UNDER SECRETARY OF DEFENSE
4000 DEFENSE PENTAGON
WASHINGTON, D.C. 20301-4000

PERSONNEL AND
READINESS

The Honorable Adam Smith
Chairman
Committee on Armed Services
U.S. House of Representatives
Washington, DC 20515

JAN - 7 2021

Dear Mr. Chairman:

The Department's response to House 116−120, pages 102−103, accompanying H.R. 2500, the National Defense Authorization Act for Fiscal Year 2020, on Hearing Protection Measures, is enclosed.

This report provides information about current hearing protection devices available to Service members for all military specialties; discusses hearing protection device effectiveness; compares Service member hearing from entry to active duty to estimated discharge date; identifies Service members receiving service-connected disability benefits for hearing loss; and includes recommended technologies to deter hearing loss or improve hearing.

Thank you for your continued strong support for our Service members, civilian workforce, and families.

Sincerely,

//SIGNED//

Matthew P. Donovan

Enclosure:
As stated

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PERSONNEL AND
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The Honorable William M. "Mac" Thornberry
Ranking Member
Committee on Armed Services
U.S. House of Representatives
Washington, DC 20515

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Dear Representative Thornberry:

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Report to House Committee on Armed Services

Hearing Protection Measures

In Response To: House Report 116–120, Pages 102−103, Accompanying H.R. 2500, National Defense Authorization Act for Fiscal Year 2020

The estimated cost of this report for the Department of Defense (DoD) is approximately $104,000.00 for Fiscal Year 2020. This includes $68,000.00 in expenses and $36,000.00 in DoD labor.

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I. PURPOSE

This report is in response to House Report 116−120, pages 102–103, accompanying H.R. 2500, the National Defense Authorization Act for Fiscal Year 2020, (Appendix A). The report requests the Secretary of Defense to submit a report to the House Committee on Armed Services on:

- Current hearing protection measures in use during combat and training and the effectiveness of these devices for a range of combat, combat support, and administrative specialties.

- A comparison of hearing for Service members upon entry into the Military Services to the end of the first term of service and compare discharged members receiving service-connected benefits for hearing loss.

- Recommendations for innovative safe technologies that could be used to deter hearing loss or improve hearing through training and combat.

In the House Report, the House Armed Services Committee indicated that "despite the widespread availability of ear protection equipment across the Department of Defense, [S]ervice members continue to experience hearing loss attributed to their military service. The committee believes that the Department of Defense should adopt a more innovative approach to prevent hearing loss."

II. OVERVIEW OF DEPARTMENT OF DEFENSE HEARING PROTECTION MEASURES

Through the implementation of programs and procedures in accordance with Occupational Health and Safety Administration (OSHA) regulations, Parts 1910 and 1960 of title 29, Code of Federal Regulations (CFR), the Department of Defense (DoD) protects noise-exposed Service members and DoD civilian employees from noise-induced hearing loss (NIHL) that can occur from exposure to hazardous occupational and operational noise. It is DoD policy to reduce personnel exposures to hazardous occupational and operational noise, while enhancing mission readiness, communication, and safety.

Hearing protection measures are included as part of the DoD Hearing Conservation Program (HCP) for noise-exposed Service members and DoD civilian employees. DoD Instruction (DoDI) 6055.12, "Hearing Conservation Program (HCP)," August 14, 2019, establishes policy for the DoD HCP (Appendix B). DoDI 6055.12:

- Implements policy, assigns responsibilities, and provides procedures for administering an HCP to prevent hearing loss resulting from occupational and operational illness and injury.

- Establishes the DoD Hearing Conservation Working Group (HCWG).

- Issues requirements for the integration of noise control into the life cycle of DoD systems and equipment.

For the purpose of this report, Congress requested the DoD to focus on hearing protection measures related to Service member hearing protection devices (HPDs); therefore, the focus of this report does not include DoD civilian employees. The use of HPDs is one of several hearing protection procedures/measures instituted by DoD to protect Service members and DoD civilian employees from hearing damage caused by exposure to hazardous noise levels. Hazardous noise levels are routinely found in military environments during training and combat operations. A comprehensive hearing conservation program includes several procedures/measures to protect hearing as directed in DoDI 6055.12, which serves as the foundation for the Services' hearing conservation program policies and procedures. The DoD Components are required to establish hearing conservation programs consistent with procedures/measures outlined in DoDI 6055.12, including Section Three of the instruction. Table 1 summarizes the elements of Section 3 of DoDI 6055.12 of the DoD hearing conservation program, one of which is the use of HPDs.

Table 1. Summary of DoD Hearing Conservation Program Procedures (Measures) Included in DoDI 6055.12.

HCP Procedure	Description	DoDI 6055.12 Reference
Written Plan	The DoD Components must prepare a written plan describing a comprehensive HCP that includes key program elements.	Section 3, Paragraph 3.1
Program Implementation	Addresses: • Criteria for when HCPs are implemented for DoD personnel, and • When acquisition programs should implement noise assessment and engineering measures through systems engineering, and system safety processes in accordance with DoDI 5000.02.	Section 3, Paragraph 3.2
Noise Measurement and Analysis	Provides DoD Component noise measurement and analysis requirements.	Section 3, Paragraph 3.3
Noise Hazard Signs and Labels	Describes requirements for how hazardous noise areas and equipment should be marked/labeled in compliance with, at a minimum, Section 1910.145 of title 29, CFR and DoDI 6055.01.	Section 3, Paragraph 3.4
Noise Abatement	Describes use of engineering controls to reduce steady state and impulse noise, purchase of new equipment with the lowest noise emissions, and technically and economically feasible by performance/environmental requirements per Section 4914, title 42, United States Code (USC).	Section 3, Paragraph 3.5
Personal Hearing Protectors	Establishes: • The use of HPDs as an interim protective measure to attenuate noise exposure while engineering controls are being considered or permanent use of HPD only if use of engineering controls is not possible; • How HPDs are to be issued to DoD personnel exposed to hazardous noise; • HPD supply considerations; • HPD fitting requirements; • Administrative controls implementation for management of exposures;	Section 3, Paragraph 3.6

	• Issuing of HPD carrying cases; • Who fits and issues HPDs; • When fit of HPDs and education of prevention of hearing loss to personnel occur; • Circumstances for when custom-molded earplugs are issued; • When personnel working in/entering hazardous noise areas must wear HPDs; • Provision of appropriate HPDs in operational environments that support sustainment of communication and situational awareness for the mission, when possible; • Assessment of adequacy of attenuation levels of HPDs for all situations where use is required using best practices; • Mandate and enforcement of the proper use of HPD at all levels of the chain of command/supervision; • Encouragement of the use of HPD to increase compliance. When noncompliance of HPD use, take corrective measures against offender/supervisor; and • Use of HPD in hazardous environments by visitors/DoD personnel not required to be included in the HCP.	
Education	Includes requirements for DoD Components to provide all DoD personnel exposed to hazardous noise and enrolled in HCPs with annual hearing education about hearing protection/conservation measures.	Section 3, Paragraph 3.7
Audiometric Testing	Specifies requirements for DoD Components to include DoD personnel exposed to hazardous noise in an audiometric surveillance program (hearing testing), audiometric testing procedural requirements, and medical and administrative actions for patients based on certain surveillance and clinical findings.	Section 3, Paragraph 3.8
Access to Information, Training, Material, and Records	Addresses Service member and DoD civilian access to hearing conservation program records, documents, and other information.	Section 3, Paragraph 3.9
Record Keeping	Establishes requirements for the DoD Components to maintain HCP audiometric testing documents, noise exposure/survey reports, and lists of noise-exposed personnel enrolled in the HCP and who received HCP services.	Section 3, Paragraph 3.10
Program Performance Evaluation	Outlines how DoD Components will evaluate annual HCP effectiveness determined by Significant Threshold Shift (STS) rates, the audiogram completion rate, Permanent Threshold Shift (PTS) rates, management of risk in accordance with DoDI 5000.2 and MIL-STD-882E, any other metrics considered important for measuring HCP effectiveness.[1]	Section 3, Paragraph 3.11

[1] The audiogram is a chart that shows the results of a pure-tone hearing test. It demonstrates how loud sounds need to be at different frequencies for an individual to hear them. The audiogram shows the type, degree, and configuration of hearing loss.

III. CURRENT DOD HEARING PROTECTION MEASURES IN USE DURING COMBAT AND TRAINING, AND THE EFFECTIVENESS OF THESE DEVICES FOR A RANGE OF COMBAT, COMBAT SUPPORT, AND ADMINISTRATIVE SPECIALTIES

Background

When selecting HPDs for Service member use, consideration is given to the appropriate level of protection (i.e., attenuation of noise to achieve safe exposure levels at the ear) for the noise level in the Service member's occupational environment. Additional factors to consider when selecting the appropriate HPD include the type of work performed and associated hearing-critical tasks.

Louder noise environments demand greater levels of attenuation (i.e., noise reduction). However, over-protection may be detrimental (e.g., by making the user feel isolated from the environment or by decreasing the user's auditory situational awareness). Auditory situational awareness is important for many operational environments. It includes, at a minimum, an ability to understand and respond to the environment through sound detection, sound localization, estimation of distance, and speech communication. In addition to noise attenuation, HPD selection may take into account how a device affects performance of hearing-critical tasks, device comfort, device compatibility with other equipment, and other non-acoustical factors such as device ease of use and cost.

Hearing-critical tasks are tasks that cannot be performed without hearing. Response to the detection, identification, location, or interpretation of sound or speech is often time sensitive and is usually related to operational safety and success. Examples of hearing-critical tasks are talking over the telephone or radio, detecting enemy presence in low visibility environments or when vision is obscured, and localizing the source of enemy gunfire.

The most expensive and the most technologically advanced HPDs are not always necessary to achieve adequate hearing protection; however, these more advanced devices often do provide the best capability for maintaining situational awareness of hearing-critical sounds. For any given military occupational or operational scenario, the best HPD will be the one that provides the necessary level of protection to prevent NIHL; fits well; is comfortable to wear; allows the Service member to hear critical sounds necessary for the job; and is consistently used and worn correctly. In DoD, audiologists, industrial hygienists, and safety professionals can assess workplaces/critical tasks and recommend appropriate HPDs for each task.

The following sections of this report provide an overview of HPDs included in the growing DoD inventory. These HPDs are used in combat and training by Service members assigned to combat, combat support, and administrative specialties. A discussion of HPD effectiveness measures is included. The U.S. Air Force Research Laboratory, 711th Human Performance Wing has conducted laboratory assessments of HPD effectiveness. These HPD effectiveness measures are based on testing methods established by several national standards. Also provided below is an overview of real-world (versus laboratory) HPD effectiveness measures that describe

reduction of noise levels reaching the ear, auditory situational awareness, and hearing threshold trends in Service members**.**

Current Hearing Protection (Devices) in Use During Combat and Training

In accordance with DoDI 6055.12, there are three primary methods to mitigate hazardous occupational noise in operational and non-operational environments:

- Engineering controls that may include making changes to the noise source or transmission path to reduce or eliminate the noise level reaching the ears to where the risk of hearing loss is reduced or eliminated.

- Administrative controls that may include making changes in the work environment that reduce or eliminate the worker exposure to noise (e.g., by reducing the amount of time of exposure to hazardous noise and by ensuring movement away from the noise source to a distance where the noise level is below a hazardous level).

- Use of HPDs to attenuate the noise level reaching the individual's ears.

The preferred method to protect hearing is the use of engineering controls to mitigate hazardous noise levels. Ideally, systems and equipment would be designed to eliminate the need for HPDs. For many types of military systems and equipment, it is not feasible to mitigate noise levels to below hazardous noise standards. The use of HPDs serves as an option to reduce Service member exposure to hazardous noise. If engineering controls and HPDs fail to reduce hazardous noise to acceptable levels as directed by DoD policies, administrative controls are employed to reduce the length or number of hazardous exposures, or to completely remove Service members from the area or source of the noise.

A variety of HPDs are available for Service member use in combat and training environments where noise exceeds safe levels. Table 2 provides a description of the general types and subtypes of HPDs used by DoD. Military units may purchase other types of HPDs, as missions require, which might not be included in this table. The DoD HPD supply is dynamic; new products are routinely introduced into the inventory and provided to Service members at no cost.

Table 2. Summary of Available HPD Types and Subtypes for DoD Use.

HPD Type/Sub-type	Description
Earplugs	Hearing protection that occludes (blocks) the ear canals.
Passive earplugs	Hearing protection that occludes the ear canals; worn to attenuate sound without electronics.
- Low level amplification, electronic earplugs	Hearing protection that occludes the ear canals; attenuates sound and can amplify low-level ambient sound for increased awareness and face-to-face communications.
- Flat-attenuation, filtered earplugs	Hearing protection that uses filters to allow equal attenuation of sound across the range of frequencies for a more natural sound and auditory situational awareness.
- Level-dependent earplugs	Hearing protection that occludes the ear canals (e.g., through use of a cap, switch, plug) to allow the user to shift from both continuous and

	impulsive noise (closed) to just provide protection from impulsive noise (open). The protection amount changes as noise levels change.
o Closed	Designed to protect the user from continuous and impulsive noise exposure (see passive earplugs).
o Open	Designed to protect the user from impulsive noise while decreasing interference with low-level (soft) sounds (e.g., communications).
- Communication earplugs	Hearing protection that occludes the ear canals; contain electronics (sometimes referred to as electronic pass-through devices) for communication.
Earmuffs	Over the ear hearing protection worn to attenuate sound that does not contain electronics.
Headsets	Traditionally, over the ear hearing protection worn to attenuate sound that contains electronics with or without communication capabilities.
- Passive headsets with communication capabilities	Headsets that contain electronics for communications.
- Headsets with active noise cancelling capabilities	Headsets that have active noise cancelling capabilities.
- Low level amplification headsets	Headsets that have the capability to provide low-level amplification of ambient sounds.
- Headsets with earpiece	Headset is worn in the ear that contains electronics for communication.
Helmets	Headgear unit that gives impact protection, attenuates sound, and/or provides communication capabilities.
- Passive helmets	Head gear unit that can contain electronics for communication capabilities.
- Noise cancelling helmets	Head gear that contains active noise cancelling capabilities.
Combinations (double protection)	Combines any two types of in the ear and over the ear hearing protection devices.

Military units use a variety of HPD purchasing options that range from contracts with vendors managed by the Defense Logistics Agency to small purchases of HPDs from vendors using the Government Purchase Card Program. Further, some HPDs are provided with a particular military system of record, such as a combat vehicle crewman helmet for use with certain armored vehicles.

It is not possible to completely and accurately account for Service member usage of HPDs. The DoD currently does not have the capability to capture and document each HPD type, subtype, feature, production and issue dates, and manufacturer that an individual Service member might use in hazardous noise environments throughout their military career. The Defense Occupational and Environmental Health Readiness System-Hearing Conservation (DOEHRS-HC) is the DoD system of record for monitoring audiometry.[2] The DOEHRS-HC audiogram includes a field to record the basic type of HPD used and reported by Service members when they receive DOEHRS-HC audiograms.[3] Historically, HCP managers have had concerns regarding the reliability and/or completeness of the HPD information reported by Service members at the time

[2] Monitoring audiometry detects changes in an individual's hearing sensitivity. The DOEHRS-HC is a vital asset in managing hearing loss through early detection and monitoring.

[3] Depending on the type of HPD, all features (e.g., manufacturer, model) of more technologically sophisticated devices may not be available in the drop-down menus in the DOEHRS-HC audiogram where the HPD is type is recorded.

of their hearing tests, and about the accuracy of how hearing conservation technicians enter HPD data on the audiogram.[4]

Effectiveness of Hearing Protection Devices Used by Combat, Combat Support, and Administrative Service Members

There are many ways to measure the effectiveness of HPDs. Measures include, at a minimum:

- Methods found in national standards conducted in laboratory conditions to evaluate HPD attenuation and auditory situational awareness;

- Effectiveness measures determined in real-world conditions such as individual HPD fit-testing; and

- Injury rates (e.g., significant threshold shift [STS]) and hearing threshold trends are methods used by DoD to assess overall hearing conservation program effectiveness, including the use of HPDs.[5,6]

The following section reviews the different ways DoD assesses HPD and HCP effectiveness.

Hearing Protection Device Effectiveness: National Standards for Evaluation Methods

The DoD uses several national standards that provide laboratory methods to evaluate effectiveness characteristics of HPDs. Table 3 summarizes the standards used to measure and determine HPD noise-reduction; insertion loss (estimate of the attenuation of noise by an HPD); speech intelligibility over communication systems; and methods to estimate from laboratory attenuation level, the sound pressure levels when HPDs are worn.

[4] As a strategy to mitigate errors, DoD hearing conservation managers provide continual mandatory and impromptu training to hearing conservation technicians regarding the proper completion of HPD information on DOEHRS-HC.
[5] For DoD, a significant threshold shift (STS) is defined as an average change of plus or minus 10 dB at 2000, 3000, and 4000 Hz, relative to the reference audiogram, in either ear, without age correction.
[6] Determining hearing status is based on understanding hearing sensitivity. To establish a person's hearing sensitivity, hearing threshold levels (HLs) are obtained during hearing testing. Hearing threshold levels are defined as the lowest level of sound that can be heard 50 percent of the time. The decibel (dB) is the unit of intensity (loudness) used to describe the hearing threshold level. During a hearing test (audiogram/audiological evaluation) the hearing threshold level is measured as dB "hearing level" (dB HL) at different frequencies (pitches) measured in Hertz (Hz) in each ear. The higher the dB of the hearing threshold level, the greater the hearing loss.

Table 3. Summary of National Standards for Evaluating the Effectiveness of Hearing Protection Devices.

Method	Purpose
American National Standards Institute (ANSI)/Acoustical Society of America (ASA) S12.6-2016, "Methods for Measuring the Real-Ear Attenuation of Hearing Protectors"	Establishes laboratory-based methods for measuring, analyzing, and reporting the passive noise-reducing capabilities of HPDs. The methods consist of psychophysical tests conducted on groups of human subjects to determine real-ear attenuation at threshold. The selection of test method, trained-subject fit, or inexperienced-subject fit, is based upon the intended application.
ANSI/ASA S12.42-2010, "Methods for the Measurement of Insertion Loss of Hearing Protection Devices in Continuous or Impulsive Noise Using Microphone-In-Real-Ear or Acoustic Test Fixture Procedures"	Establishes uniform instrumentation requirements and procedures for the measurement of insertion loss of HPDs at supra-threshold levels of continuous noise using the microphone-in-the-ear method with human subjects, and at supra-threshold levels with continuous or impulsive noise using the acoustical test fixture method.
ANSI/ASA S3.2-2009, "Methods for Measuring the Intelligibility of Speech Over Communication Systems"	Establishes uniform methods for measuring the intelligibility of speech over communication systems.
ANSI/ASA S12.68-2007 (R2017), "Methods of Estimating Effective A-Weighted Sound Pressure Levels When Hearing Protectors Are Worn"	Establishes three methods for the estimation of the sound pressure levels that are effective when a hearing protector is worn.

Hearing Protection Device Noise Reduction Ratings

An HPD effectiveness rating commonly available to the end user is the Environmental Protection Agency standard for noise reduction ratings (NRRs). Manufacturers of HPDs are required to include the NRR on the HPD label as specified by CFR-2003, title 40 "Product Noise Labeling," Part 211. The NRR is a computational requirement used to determine the potential effectiveness rating of HPDs to decrease hazardous noise exposure that ranges from approximately 0–33 decibels (dB) (a higher number means greater sound attenuation in the ear canal). The Occupational Safety and Health Administration (OSHA), through 29 CFR 1910.95(j)(2), Occupational Noise Exposure, mandates that HPDs must attenuate employee exposure to an 8-hour TWA of 90 A-weighted decibels (dBA) or lower, using a 5 dB exchange rate, as specified in Appendix C. The DoD mandates a more stringent criteria than OSHA, limiting steady-state noise exposure to an 8-hour TWA of 85 dBA or lower (Appendix D), with a 3 dB exchange rate (rather than OSHA's use of a 5 dB exchange rate). Both DoD and OSHA require impulsive noise exposures to be 140 dB peak (dBP) sound pressure level or lower.[7]

The NRR is based on laboratory testing conditions, and it does not take into account the loss of protection (loss of noise attenuation) that occurs when HPDs are not fit properly, or when they are not worn during the entire time the wearer is exposed to noise. There is an abundance of

[7] The DoD uses the same criteria as the National Institute for Occupational Safety and Health (NIOSH) for steady-state noise (A-weighted).

evidence from more than 45 years of research indicating that real-world (field) attenuation achieved by HPD users is generally much lower than what is observed during laboratory testing. As such, 29 CFR 1910.95(j)(2) (Appendix E) provides four methods for estimating the adequacy of hearing protection attenuation for personnel in HCPs.

Hearing Protection Device Fit Testing

Fit testing is a promising strategy for measuring individual, real-world HPD effectiveness and improving hearing protection attenuation. It is a best practice recognized by OSHA, NIOSH, and the National Hearing Conservation Association. Fit-testing systems are used to verify that individuals are receiving the desired protection from hazardous noise with their issued HPDs. Each individual is tested with the preferred HPD for his/her work environment, resulting in a Personal Attenuation Rating.[8]

Evidence from military and nonmilitary studies regarding the use of fit-testing systems supports the DoD HCWG's decision to adopt individual fit testing as the preferred method to determine effective real-world HPD attenuation. DoDI 6055.12, paragraph 3.6(l)(a) allows DoD HCPs to use a fit-testing system as a best practice, when possible, for DoD individuals found to have an STS on an annual hearing test. The DoD HCWG has undertaken efforts to assess the feasibility of providing enterprise-wide fit testing for Service members (and DoD civilian employees) when an STS occurs as well as for other indications (e.g., prior to firing the Multi-Role Anti-Armor/Anti-Personnel Weapon System for Army personnel and during initial issue of HPDs at accession, hiring, and during annual hearing conservation education). A limited number of military HCP clinics are resourced with equipment and personnel to deliver fit-testing services. However, the majority of DoD HCPs do not have the capabilities to perform fit testing.

Hearing Protection Device Effectiveness: Auditory Situational Awareness

In military training and combat environments, adequate auditory situational awareness and hearing protection from hazardous noise levels are often competing priorities. Service members frequently prioritize auditory situational awareness rather than use certain HPDs for noise attenuation purposes that they perceive or believe will degrade their auditory situational awareness. Research findings and military and civilian HPD user feedback indicate that while traditional passive HPDs protect against hearing loss, they can also degrade auditory situational awareness and reduce safety. Many Service members choose survivability over protection from hearing injury, thus leaving personnel at risk for NIHL.

In recent years, there have been efforts to design HPDs that incorporate features to maintain or enhance auditory situational awareness. Three common types of HPD augmentations are included in certain HPDs used by DoD (i.e., Combat Arms™ Earplugs, BattlePlugs®, SureFire EP3 Sonic Defenders®). Devices that have active electronics such as amplification are also called "active" HPDs (e.g., the U.S. Army Tactical Communication and Protective System). Standards exist that specify methods for measuring the effectiveness of the attenuation properties

[8] Fit-testing systems are comprised of hardware and software components with outcome measures presented as either a pass/fail or a more quantitative personal attenuation rating depending on the fit-test system technology.

of these types of HPDs. However, until recently, there were no standards for methods to measure the effectiveness and impact of HPD auditory situational awareness (e.g., localization of sound) features on user auditory situational awareness for hearing-critical tasks.

To address this gap, the DoD Hearing Center of Excellence (HCE) facilitated a national standard development effort in collaboration with Service HCP and public health experts, DoD and Service research organizations, academic partners, ANSI, and the ASA. In 2019, ANSI and ASA published ANSI/ASA S3.71-2019, "Methods for Measuring the Effect of Head-worn Devices on Directional Sound Localization in the Horizontal Plane." This standard provides methods that enable accurate, repeatable, and reliable measurement of sound localization performance by human listeners.

The DoD continues to conduct research related to auditory situational awareness. These research efforts include initiatives to further validate the 2019 ANSI/ASA standard and collect data that inform additional methods and standards to evaluate auditory situational awareness hearing-critical task effectiveness of HPDs (mentioned later in this report). The DoD goal is to provide Service members with HPDs that provide appropriate attenuation of noise they can trust and will use. These HPDs should allow effective operational performance for successful mission accomplishment, while also providing hearing protection to prevent NIHL.

Service Member Hearing Trends as a Potential Indicator of Hearing Protection Measure Effectiveness

Since DoD's implementation of HCPs after World War II and the Korean War, it is reasonable to expect an observable decrease over time in NIHL among Service members who have used hearing protection measures. The DoD Components establish, maintain, and evaluate the effectiveness of HCPs using established measures of effectiveness (MOEs), (e.g., Service member STS and hearing impairment rates). However, it is challenging to attribute a cause and effect relationship between/among MOEs and specific hearing protection measures (such as HPDs).

Evidence-based conclusions crediting the effectiveness of HCP components are limited by data constraints and the ability of reporting systems. The greatest obstacle to determining HCP effectiveness is the ability to control for the multifactorial influences on Service member hearing. Continued research and use of the newly-available Joint Hearing Loss and Auditory System Injury Registry (JHASIR) are important to gain greater clarity regarding hearing protection measure effectiveness.[9] The DoD continues to address barriers to achievement of greater

[9] The Duncan Hunter National Defense Authorization Act for Fiscal Year 2009 (Public Law 110−417), section 721, establishes the requirement for DoD to develop the JHASIR. The JHASIR reached full operational capability on January 30, 2020. The registry provides longitudinal hearing loss and auditory-vestibular system injury data for Service members and veterans (within both the DoD and Department of Veterans Affairs (VA) health care systems) in a digitized, structured, and queryable format. It facilitates research and best practice development through DoD-VA bi-directional data exchange to advance solutions and eliminate gaps in hearing and balance health. The JHASIR also is a tool that assists in determining hearing conservation program effectiveness. The JHASIR was used in Sections III and IV of this report to identify and analyze Service member and veteran hearing and VA benefits information over time.

precision for understanding the impact of HCP/hearing protection measures on Service member hearing.

Examples of Service Member Hearing Injury Rates and Hearing Trends in Recent Years

Each of the Services evaluates its HCP effectiveness by identifying rates of hearing injury such as STS. An STS may be temporary (i.e., temporary threshold shift—TTS, an STS that resolves on follow-up hearing testing) or permanent (i.e., permanent threshold shift—PTS, an STS that fails to resolve on follow-up testing and is determined to be permanent).

In January 2020, the DoD HCWG and DoD HCE published the *Hearing Health Surveillance Data Review Military Hearing Conservation – CY18 [Calendar Year 2018]* report (Appendix F) that provides trends in STS rates and percentages of individuals with hearing impairment for Service members (including active duty and Reserve Components) and DoD civilian employees from CY 2012 to CY 2018. The data showed that hearing metrics improved over the seven-year period for Service members enrolled in the DoD HCP. Evidence of this improvement was observed as decreased hearing impairment, decreased hearing impairment in enlisted accessions, and decreased VA disability eligibility rates.[10]

Another example examining hearing trends among Service members compares Service members with hearing impairment (i.e., hearing threshold levels of 26 dB HL or more) to those with clinically normal hearing (i.e., hearing thresholds of 25 dB HL or less). Rates of normal hearing and hearing impaired are calculated separately by dividing the number of individuals with normal hearing by the total number of individuals who received a periodic or reference hearing test for the same year, and dividing those with hearing impairment (based on periodic or reference hearing test per year) by the total number of individuals who received a periodic or reference hearing test for the same year, respectively. All DoD Service members who received periodic or reference (baseline) hearing tests in CY 2010 and CY 2019 were included in this analysis. Results demonstrate a decrease in hearing impairment rates across DoD between CY 2010 (20.8 percent) and CY 2019 (14.2 percent), as seen in Table 4.

10 The VA benefits eligibility criteria using hearing threshold levels in the CY 2018 hearing review report were only an indicator of a trigger for a VBA/VA compensation and pension evaluation for service-connected hearing loss, and use of ONLY the hearing threshold levels indicated below alone do not determine service-connection disability for hearing loss:

- The auditory threshold in any of the frequencies 500, 1000, 2000, 3000, or 4000 Hertz (Hz) is 40 dB HL or greater, or
- The auditory thresholds for at least three of the frequencies 500, 1000, 2000, 3000, or 4000 Hz are 26 dB HL or greater.

There are several additional rating requirements/criteria (e.g., speech recognition scores, Duty Military Specialty Noise Exposure Listing, combat duties, medical opinion) used by VBA/VA to determine service-connection disability ratings for hearing loss in addition to the hearing threshold levels indicated above.

Table 4. Number and Percentage of Service Members Identified with Hearing Impairment in CY 2010 and CY 2019.

Description	CY 2010	CY 2019
Number of Service Members Tested	1,173,342	1,470,186
Number of Service Members Identified with Hearing Impairment	243,586	208,440
Percent of Service Members with Hearing Impairment	20.8 percent	14.2 percent

IV. COMPARISON OF SERVICE MEMBER HEARING UPON ENTRY INTO MILITARY SERVICE AND AT THE END OF THE FIRST TERM OF SERVICE WITH COMPARISON TO DISCHARGED MEMBERS RECEIVING SERVICE-CONNECTED BENEFITS FOR HEARING LOSS

As requested by Congress, Service member hearing was compared at two points in time during military service. Following this comparison, it was determined whether any Service members in the study cohort (group) received Veterans Benefits Administration (VBA)/VA service-connected disability benefits for hearing loss after leaving active duty. Below is a description of the data analysis methods, findings, and conclusions.

Comparison of Hearing for Service Members Upon Entry into Military Services to the Estimated End of First Term of Service

An analysis was conducted of audiograms (record of a hearing test) for 688,783 Service members from all Military Service branches who had served or were serving on active duty. Service members entering the military between CY 2008 and CY 2013 (six different year groups) were identified for inclusion in this analysis.[11]

The audiograms for these Service members consisted of audiometric pure-tone air conduction hearing threshold levels recorded at six test frequencies (500, 1000, 2000, 3000, 4000, and 6,000 Hz) on the DOEHRS-HC audiogram. Service members *without* audiometric data at the time of entry *and* within two to five years after entry to active duty were excluded from the cohort. The end of first term of service date (date when a Service member left active duty) was not available for this analysis due to limitations of the personnel system data.[12] Therefore, to determine an approximate date of the end of first term for an audiogram, the following process was used: if an audiogram was available in the second to fifth CY from the Service member's date of entry to active duty, the latest audiogram was used as the estimated end of first term audiogram.

[11] The CYs of 2008–2013 were selected for use in this comparison to allow sufficient time for departing Service members to apply for and receive awards for VBA/VA service-connected disability benefits for hearing loss. The majority of enlisted Service members leave active duty following three to five years of military service. The Data Analysis Subject Matter Expert Group for this report determined that hearing threshold levels for Service members for a six-year period (six separate year groups) would provide sufficient data to show recent military hearing trends.
[12] The Defense Manpower Data Center data file for Service member Expiration Term of Service date was incomplete.

- The mean (average) hearing threshold levels were calculated at each test frequency for the entry to active duty (entry) audiograms, combining data for all six year groups. This mean is termed Mean Audiogram All Frequencies Entry.

- The black line in Figure 1 shows Service member Mean Audiogram All Frequencies Entry for entry audiograms. The Mean Audiogram All Frequencies Entry thresholds are normal at all test frequencies (all year groups combined). Hearing is considered normal if hearing threshold levels are 25 dB HL or less (dashed line in Figure 1). However, when reviewing Service member individual data, 13 percent of the 688,783 Service members had some degree of hearing loss when they entered active duty. The DoD accession standards for hearing allow for a certain degree of hearing loss at entry to active duty.

- Next, the *magnitude of change* was categorized in hearing for individual Service members, measured from their entry to active duty audiogram to their estimated end of first term audiogram for all year groups combined. The magnitude of change for hearing threshold levels for each Service member was determined by calculating the mean (average) change in hearing threshold levels at 2000, 3000, and 4000 Hz from the entry audiogram to the estimated end of first term audiogram (this mean is termed Mean Magnitude Change High Frequency). The average hearing threshold change at these three test high frequencies is used by OSHA and DoD to detect potential NIHL for personnel in HCPs. These frequencies are susceptible to NIHL and important for speech understanding.

- The magnitude of change in hearing threshold levels from entry to active duty to the estimated End of First Term for Service members (Figure 1) were categorized as:

  - Less than an average of 10 dB change in hearing (Figure 1 green line),

  - An average of 10−19 dB change (Figure 1 blue line),

  - An average of 20−29 dB change (Figure 1 yellow line), or

  - An average of 30 dB or more change (Figure 1 orange line).[13]

- The colored lines in Figure 1 (and numerically in Table 6) show the mean hearing threshold levels at all test frequencies (500–6000 Hz) for all Service members (this mean termed is Mean Audiogram All Frequencies End), with the six year groups combined, stratified by the four magnitude of change in hearing categories.

- Figure 1 shows for all year groups combined, the majority (89.5 percent) of Service members had little, if any change (less than 10 dB) in their hearing from entry to active duty to the estimated End of First Term. Just over seven percent (7.2 percent) had an average change of 10−19 dB. Almost two percent (1.9 percent) experienced an average change of 20−29 dB in

[13] Degrees of hearing loss are described in Appendix G (Table 5).

hearing, and just over one percent (1.4 percent) experienced an average change of 30 dB or more.

Figure 1. Mean Hearing Threshold Levels Across Test Frequencies at Entry to Active Duty (Mean Audiogram All Frequencies Entry) and Mean Hearing Threshold Levels for Estimated End of First Term for Service Members (Mean Audiogram All Frequencies End) for Each Magnitude of Change in Hearing Threshold Level Category (CY 2008–CY 2013 Groups Combined). The Percent of Service Members for All Year Groups Combined Are Displayed for Each Magnitude of Hearing Change Category.

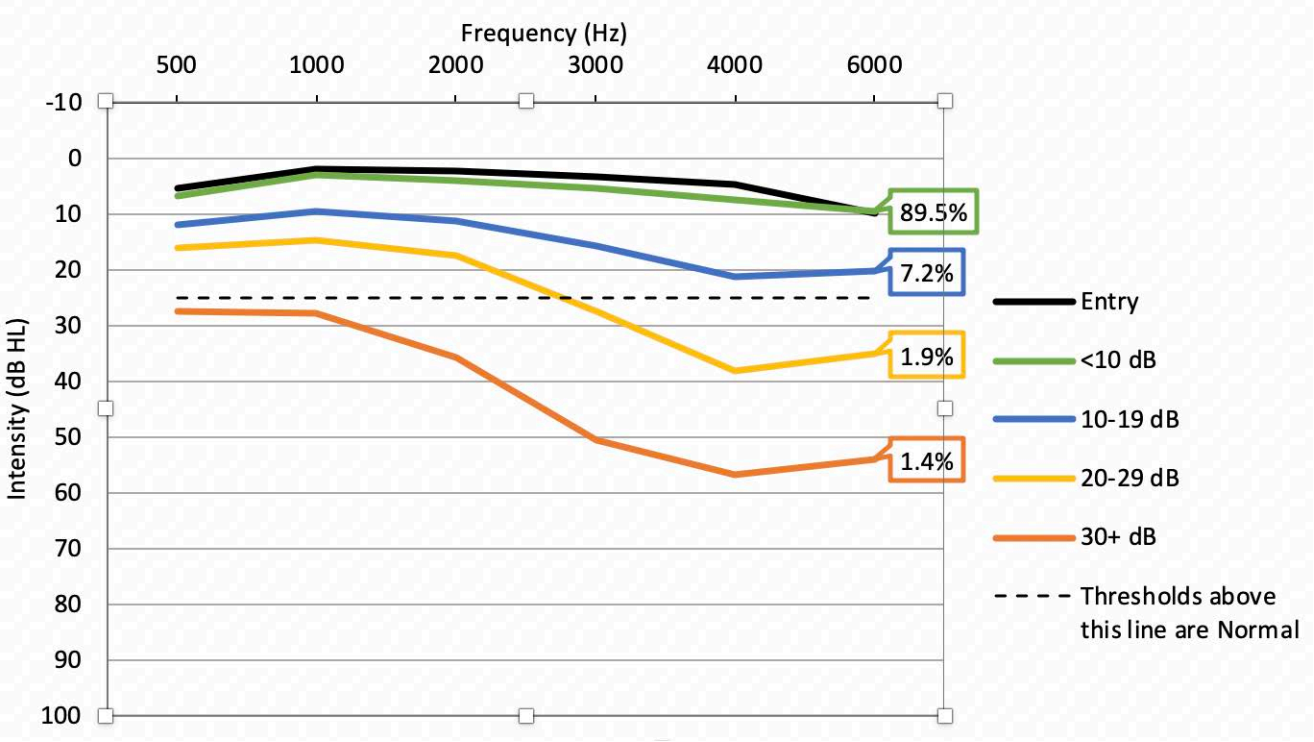

Table 6. Mean Audiogram All Frequencies in dB HL for Service Members at Entry on Active Duty and Mean Audiogram All Frequencies End in dB HL for Each Magnitude of Hearing Change Category (All Year Groups Combined).

Magnitude of Hearing Change Category	Frequency (Hz)					
	500	**1000**	**2000**	**3000**	**4000**	**6000**
Entry on active duty dB HL (N=688,783)	5	2	2	3	5	10
<10 dB (N=616,423)	7	3	4	5	8	9
10−19 dB (N=49,645)	12	9	11	16	21	20
20−29 dB (N=12,841)	16	15	18	28	38	35
30+ dB (N=9,874)	27	28	36	51	57	54

Year Group Hearing Trends for Magnitude of Hearing Change Categories, CY 2008 to 2013

To examine potential hearing trends for the four magnitude of hearing change categories over time (from CY 2008 to CY 2013), the mean change in hearing threshold levels were compared at 2000, 3000, and 4000 Hz, from the entry audiogram to the estimated end of first term (this mean is termed Mean Magnitude Change High Frequency). From CY 2008 to CY 2013, the percent of Service members who experienced an average hearing threshold level change of 10 dB or more generally decreased for each subsequent year group (see Figure 2a), while the percent of Service members with less than 10 dB mean change increased (see Figure 2b).

Figure 2a. Percent of Service Members Experiencing a 10 dB or Greater Change in Hearing From Entry to Estimated End of First Term of Service by Year of Entry. Average Hearing Change Magnitude Measured at 2000, 3000, and 4000 Hz (Mean Magnitude Change High Frequency) is Grouped by 10−19 dB, 20−29 dB, and 30+ dB.

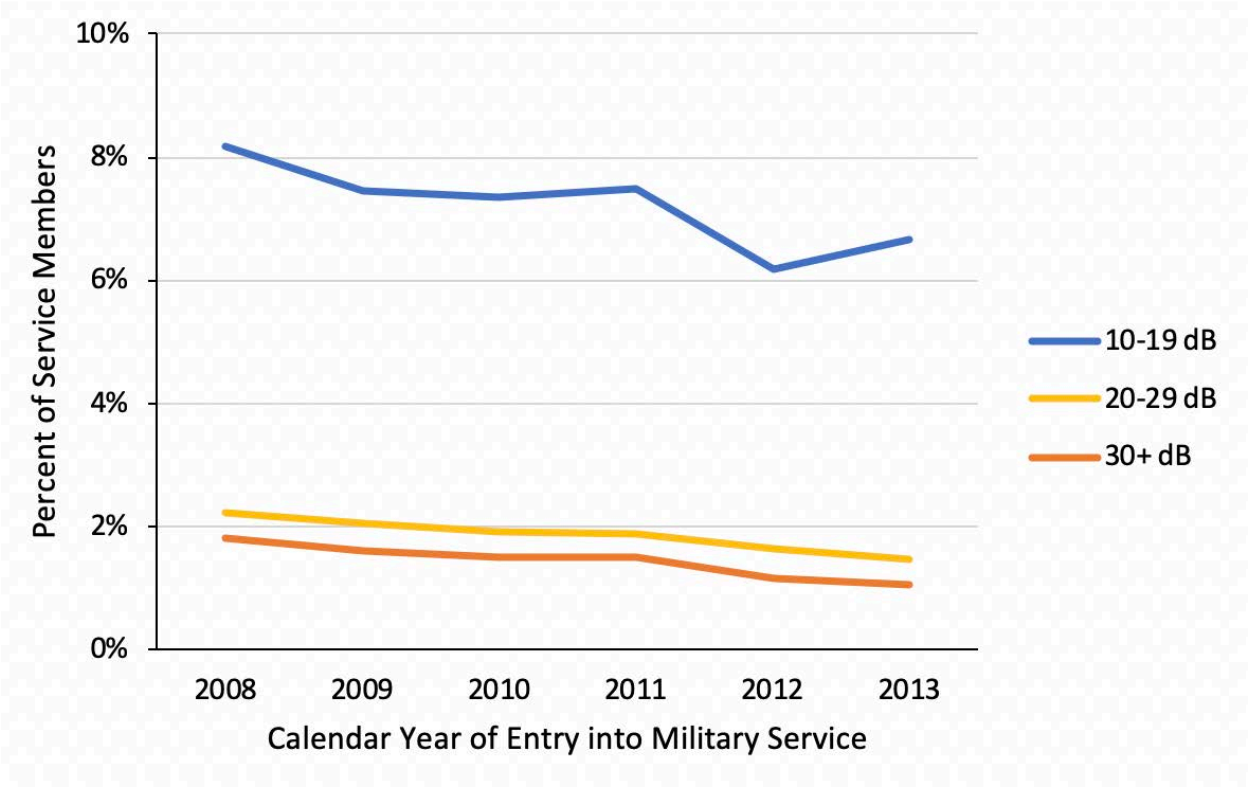

Figure 2b. Percent of Service Members Experiencing Less Than 10 dB Change in Hearing From Entry to Estimated End of First Term of Service by Year of Entry (Mean Magnitude Change High Frequency).

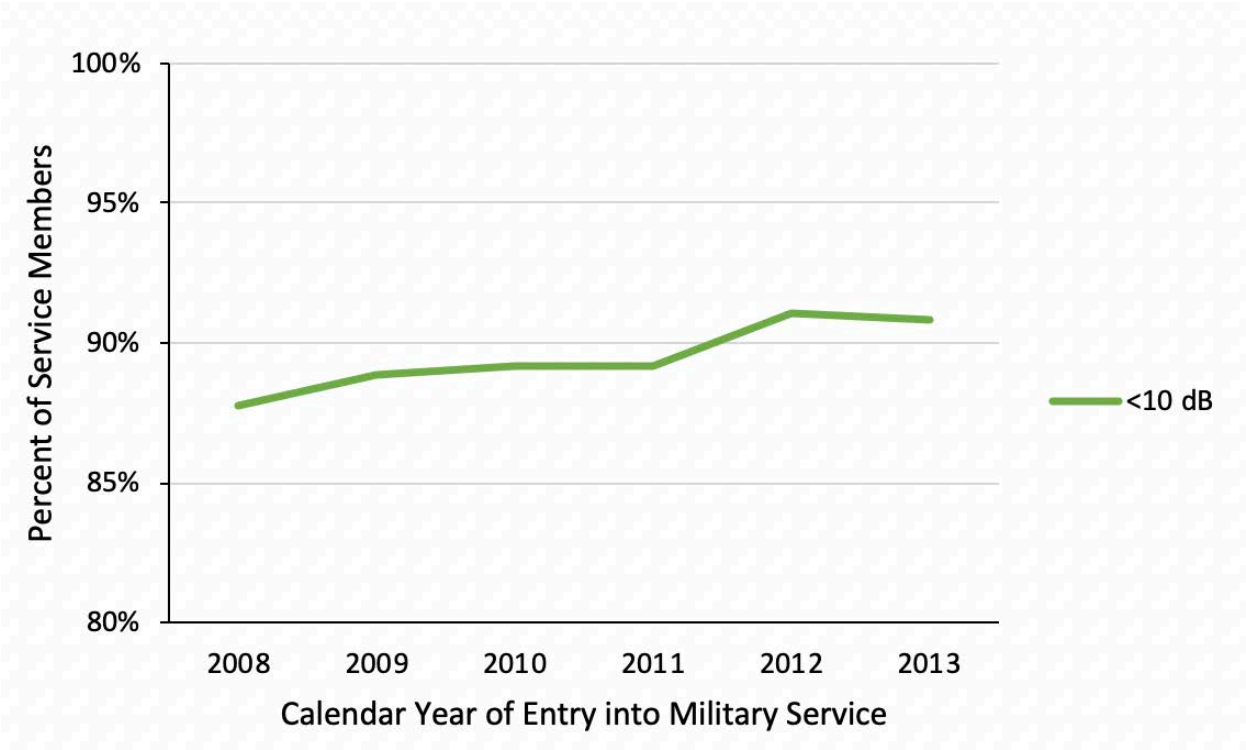

Table 7 provides the same information presented in Figures 2a and 2b in a numeric format. While the percent of changes from year to year are relatively small, the trends for these changes are all in the desired direction. These changes suggest that, over time for each subsequent cohort of Service members from CY 2008 to CY 2013 (six cohorts), high-frequency hearing threshold levels (2000, 3000, and 4000 Hz) were not degraded as much, when compared to previous year groups for the population of Service members during their first term of military service.

Table 7. Percent of Service Members for Each Magnitude of Hearing Change From Entry to Active Duty to Estimated End of Service (Based on Audiograms for Service Members in Each of the Six CY Groups).

Magnitude of Hearing Change Category	CY Group					
	2008	2009	2010	2011	2012	2013
<10 dB	87.8	88.9	89.2	89.2	91.1	90.8
10−19 dB	8.2	7.5	7.4	7.5	6.2	6.6
20−29 dB	2.2	2.1	1.9	1.9	1.6	1.5
30+ dB	1.8	1.6	1.5	1.5	1.1	1.0

Service Members from the Cohort Who Left Military Service and Received VBA/VA Benefits for Hearing Loss

VBA/VA records were examined to determine if any of the Service members in the original cohort of the six year groups (688,783 Service members with both entry to active duty and estimated end of first term audiograms) received VA service-connected disability benefits for hearing loss.

- The VBA/VA records showed that of the cohort of Service members that had hearing tests both at entry and at estimated End of Term who then left active duty (508,884 individuals), and then applied for VBA/VA service-connected disability compensation for hearing loss, over four percent of those Service members (4.3 percent or 21,826 individuals, now veterans) received VBA/VA service-connected disability benefits for hearing loss.[14]

- Figure 3 shows mean (average) hearing threshold level trends for veterans receiving VBA/VA benefits for hearing loss for the six year groups combined (this mean termed Mean Entry Thresholds Benefits Veteran). The mean hearing threshold levels (Mean Entry Thresholds Benefits Veteran) for Service members who later received VBA/VA benefits were within normal limits at entry to active duty (black line). However, for the estimated end of first term hearing test, the mean hearing thresholds for these individuals (this mean termed Mean End Thresholds Benefits Veteran) show an increase in hearing threshold levels across the entire frequency range (500–6000 Hz) and demonstrate a mild hearing loss for the high frequencies above 3000 Hz (red line). The actual numeric hearing threshold levels in dB HL are presented in Table 8 below.

[14] Award of VA service-connected disability benefits for hearing loss can be based on many factors - not only changes in hearing threshold levels during military service. For example, in granting service-connected disability benefits for hearing loss, the VA considers:

- Word Recognition Scores (testing to determine the veteran's optimum performance for word recognition under controlled and standardized conditions) of less than 94 percent;
- A permanent positive threshold shift worse than reference audiogram threshold "greater than normal measurement variability" at any frequency between 500–6000 Hz; and
- Determination of etiology affected by several facts, court decisions, and/or by VBA direction. For instance:
  - Instead of conceding noise exposure for a military occupational specialty (MOS) with moderate or high probability for noise exposure, Veteran Service Representatives and Rating Veteran Service Representatives must now concede noise exposure for ALL MOS's (low, moderate, and high probability of noise exposure, rather than only moderate and high probability of noise exposure MOS's) for the purposes of establishing an event in service.
  - When hazardous noise exposure is conceded based on the veteran engaging in combat, accept satisfactory lay or other evidence of service incurrence or aggravation of such injury or disease, if consistent with the circumstances, conditions, or hardships of such service, even if there is no official record of such incurrence or aggravation in such service. There is a requirement to resolve every reasonable doubt in favor of the veteran, unless there is clear and convincing evidence to the contrary. (*Reeves v. Shinseki, 682 F.3d 988, Fed.Cir. 2012).*

Figure 3. Mean Hearing Threshold Levels at Entry to Active Duty (Mean Entry Thresholds Benefits Veteran) and Mean Estimated End of First Term (Mean End Thresholds Benefits Veteran) for the 21,826 Discharged Service Members Who Received VBA/VA Service-Connected Benefits for Hearing Loss (All Year Groups Combined).

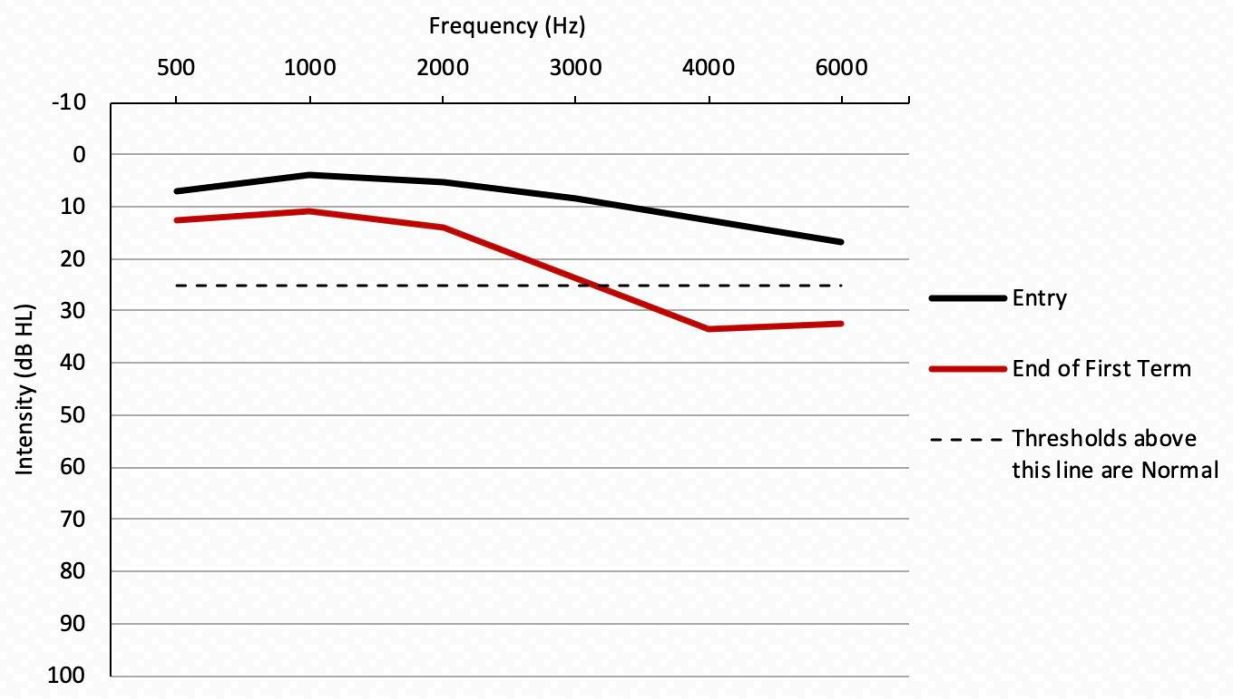

Table 8. Mean Hearing Threshold Levels in dB HL at Entry on Active Duty (Mean Entry Thresholds Benefits Veteran) and Mean Hearing Threshold Levels in dB HL for Estimated End of First Term (Mean End Thresholds Benefits Veteran) for Discharged Service Members Receiving VBA/VA Service-Connected Disability Benefits for Hearing Loss (Year Groups Combined, N=21,826).

Time of Hearing Test	Frequency (Hz)					
	500	1000	2000	3000	4000	6000
Entry on Active Duty	7	4	5	8	13	17
End of First Term	13	11	14	24	33	33

Conclusions and Considerations

Based on the population studied for the comparison of Service member hearing (688,783 Service members for six year groups, CY 2008–CY 2013), it was determined that at the estimated end of first term of military service, 89.5 percent of the Service members had a minimal (0–<10 dB) change in hearing threshold levels and 10.5 percent had a greater (10–30+ dB) change in hearing thresholds levels when examining the average hearing thresholds levels at the test frequencies most susceptible to NIHL (i.e., calculating the mean change in hearing threshold levels at 2000, 3000, and 4000 Hz from the entry audiogram to the estimated end of first term audiogram). As such, one might conclude that most Service members end their estimated first term of military

service with their hearing similar to what it was when they entered military service while slightly more than 10 percent have experienced some greater degradation of their hearing during this period. As mentioned earlier in this report to Congress, it is challenging to attribute a cause and effect relationship between/among MOEs (such as hearing threshold levels) and specific hearing protection measures (such as HPDs). The ability to control for the multifactorial influences on Service member hearing is a significant obstacle to making definitive conclusions.

Further, at the time of analysis of the data for this report to Congress, 508,884 individuals from the original 688,783 Service member population left active and could have applied for VBA/VA service-connected disability compensation for hearing loss. The analysis showed that over 4 percent of the individuals who left active duty were awarded service-connected disability compensation for hearing loss. As highlighted earlier in this report, one should be cautious about making any conclusions regarding relationships among hearing threshold levels, HCP components, and VBA/VA hearing loss disability as the award of VBA/VA service-connected disability benefits for hearing loss can be based on many factors, not only changes in hearing threshold levels during military service.

V. INNOVATIVE SAFE TECHNOLOGIES TO DETER HEARING LOSS OR IMPROVE HEARING

Innovative Safe Technologies

The following are innovative safe technologies used in DoD with the potential to prevent NIHL or improve hearing in Service members:

- **HPDs that are functional for job task and prevent hearing injury.** The DoD continues to establish requirements, conduct research, and acquire HPDs to attenuate sounds to a safe listening level (for impulsive and steady-state noise) and preserve Service member auditory situational awareness with minimal to no degradation to communication ability and operational performance. Hearing protection capabilities can be integrated into certain communication systems, such as tactical radio systems. Examples include electronic pass-through type HPDs and level dependent HPDs.

- **HPDs with reduced occlusion effect**.[15] There are current and emerging technologies that reduce, or are expected to reduce, the occlusion effect in both passive and active HPDs. Research has shown that auditory occlusion effects can inhibit individuals from using HPDs when exposed to hazardous noise.

- **Passive HPDs with a flat frequency response.** Most earplugs reduce sound to a greater degree in the high frequencies than in the lower and mid-range frequencies. This type of attenuation and frequency response can alter environmental sounds and speech intelligibility,

[15] The occlusion effect is the sensation of increased loudness that a person experiences to self-generated sounds (e.g., talking, chewing, swallowing). The problem often occurs when the ears are covered, or the ear canal is blocked (occluded) such as with the use of hearing protection devices.

potentially reducing HPD use (compliance) and negatively impacting operational performance and safety. Conversely, there are HPDs that provide a flat frequency response by allowing equal attenuation of sound across the range of frequencies; these may benefit Service members operating in certain noise environments (e.g., appropriate for lower but still hazardous noise levels). Anecdotal reports from the field suggest that higher cost often deters military units from purchasing these devices for use.

- **Personal fit-testing technology and best practices.** As previously discussed, fit testing is a method to verify the performance of HPDs for individuals enrolled in HCPs. Adequate HPD protection depends on proper fit and quality training regarding HPD use. Fit testing is also an educational tool, allowing Service members to experience what the "right" fit feels like. Additional research is needed to determine if proper fitting of HPDs is a perishable skill that should be included in Service member training of basic skills and tasks. Widespread use of fit testing is currently limited in DoD by cost (fit-check equipment expense) and time requirements.

- **Innovative tablet-based technology training capabilities for annual hearing health education requirements for Service members in HCPs.** No HPD technology is effective unless its user understands the importance of hearing protection and knows how to properly use the device. While hearing health education and training include the proper use of HPDs and are an annual requirement in DoDI 6055.12, unit training demands often abbreviate hearing conservation education and training.[16] To address this knowledge gap, the DoD HCE; Army Hearing Program, Army Public Health Center; and the Audiology and Speech Pathology Center, Walter Reed National Military Medical Center are developing and evaluating the effectiveness and feasibility of tablet-based technology training that units can use to present the required training to Service members while they wait for their annual hearing tests. This health education technology aims to improve the effectiveness of HPDs by educating Service members on their proper use (to include proper fit) and other aspects of hearing conservation.

- **Telehealth capabilities to support monitoring hearing of noise-exposed Service members and the use of hearing protection devices.** Each Service has ongoing telehealth projects to address various HCP gaps. A representative effort is the Air Force's Telehealth for Hearing Conservation: Clinical Video Initiative that is a real-time videoconferencing and diagnostic care service between military medical treatment facilities. The videoconferencing capability replicates face-to-face consultations between patient and provider to address:

    - Completion of expedient HCP evaluations,

    - Provision of direct operational support for HCP program referral needs, and

[16] DoDI 6055.12 requires Service members in hearing conservation programs to receive annual hearing health education regarding (1) the purpose of hearing protection; (2) instructions on selection, fit, use, and care of hearing protection; and (3) the importance of using personal hearing protectors when exposed to hazardous noise during off-duty activities.

- Reduction of extraneous and redundant provider care.

Examples of DoD Research and Development Efforts to Improve Hearing Protection Device Effectiveness

The DoD continues to explore advanced HPDs by conducting and sponsoring research to develop and improve HPD technologies for Service members. These efforts aim to provide appropriate sound attenuation and auditory situation awareness capabilities that are effective in various military operational environments. Table 9 in Appendix H provides examples of ongoing and completed research projects involving advanced HPDs and other hearing protection strategies.

Hearing Protection Measures Regarding Program Administration, Policies, and Best Practices

While there are innovative safe HPD technologies, DoD also is focused on improving hearing protection measures that do not involve technologies, but rather address HCP administrative processes, policies, and best practices. These initiatives are at various stages of development and implementation. Examples of these efforts are included in Table 10, Appendix I.

VI. CONCLUSION

Hearing is a critical sense for Service members, impacting their ability to train and fight. The DoD is committed to protecting Service members from NIHL and other auditory system injuries caused by exposure to hazardous noise levels. The DoD implements a holistic, multifaceted HCP to implement hearing protection measures. These measures include innovative HPD technologies to maximize the lethality, medical readiness, and operational performance of the Armed Forces.

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VIII. ACRONYMS

AFRL	Air Force Research Laboratory
ANR	active noise reduction
ANSI	American National Standards Institute
APHC	Army Public Health Center
ARL	Army Research Laboratory
ASA	Acoustical Society of America
CEP	communication earplug
CFR	Code of Federal Regulations
dB	decibel(s)
dBA	decibel(s), A-weighted
dBP	decibel(s), peak
DHA	Defense Health Agency
DMRDP	Defense Medical Research and Development Program
DoD	Department of Defense
DoDI	Department of Defense Instruction
DOEHRS-HC	Defense Occupational and Environmental Health Readiness System-Hearing Conservation
HCE	Hearing Center of Excellence
HCP	hearing conservation program
HCWG	Hearing Conservation Working Group
HL	hearing level, hearing threshold level
HPD	hearing protection device
HRTF	head-related transfer function
Hz	hertz
JHASIR	Joint Hearing Loss and Auditory System Injury Registry
JPC	Joint Program Committee
MIL-STD	military standard
MIT	Massachusetts Institute of Technology
MOE	measure of effectiveness
NIOSH	National Institute for Occupational Safety and Health
NIHL	noise-induced hearing loss
NSMRL	Naval Submarine Medical Research Laboratory
NRR	noise reduction rating
ONR	Office of Naval Research
OSHA	Occupational Safety and Health Administration
PAR	personal attenuation rating

PTS	permanent threshold shift
REAT	real ear attenuation threshold
SBIR	Small Business Innovative Research
SPL	sound pressure level
STS	significant threshold shift
TCAPS	Tactical Communication and Protective System
TTS	temporary threshold shift
TWA	time-weighted average
USAARL	U.S. Army Aeromedical Research Laboratory
U.S.C.	United States Code
USUHS	Uniformed Services University of the Health Sciences
VA	Department of Veterans Affairs
VBA	Veterans Benefits Administration
VHA	Veterans Health Administration
WAHTS	Wireless Automated Hearing Test System
WRAIR	Walter Reed Army Institute of Research

IX. DEFINITIONS

Audiogram	Graph of hearing threshold level as a function of frequency.
Decibel	Unit of level when the base of the logarithm is the 10th root of 10 and the quantities concerned are proportional to power.
Decibel, A-weighted (dBA)	The standard abbreviation for sound levels measured or calculated after application of an A-weighting curve defined in Part 1 of International Electrotechnical Commission Standard 61672-1. The A-weighting process accords greater emphasis to sounds in the 500 to 2000 Hz range and is commonly used for hearing conservation purposes dealing with steady-state sound.
Decibel (dBP)	The standard abbreviation for the maximum sound pressure during a measurement period or noise event, usually associated with an impulse sound. Measured using filters or weighting scales necessary to capture the true peak sound pressure level. Often used in the measurement of impulse noise.
Frequency	Frequency, *f*, is a measure of the number of vibrations (i.e., sound pressure cycles) that occur per second. It is measured in hertz (Hz), where one Hz is equal to one cycle per second.
Hearing threshold level or hearing level	For a specified signal, amount in decibels by which the hearing threshold for a listener, for one or both ears, exceeds a specified reference equivalent threshold level. Unit, dB HL.
Impulse (or impulsive) noise	Impulse (or impulsive) noise is characterized by a sharp rise and rapid decay in sound levels and is less than one second in duration.
Noise reduction rating	Indicates a hearing protector's noise reduction capabilities, is a single-number rating that is required by law to be shown on the label of each hearing protector sold in the United States. Unit, dB.
Personal attenuation rating	Obtained from an attenuation measurement at one or more than one frequency. The Personal Attenuation Rating is regarded as more accurate than the NRR because it is calculated per individual and per hearing protection device, while NRR is a generalized estimate of potential sound reduction based on the protection provided to a small population of people. It gives the evaluator an estimate of the total noise exposure an individual is receiving when wearing hearing protection.
Potentially hazardous noise area	Any area where Service members or civilian employees are likely to be exposed to noise levels greater than or equal to an eight-hour time-weighted average (TWA) of 85 dBA, or where impulse noise levels are greater than or equal to 140 dBP (as defined in DoDI 6055.12).
Permanent threshold shift (PTS)	Permanent increase in the threshold of audibility for an ear.

Reference audiogram	A baseline audiogram free from auditory fatigue and other transient otologic pathology, against which future audiograms are compared.
Significant threshold shift (STS)	An average change of plus or minus 10 dB at 2000, 3000, and 4000 Hz, relative to the reference audiogram, in either ear, without age correction (DoD).
Sound pressure level, SPL	A measure of the ratio of the pressure of a sound wave relative to a reference sound pressure. Sound pressure level in decibels is typically referenced to 20 μPa. When used alone (e.g., 90 dB SPL), a given decibel level implies an unweighted sound pressure level.
Steady-state noise	Noise of which the level does not change by more than 5dB at a given place and during a given time period.
Temporary threshold shift (TTS)	Temporary increase in the threshold of audibility for an ear caused by exposure to high-intensity acoustic stimuli. Such a shift may be caused by other means such as use of aspirin or other drugs. Unit, dB.
Threshold	Lowest level of sound that can be heard 50 percent of the time. The decibel (dB) is the unit of intensity (loudness) used to describe the level of hearing threshold.
Time-weighted average (TWA)	The averaging of different exposure levels during an exposure period. For noise, given an 85 dBA exposure limit and a 3 dB exchange rate, the TWA is calculated according to the following formula: TWA = 10.0 × Log(D/l 00) + 85 where D = dose.

X. APPENDICES A−I (See Attachments)