new and unique high-quality demonstrations that support compliance with annual OSHA hearing conservation training requirements. The ability to easily generate demonstrations that feature a broad selection of musical genres and communication scenarios is particularly important in successfully motivating hearing loss prevention behavior both within a diverse employee population and over the span of a particular employee's career. Current work is focused on the development of 3-D and binaural recording techniques with the intention of increasing the realism of the auditory demonstrations and expanding the range of demonstrated phenomena into localization and spatialization (the loss of which are often secondary effects of noise-induced hearing loss).

2.4 Auditory Demonstration Laboratory "*EARLAB*" Website

The final, but critical, element of the ADL development project is the creation of a web-based system for marketing and efficiently delivering the hearing loss prevention resources and tools developed by the Auditory Demonstration Laboratory to a growing constituent population that includes hearing conservationists, engineers, educators and the general public. This approach, appropriate to the current global technological and communication environment, requires that the resources be made available in all-digital format, either for online viewing/listening only or as file downloads, in order to fully respond to the increasing demand for resources from around the world. Neither the use of social media sites nor the capability of producing and delivering (and, for requestors, of playing and/or downloading) the equivalent of a CD's worth of audiovisual files was either technically feasible or permissible under government regulations regarding the use of social media until recently. The NASA Auditory Demonstration Laboratory website (see Figure 6), developed by Gelfand Design, is the centerpiece of a new communication strategy that aims to deliver hearing loss prevention resources that support NASA's agency-wide hearing conservation program while making those resources publicly available at no additional cost.

3. REFERENCES

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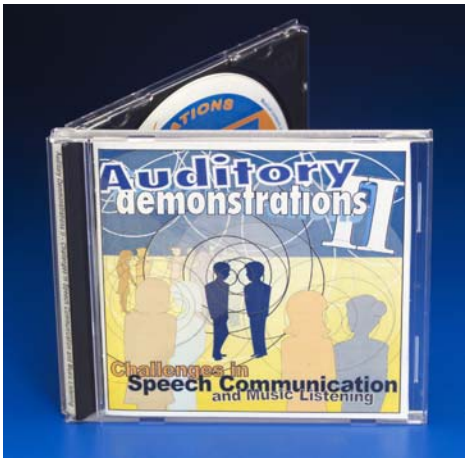
2. Schmitt, Jeff G., Nelson, David A., and Cooper, Beth A. "The Development of NASA EARLab for Measurement of Real Ear Attenuation of Hearing Protection Devices." Proceedings of Noise-Con 2010. Baltimore, MD. 19-21 April, 2010.



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You may update your profile at any time

Go Reset

If not registered, please complete the form below to create your profile.
If you are under 13 years of age, please ask a parent or guardian to provide and submit the information requested below.

* First Name:	
* Last Name:	
* Company or Organization:	
* Business Address Line 1:	
Business Address Line 2:	
* City / Territory:	
* Country:	UNITED STATES
State / Province / Territory:	Select State
Zip Code:	
* Business (Primary) email address:	
Secondary (additional) email address:	
* Technical Discipline:	Select One
* Employer:	Select One

* *indicates a required field...* Submit

Fig. 1 - NASA hearing conservation resources. a) Historically, auditory demonstrations and other resources have been distributed on CD, via postal mail. b) Requests for resources are submitted using online forms.

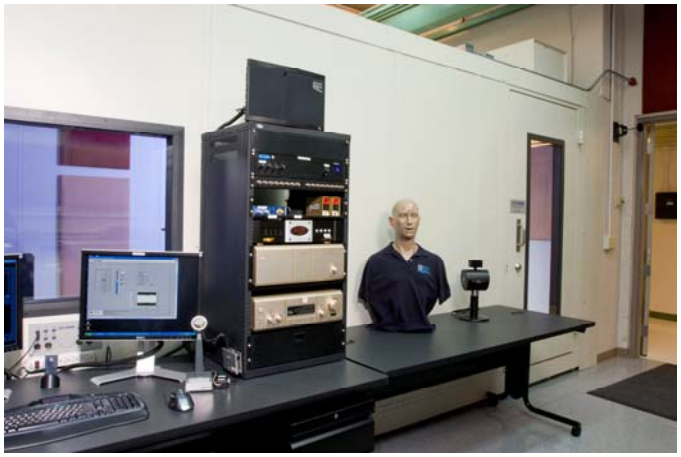

Fig. 2 - NASA Auditory Demonstration Laboratory. a) An abandoned radiation laboratory provided a low-noise host space. b) The space now houses a test chamber with adjacent control room/office.

Fig. 3 - Hearing protector evaluation. a) Control console includes equipment racks for hearing protector testing (left) and auditory demonstrations (right). b) Removable absorptive wall panels allow the chamber to be reconfigured as a free-field room for developing and presenting auditory demonstrations.

Fig. 4 - Test chamber interior. a) A hard-walled test chamber with diffuser panels (shown in "auditory demonstrations mode" with removable absorptive wall panels) provides a low-noise reverberant environment for hearing protector evaluation. b) Hearing protector evaluations on human subjects seated in the test chamber are conducted from the control console by means of a visualization window and two-way communication system.

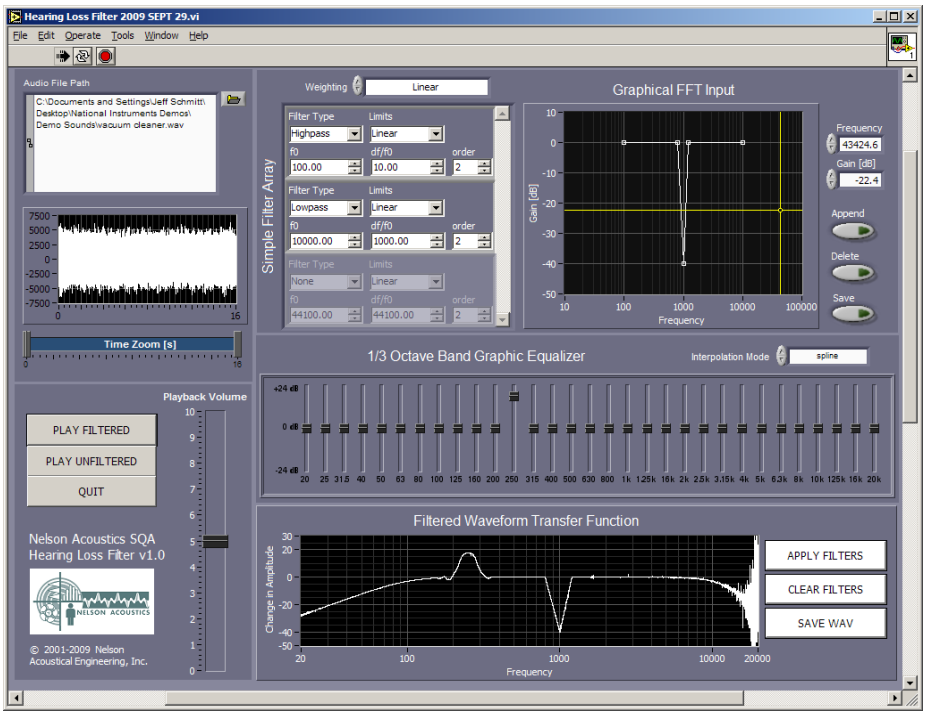

Fig. 5 - Custom filtering software (shown in draft), together with the test chamber, sound system, and 3-D audio recording capability, enables the development of auditory demonstrations onsite at the Auditory Demonstration Laboratory.

Fig. 6 - New NASA Auditory Demonstration Laboratory "EARLAB" website focuses on web-based delivery of all-digital hearing conservation resources.