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The Assessment of Sound Attenuation and Speech Intelligibility of Selected Active Noise Reduction Devices and the Communications Earplug When Used With the HGU-56/P Aviator Helmet

By

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January 1997

U.S. Army Aeromedical Research Laboratory
Fort Rucker, Alabama 36362-0577

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The Program Manager for Aircrew Integrated Systems (PM-ACIS), formerly Aviation Life Support Equipment (PM-ALSE), requested the U.S. Army Aeromedical Research Laboratory (USAARL) examine the status of active noise reduction (ANR) systems available in the marketplace. The mechanism for acquiring the devices was a Cooperative Research and Development Agreement (CRDA) which was implemented with three U.S. corporations. Each corporation agreed to modify three HGU-56 aviator helmets, furnished by the Government, by installing their ANR system.

The modified helmets, the communications earplug (CEP), and the standard HGU-56 helmet were evaluated by the USAARL Aircrew Protection Division to determine the electro-acoustic, hearing protective, and speech intelligibility characteristics. Standard techniques, using human subjects for sound attenuation and speech intelligibility, were used to complete the measurements.

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Results show the ANR and CEP provide improvements in sound attenuation and speech intelligibility over the standard HGU-56. Measurements conducted while wearing the M-45 CB mask with the helmet showed the CEP provides significant improvements in sound attenuation and speech intelligibility over all other devices.

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The authors wish to thank Mr. Tom Metzler, Project Manager, Aircrew Integrated Systems, ATCOM, for funding support, and Mr. Jerry Pickett and his staff for their efforts in the loan of equipment, negotiations with manufacturers, and guidance in many other areas during this study. They also wish to thank Dr. John Ribera and LTC Robert Staton for their technical assistance and enthusiasm in continuing the development of the communication earplug.

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Introduction

Noise levels in U.S. Army helicopters exceed safe limits when assessed in accordance with limits set in DODI 6055.12 (1991). In some cases, the ability to protect hearing of the aviator with the helmet worn alone is marginal. Using combination protection, by wearing earplugs, compounds the problem in cases where intercommunications systems are not capable of producing speech levels needed to overcome the earplug sound attenuation.

Voice communications are critical to the successful completion of the aviator's mission. The aviator must be able to understand complex messages quickly and completely in order to maintain full advantage over opposing forces. The effects of poor communications may be reflected in compromising the mission and may result in the loss of life and property.

The cost of hearing loss can be described in dollars of compensation after retirement but the hidden cost of property loss, lower performance, and loss of productivity are more difficult to determine. The Veterans Administration compensation for hearing loss, as a result of Army noise exposure, is almost $165 million per year. The soldiers' commitment to serve their country should not result in decreased quality of life caused by preventable hearing loss.

Adequate sound attenuation and speech intelligibility (SI) are necessary for the health and optimum performance of the Army aviator. Noise environments within rotary-wing aircraft exceed limits considered safe in accordance with DoD Instruction 6055.12, "Hearing Conservation." The noise spectrum within the helicopter is predominantly low frequency with peak levels occurring near the blade passing frequency. Noise sources, in addition to the blades, include engines, blowers, transmissions, vibration, and turbulence caused by the movement of the helicopter through the atmosphere. Since levels normally exceed 85 dBA, hearing protection is required. In most cases, all of the aircrew use electrically-aided communication systems for crew coordination.

The effectiveness of hearing protective devices (HPDs) with communication capability is generally determined using standard laboratory techniques. Results from the laboratory evaluations then are applied through models to estimate expected performance in a user's particular noise environment. This evaluation was designed to provide measurement data for a variety of conditions which may be encountered in the operational environment so estimates of effectiveness can be derived.

Protective capability of hearing protective devices which fit around the external ear is reduced whenever the earseal-to-head interface is interrupted. This study assessed the performance of the candidate systems under optimum conditions and when worn in combination with ancillary equipment. The ancillary equipment included spectacles and chemical biological (CB) protective mask. The spectacles were of a type with bayonet temples which are standard issue for aviators. The CB mask used in the evaluation was the M-45 mask.

The program manager for Aircrew Integrated Systems (PM-ACIS), formerly Aviation Life Support Equipment (PM-ALSE), U.S. Army Aviation and Troop Command, St. Louis, Missouri, requested the U.S. Army Aeromedical Research Laboratory (USAARL) to examine the status of active noise reduction (ANR) systems available in the marketplace. The mechanism for acquiring the devices was a cooperative research and development agreement (CRDA) which was implemented with three U.S. corporations. Each corporation agreed to modify three HGU-56 aviator helmets furnished by the Government by installing their ANR system.

Candidate devices included the communications earplug (CEP) and ANR systems from three manufacturers: Grumman-Aerospace, Bose, and Gentex Corporations.* Results from evaluations of the candidate devices were compared to the standard HGU-56/P helmet. Results of the evaluations of sound attenuation and SI were accomplished on the devices when worn alone, with spectacles, and with the CB mask.

Background

Hearing protector sound attenuation usually is measured using either of two preferred standard techniques. American National Standards Institute (ANSI) S12.6, "Method for the measurement of real-ear attenuation of hearing protectors" (1984), uses the hearing threshold shift of individuals to measure the attenuation of a hearing protector. Military Standard (MIL-STD) 912, "Physical-ear noise attenuation test," (DOD, 1990) is the other preferred method which measures insertion loss (sound attenuation) using miniature microphones in the ear canal openings of human subjects. The assessment of sound attenuation of ANR hearing protectors cannot be completed with S12.6 due to an increase in the measured hearing threshold shift because of masking caused by background noise generated by the ANR electronics. The preferred method for the ANR assessment is MIL-STD-912. The preferred method for the assessment of insert protectors is ANSI S12.6 because of the difficulty of placing a microphone into the ear canal under the earplug.

Speech intelligibility of a "system" may be measured using any of several methods. Generally, the listener is placed in the noise environment which simulates the noise environment in which the device is to be used. The listener is asked to transcribe words heard over the communications system with percent transcribed correctly being defined as SI. Speech material may be from several sources, but they are commonly monosyllabic.

Hearing protector effectiveness may be affected by any combination of several factors such as improper sizing for the individual, use of ancillary equipment which may affect the interface of the protector to the subject, or inherently inadequate sound attenuation for the noise environment in which it is to be used. The primary factor which affects SI is speech-to-noise ratio which

* See list of manufacturers.

is directly related to sound attenuation of the hearing protector. However, other factors which affect SI are bandwidth, speech signal distortion, and frequency response of the transduced sound signal.

Method and instrumentation

Electro-acoustic measurements were completed on devices submitted by each manufacturer participating in the CRDA. Tests included operation of the ANR system under quiet and noise, frequency response and distortion of the communications components, impedance of the communication receiver circuit, and power required for operation of the ANR system in noise. The measurements were completed on each individual earcup of each individual helmet.

Each helmet was fitted on the head and torso simulator (HATS), model 4128, manufactured by Bruel and Kjaer*. HATS is equipped with microphones which are used to measure sound impinging on the ear. Fit of the helmets on the HATS was optimized for sound attenuation by adjusting the helmet until minimum noise was measured at each of HATS's ears. Electro-acoustic measurements for some conditions were completed in a sound field simulating noise produced by the UH-60 helicopter flying at 120 knots.

Narrowband spectra of noise measured by HATS's ears were determined using a fast Fourier transform (FFT) analyzer, model 2630, manufactured by Tektronix Inc.* Distortion of the communications system was determined using sinusoid signals of 500, 1000, and 2000 hertz generated by the FFT system while the ANR system was on. The voltage level of the sinusoid was adjusted to produce approximately 85 dB output, averaged across the ears of HATS.

Output characteristics of the devices were evaluated also for various combinations of noise, ANR, and speech using a real time analyzer, model 3100 RTA, manufactured by Larson Davis*. Signals measured by HATS's ears were analyzed into one-third octave band levels, and dBA and dB linear levels. An attenuator setting of 30 dB was selected arbitrarily because output was expected to be near the target level of 85 dBA speech level. Results from this measurement were used to determine the attenuator setting required for the speech levels during the speech intelligibility portion of the protocol. Final characteristics of the hearing protective system were determined using MIL-STD-912, "Physical Ear Noise Attenuation Test" (DOD, 1990), and ANSI S12.6 "Method for the measurement of real ear attenuation of hearing protectors" (ANSI, 1984).

Electrical current required for normal operation was determined using a DC current meter, model 467, manufactured by Simpson, Inc.*, inserted in line with the power source for each of the ANR systems. Measurements were completed for the noise off and noise on conditions while the helmet was fitted on the HATS. Only a slight increase was detected for the ANR systems as the noise increased. This slight increase was due to a "good" fit which reduces the noise in the earcup and controls the volume of the internal earcup enclosure. Impedance of the combined earphones was measured using an impedance meter, model 252, manufactured by Electro Scientific Industries*.

Physical-ear attenuation test

A block diagram of the MIL-STD-912, physical-ear attenuation test (PEAT) system is shown in Figure 1. The personal computer (PC) system controls data collection, data storage, and analysis. The sound room sound field was calibrated in accordance with ANSI S12.6 for nondirectionality and level variation around the subject's head location.

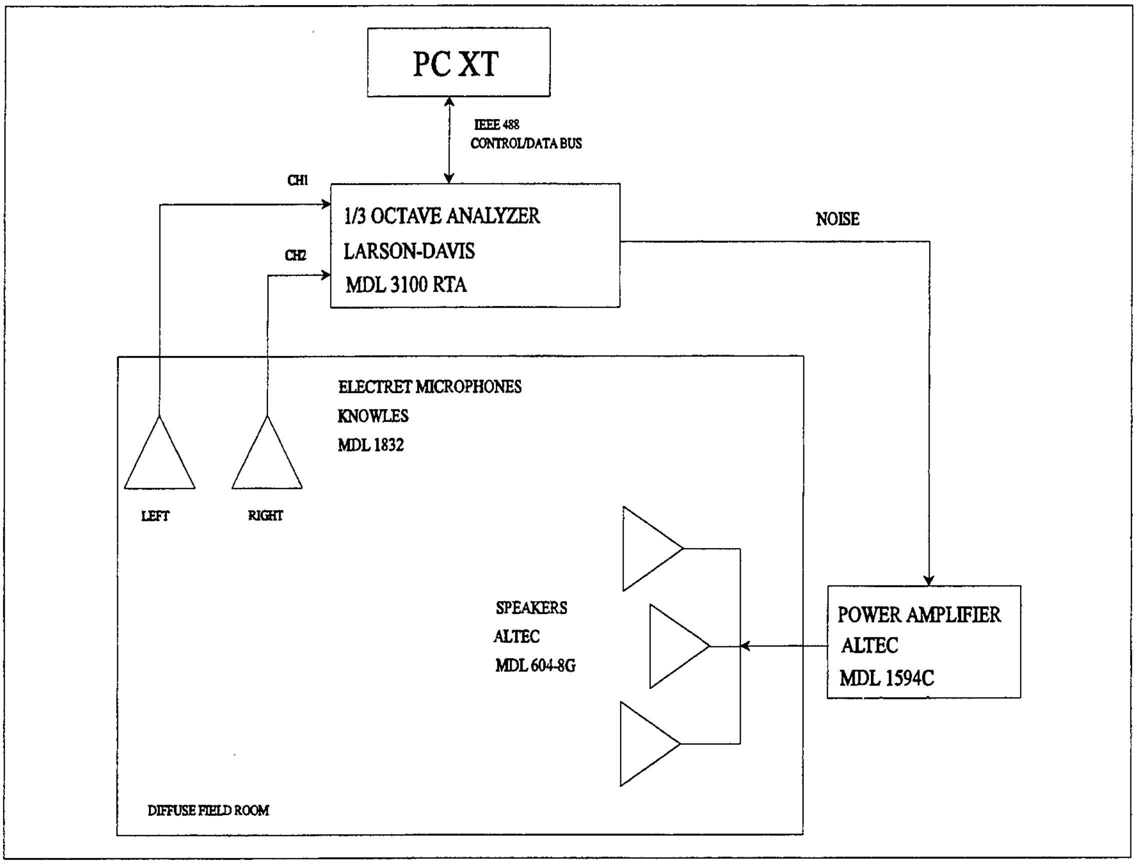

Figure 1. Block diagram of the system used to measure physical-ear attenuation.

Subjects were fitted with moldable earplugs which served as hearing protection and a mounting base for the microphones. Two miniature microphones were embedded into the earplug at the subject's ear canal opening. Each subject was placed in the sound field of approximately 105 dBA while the microphone output from each ear was analyzed into one-third octave band levels. The subject donned the hearing protective device and, again, the microphone output was analyzed from each ear. The difference in level between wearing and not wearing the hearing protector is defined as the PEAT attenuation. The procedure of measuring the levels with the hearing protector removed and refitted was repeated two more times. The PEAT attenuation is an average of the three evaluations for each of 10 subjects. Noise exposure for the subject during the evaluation was below 85 DBA which is considered safe in accordance with DODI 6055.12.

Real-ear attenuation test

The real-ear attenuation test (REAT) is a psychophysical measurement conducted in accordance with ANSI S12.6-1984. Figure 2 shows a block diagram of the S12.6 test system. The method utilizes human subjects by measuring the difference in their hearing threshold when wearing and not wearing the hearing protector. This method uses one-third octave bands of noise as the stimulus with center frequencies at 125, 250, 500, 1000, 2000, 3150, 4000, 6300, and 8000 hertz. Evaluations were completed in a hard-walled sound room which produces a nondirectional sound field for the stimulus.

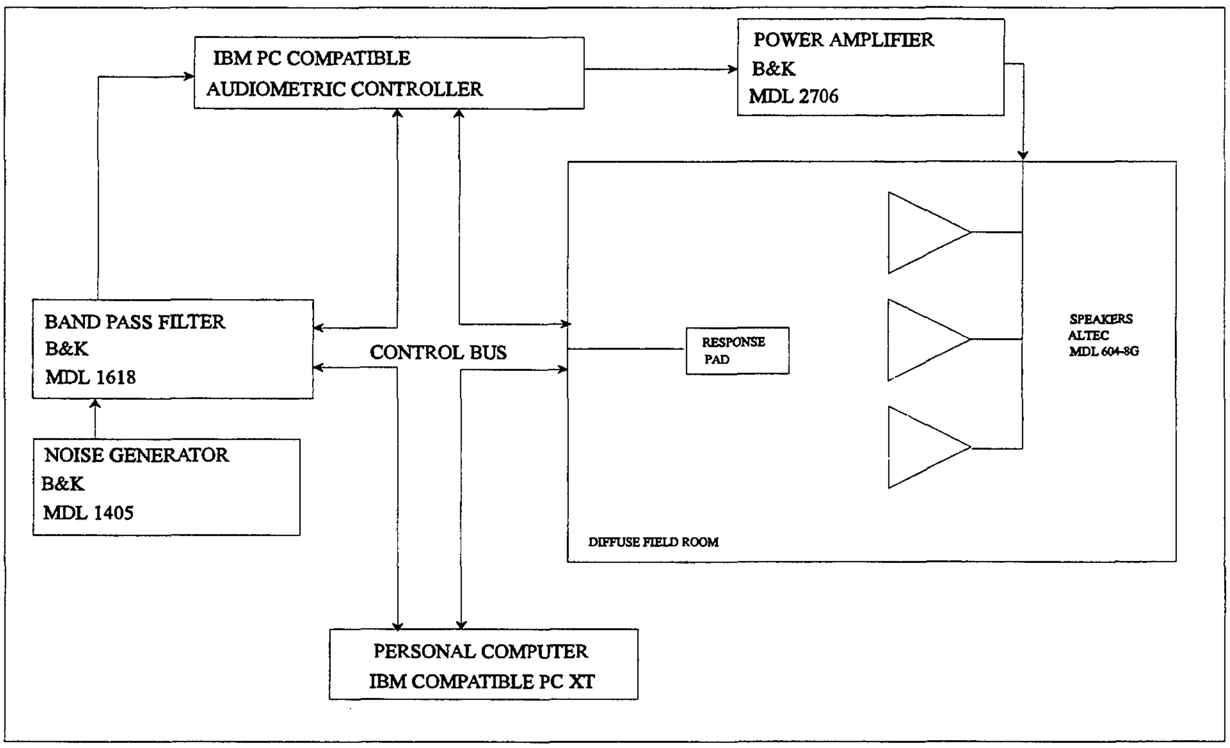

Figure 2. Block diagram of the system used to measure real-ear attenuation.

The method of adjustment psychophysical procedure was used to assess the hearing threshold of the subjects (Nelson and Mozo, 1988). All subjects were seated in the sound room with their heads placed at a fixed location in space. A key pad, controlled by the subject, was used to increase or decrease the stimulus level during the experiment. The subjects were instructed to adjust the stimulus level to their auditory threshold for four separate trials for each of the test frequencies. The average stimulus level of the four trials at each test frequency was defined as the threshold for that frequency. The difference between occluded (wearing the helmet) and unoccluded (not wearing the helmet) threshold is defined as the attenuation. The attenuation for each of the test frequencies was measured for three separate fittings of the hearing protector for each subject in the evaluation. The attenuation for each fitting of all subjects was used to calculate an average and standard deviation value for each of the test frequencies.

Speech intelligibility

Speech signal levels produced by each hearing protective device combination were measured for use in establishing a reference for speech level output which was used during SI testing. The determination was made using an anthropometric manikin, HATS, Model 4128, manufactured by Bruel and Kjaer. A block diagram of the SI system is shown in Figures 3 and 4.

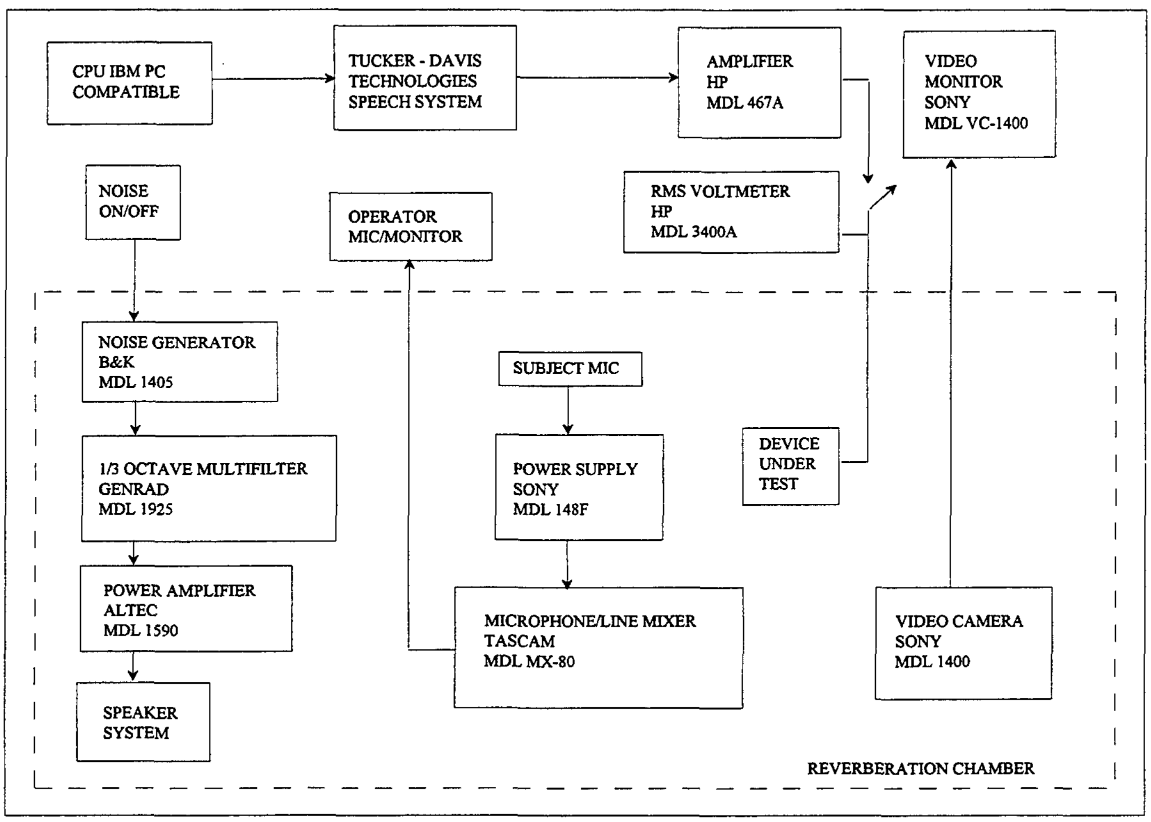

Figure 3. Block diagram of the system used to measure speech intelligibility.

The levels of speech material used in the test were determined by reproducing speech samples through the SI testing system to the device under a test (DUT) fitted on the HATS. The sound exposure level (SEL) of the speech material was measured for a complete word list using a Larson Davis real time analyzer (RTA), model 3100. The sound pressure levels (SPLs) and required attenuator settings for the SI measurement were calculated from the SEL values. Each hearing protector, not ancillary equipment, was fitted to the HATS with the speech drive signal to the DUT adjusted to produce a speech level output of about 85 dB, as measured by the HATS. The speech level of the HGU-56/P with yellow foam earplug (E-A-R) condition was set at the level of the HGU-56/P alone plus 20 dB.

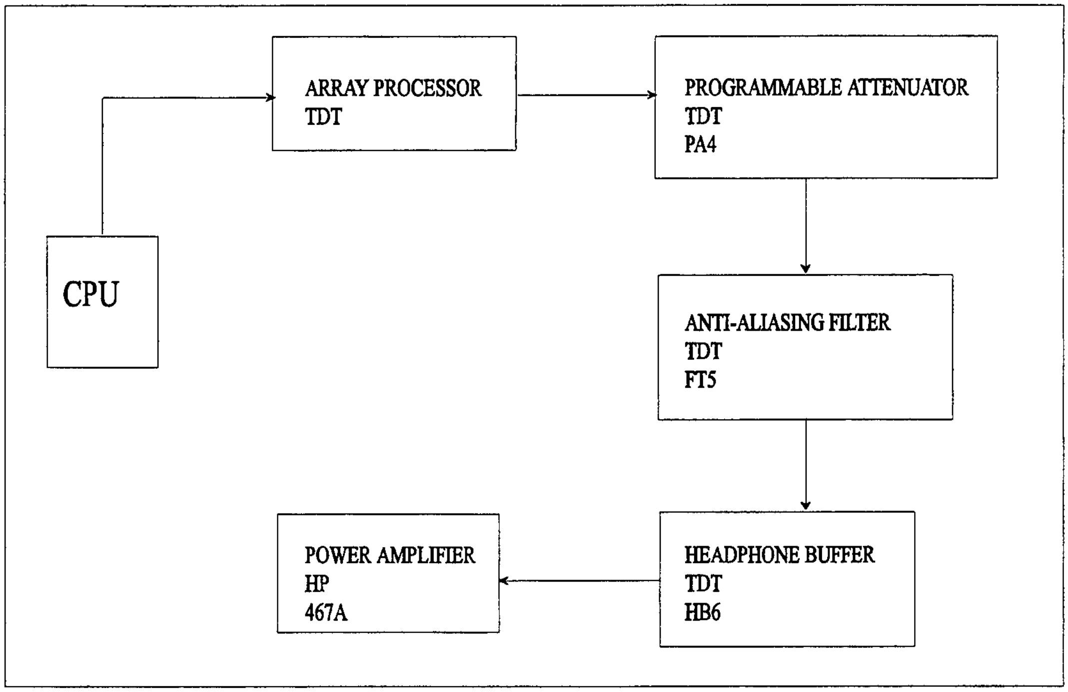

Figure 4. Block diagram of the Tucker-Davis Technologies speech system.

Speech materials used to determine SI consisted of four prerecorded lists of W-22 words with four orderings of each list and a list of 36 W-1 spondaic words (Newby, 1972). The recordings were commercial products purchased from Auditec* of St. Louis, Missouri. Each W-22 list consisted of 50 monosyllabic words.

W-22 words were presented at 85 dB and 95 dB for each of the devices under investigation. The words were presented to the listener at a rate of 12 per minute. The SI for constant speech level input of 85 and 95 dB was used to determine the relative merit of the devices at levels near the acceptable SPL input limit. These levels were derived from research by Camp, Mozo, and Patterson (1975). The SI measurements were conducted in a noise environment that simulated the UH-60 helicopter spectrum at a level of 105 dBA (re 20 micro-Pascal). Subjects were instructed to write each test word heard over the DUT on a numbered answer sheet. As tests were completed, lists were scored for percent of correct responses. Scores were recorded as the SI for that test condition for that subject. A speech recognition threshold (SRT) was obtained for each helmet condition using spondaic words (Van Tassel and Yanz, 1987). The SRT is defined as the level of spondaic speech samples at which the listener has a 50 percent correct response.

Human subjects

Measurements of SI and sound attenuation were made using 18 normal-hearing male volunteer subjects. The subjects were selected from a group of flight students in a delay status between phases of flight training. Subjects received a pure-tone audiogram before participation to verify meeting requirements of ANSI S12.6 and at the end after all data collection was completed. Each subject was given an SI pretest to screen subjects who might have had difficulty performing the SI task.

Volunteers were trained in performing the real-ear test procedures to ensure their ability to provide reproducible thresholds for each of the test frequencies. They were fully familiarized with the four word lists used in the SI measurements. Subjects first read each list, listened to each list reproduced at a level of 70 dB in quiet background, and then were tested to ensure an understanding of words in the lists.

Volunteers were trained in proper fitting techniques by a technician experienced in hearing protector fitting procedures. Fitting for each test sequence was accomplished by the individual volunteer. The fit of the device was monitored by the technician and additional training was accomplished as deemed necessary. Each of the volunteers were tested in each of the three test conditions: DUT alone, DUT with CB mask, and DUT with spectacles.

A measure of real-ear attenuation using ANSI S12.6 was accomplished for each test frequency for each subject for the passive protectors: HGU-56/P, HGU-56/P with CEP, and HGU-56/P with E-A-R. The passive HGU-56/P and HGU-56/P with ANR helmets were evaluated for sound attenuation using MIL-STD-912. Attenuation measurements were accomplished for each device worn alone and in combination with spectacles and CB mask. Results from these measurements also were used to ensure noise exposure for each subject was less than 85 dBA for test conditions used in the SI evaluation.

Devices and test conditions

The devices included in these tests were compared to the HGU-56/P standard helmet. The systems included the HGU-56/P worn in combination with the E-A-R, HGU-56/P worn in combination with CEP, and HGU-56/P helmets fitted with ANR devices from each manufacturer are shown in appendix A. Each manufacturer fitted their ANR device into the HGU-56/P helmets prior to transferring the helmets to the Army for testing.

Each system was worn alone and in combination with spectacles and CB mask for sound attenuation and SI evaluations. The order of tests were randomized using a Latin Square design (Box, Hunter, and Hunter, 1978) to minimize any learning effects. Tests included REAT to determine passive protection provided by the CEP, HGU-56/P in combination with the E-A-R and HGU-56/P worn alone, and PEAT to determine total protection provided by the HGU-56/P passive and each of the HGU-56/P equipped with ANR. SI tests were conducted in a reverberant chamber utilizing noise levels which simulated a UH-60 helicopter during cruise at 120 knots. Overall levels of the noise were adjusted to 105 dBA. Upon measurement of attenuation of the CB mask condition, the level was readjusted to 95 dBA for the HGU-56/P and the ANR helmets due to noise exposures exceeding 85 dBA. Speech tests included SRT and SI at two speech levels, 85 dB and 95 dB, for each system combination. Each device was refitted between speech level tests.

The data were subjected to a general multivariate analysis of variance (MANOVA) using a PC-based statistical analysis program developed by Statsoft*. Postanalysis was conducted using the Tukey's "honestly significant difference" test. The level of significance was selected to be 5 percent.

Results and discussion

Electro-acoustic and physical characteristics

Electro-acoustic tests included sensitivity, distortion, and frequency response of the speech output system. The distortion results were not reported if there was less than 1 percent total harmonic distortion. Weight measurements were completed with an Ohaus triple beam balance. Measurements included an estimate of one-half of the communications cord without spacer pads, batteries, or other parts which may be used for fitting purposes. Results from tests conducted on each manufacturer's system are shown in the following paragraphs. The standard HGU-56/P helmet system is shown and may be compared with each of the other systems.

HGU-56/P

The following results collected from the three HGU-56/P helmets are shown for reference purposes. Helmet weights were measured since the ANR systems varied significantly across manufacturers.

Table 1 shows results of the impedance of the communications circuit and current measurements for the power supply for the ANR system. The current was measured for the noise on and off conditions. Only a slight increase was detected as the noise increased. This slight increase was due to a "good" fit which reduced noise in the earcup and controlled the volume of the internal earcup enclosure. Since the HGU-56/P does not require power, N/A is shown in the current columns.

Table 2 shows the weight in kilograms of the HGU-56/P helmet.

Table 1.
HGU-56/P impedance measurements.

Helmet	Impedance	Noise off	Noise on
1	11.4	N/A	N/A
2	11.1	N/A	N/A
3	11.9	N/A	N/A

Table 2.
Helmet weight of the HGU-56/P in kilograms.

Helmet	Weight
1	1.320
2	1.372
3	1.389

Bose

The helmet provided by Bose includes an earcup different from ones used in the HGU-56/P helmet. The earseals are the silicone gel seal which is common in some of the Bose headset products. The ANR electronics are integrated into the earcup. The communications connector is similar to the type provided with the Army's integrated helmet and display sighting system (IHADSS) helmet, manufactured by Nexus*. Communications signals are provided in the female connector portion which is compatible with the standard aviation connector (U/92A). Power for the ANR circuitry is supplied through the female portion of the connector, through a short adapter cable compatible with the interface to the battery package. Impedance, current during operation, and weight are shown in the following tables. Battery supplies for the helmet included 16 AA cells mounted in a plastic case. During the operational tests, additional battery packs were provided by Bose which used three 9V cells.

Table 3 shows results of the impedance and current measurements. The current was measured for the noise on and off conditions. Only a slight increase was detected as the noise increased. This slight increase is due to a "good" fit which reduced noise in the earcup and controlled the volume of the internal earcup enclosure. Weight measurements are shown in Table 4 and were completed with an Ohaus triple beam balance. Measurements were completed without spacer pads, batteries, or other parts which may be used for fitting purposes.

Table 3.
Impedance in ohms and electrical current milliamps supplied for the indicated conditions.

Helmet	Impedance(ohms)	Noise off(ma)	Noise on(ma)
1	10	29.9	31.0
2	9.8	30.2	33.0
3	10.2	30.2	31.5

Table 4.
Helmet weight in kilograms.

Helmet	Weight
1	1.586
2	1.580
3	1.636

Grumman

The HGU-56/P helmet was modified to a great extent. The internal suspension system was replaced with an insert similar to ones used in the combat vehicle crewman (CVC) helmet. The thermoplastic (TPL™) fitting liner in the HGU-56/P was used to replace the insolite pads commonly used in the CVC helmet. The earcup area of the helmet was cut away to provide space for the earcup used in the system.

The earcup used in the Grumman helmet is different from the standard HGU-56/P earcup. A foam cylinder mounted at the surface of the inner earcup structure rests against the pinna of the wearer and may cause discomfort with long-term use, more than 1 hour. The communication connector is compatible with the ground radio systems used in armored vehicles. Currently, power for the ANR system must be supplied from an external source. Impedance, current requirements, and weight are shown in the following tables. Impedance measurements of the helmet earphones (receivers) are similar to impedance of headsets used in ground vehicles. Weight measurements, shown in Table 6, were completed with an Ohaus triple beam balance. Measurements were completed without spacer pads, batteries, or other parts which may be used for fitting purposes.

Table 5 shows results of the impedance and current measurements. The current was measured for the noise on and off conditions. Only a slight increase was detected as the noise increased. This slight increase is due to a "good" fit which reduced noise in the earcup and controlled the volume of the internal earcup enclosure.

Table 5.
Impedance and power requirements for the indicated conditions.

Helmet	Impedance	Noise off	Noise on
1	437	50.8	51.2
2	417	51.5	51.9
3	390	51.2	51.3

Table 6.
Helmet weight in kilograms.

Helmet	Weight
1	1.686
2	1.724
3	1.707

Gentex

The helmet provided by Gentex includes the energy-absorbing earcup with a modular ANR system within the earcup. The earseal includes a raised ridge, 1/8th inch, at the inner surface. Left and right frequency response dBA levels show a range of more than 6 dB for the three helmets. Distortion for the output sound pressure levels for 500, 1000, and 2000 hertz range from 0.3 to 12.9 percent for input levels which produce approximately 85 dB as measured by HATS (Table 7). We have some concerns that distortion of this magnitude may have influence on the speech intelligibility characteristics of the system.

Table 7.
Distortion in percent of earphone output for three frequencies.

Helmet	EAR	500 Hz	1000 Hz	2000 Hz
1	Left	3.2	12.0	1.3
1	Right	8.3	12.9	0.4
2	Left	3.6	10.5	1.5
2	Right	2.5	12.2	0.8
3	Left	2.7	6.4	1.5
3	Right	1.1	6.2	0.3

Table 8 shows the results of the impedance and current measurements. The current was measured for the noise on and off conditions. Only a slight increase was detected as the noise increased. This slight increase is due to a "good" fit which reduces the noise in the earcup and controls the volume of the internal earcup enclosure. During the execution of the SI measurements on real heads, we will further characterize the current requirements.

Table 9 shows the weight of each helmet. Measurements were completed with a Ohaus triple beam balance. Measurements were completed without spacer pads, batteries, or other parts which may be used for fitting purposes.

Table 8.
Impedance and current requirements for the indicated conditions.

Helmet	Impedance	Noise off	Noise on
1	6.0	21.0	22.4
2	6.0	20.9	21.5
3	7.4	20.8	21.5

Table 9.
Helmet weight in kilograms.

Helmet	Weight
1	1.409
2	1.433
3	1.480

Analysis

Sound attenuation

The sound attenuation provided by the ANR and HGU-56/P helmets was measured using the MIL-STD-912 (PEAT) procedure. The devices were worn alone and in combination with ancillary devices. The mean and standard deviation of the attenuation measurement results for each of the test frequencies are shown in Table 10. The sound attenuation provided by the CEP, E-A-R, and HGU-56/P helmets was measured using the ANSI S12.6 (REAT) procedure. The devices were worn alone and in combination with ancillary devices. The mean and standard deviation of the REAT attenuation measurement results for each of the test frequencies are shown in Table 11.

Table 10.
Physical-ear attenuation characteristics of the CRDA test devices worn alone, with CB mask, and with spectacles.

			Test frequency in Hertz								
Mfg	Ancillary		125	250	500	1000	2000	3150	4000	6300	8000
Bose	1	Mean	21.2	31.2	29.7	34.4	39.9	43.7	47.7	48.8	48.8
		S.D.	4.9	4.9	2.5	3.8	2.5	1.5	2.6	1.6	3.2
	2	Mean	2.6	12.4	16.4	17.6	19.6	33.8	32.7	32.6	31.7
		S.D.	4.7	5.9	3.0	3.1	5.4	2.3	3.9	3.6	3.3
	3	Mean	17.9	27.8	27.8	33.0	36.4	38.6	41.3	43.6	44.7
		S.D.	6.7	6.6	3.8	3.3	2.4	2.4	4.1	3.0	4.4
Gentex	1	Mean	24.7	27.6	33.7	38.4	28.5	42.7	44.9	46.9	46.2
		S.D.	1.4	1.5	3.6	2.4	3.1	1.8	3.5	2.8	4.4
	2	Mean	-1.0	9.4	14.3	18.1	15.8	31.6	31.3	31.7	30.6
		S.D.	3.8	3.6	3.9	3.2	3.9	3.2	3.3	3.6	4.0
	3	Mean	15.6	22.3	30.8	35.6	25.0	37.2	38.4	36.7	36.6
		S.D.	4.7	3.3	3.8	2.4	2.0	1.3	4.5	2.5	5.1
Grumman	1	Mean	18.6	21.6	30.2	29.8	30.3	40.2	43.3	37.9	34.8
		S.D.	8.5	6.4	5.6	6.7	6.5	2.6	6.9	3.4	7.6
	2	Mean	-.02	6.1	14.1	12.1	17.7	31.9	33.1	32.9	30.5
		S.D.	2.3	4.7	3.8	3.9	5.2	2.7	6.2	2.9	5.7
	3	Mean	11.3	16.9	26.5	26.4	25.6	34.2	36.7	29.1	28.1
		S.D.	7.7	6.0	5.5	6.2	5.4	3.0	6.8	3.0	6.1
HGU-56	1	Mean	10.2	13.0	23.0	31.9	35.1	42.3	44.3	41.0	37.7
		S.D.	2.2	1.7	2.1	3.0	1.5	1.2	2.2	2.6	4.4
	2	Mean	-2.7	0.2	12.9	18.8	18.1	32.0	31.1	30.2	28.6
		S.D.	2.3	4.5	4.2	4.3	6.4	3.3	5.1	3.8	5.0
	3	Mean	3.1	8.2	19.9	30.0	33.0	39.8	40.6	29.4	28.8
		S.D.	4.6	3.8	2.7	3.7	2.6	1.4	4.7	2.2	5.2

Ancillary: 1=Alone, 2=CB Mask, 3=Spectacles

Table 11.
Real-ear attenuation characteristics of the CRDA test devices.

Mfg	Ancillary		125	250	500	1000	2000	3150	4000	6300	8000
			Frequency in Hertz								
CEP	1	Mean	29.1	26.0	33.0	30.6	40.1	50.2	55.6	54.1	53.5
		S.D.	6.2	6.6	6.4	3.9	3.9	4.4	6.7	5.7	5.7
	2	Mean	25.6	25.0	31.0	32.5	40.6	54.1	57.4	56.5	55.6
		S.D.	8.6	8.2	9.8	8.3	5.2	4.1	4.1	5.5	5.8
	3	Mean	25.5	26.1	35.2	29.8	39.4	49.0	52.3	51.8	53.7
		S.D.	9.0	7.2	8.1	5.0	2.6	4.4	4.5	7.2	6.2
E-A-R	1	Mean	30.0	29.6	36.2	31.7	40.5	51.0	54.2	54.1	53.9
		S.D.	6.5	4.3	6.7	5.8	3.9	5.6	5.0	5.6	5.4
	2	Mean	26.0	25.2	32.6	31.1	40.0	53.4	57.3	59.1	56.9
		S.D.	7.7	7.8	5.6	5.8	4.4	3.4	5.1	5.1	4.5
	3	Mean	24.4	25.3	32.7	31.0	39.1	49.4	53.7	52.4	52.1
		S.D.	8.5	8.2	8.7	5.6	4.1	4.4	3.9	5.8	5.0
HGU-56	1	Mean	15.7	14.7	20.0	23.9	27.8	37.2	40.6	43.2	43.4
		S.D.	3.9	3.3	3.6	4.9	3.7	4.3	2.8	7.1	9.6
	2	Mean	9.1	9.5	14.6	17.3	25.6	34.5	35.9	35.0	33.3
		S.D.	6.5	6.5	5.8	8.4	7.8	6.2	7.5	7.2	6.8
	3	Mean	10.6	12.6	19.2	24.0	25.9	35.2	37.7	28.2	27.4
		S.D.	6.6	5.1	6.8	6.5	3.9	5.0	5.3	8.2	8.3

Ancillary: 1=Alone, 2=CB Mask, 3=Spectacles

Generally, the standard deviations of the attenuation measures for REAT and PEAT are greater for the two ancillary conditions than when the device is worn alone. Head shape and fit of the device on the subject accounts for most of the variability of the attenuation measurement. However, some of the variability in the REAT measure can be accounted for in the behavioral aspect of the measurement, while placement of the microphone may account for some of the variability in the PEAT measure. A comparison of the HGU-56/P shows standard deviations are higher for the REAT technique while mean attenuation values measured with PEAT are lower for the lower frequencies.

Effective exposure level (EEL) is a mathematical calculation used to estimate sound level in dBA at the ear. The EEL may be used to estimate hazards in terms of currently used criteria contained in DODI 6055.12, "Hearing conservation program." The EEL is a power summation of octave band levels of aircraft noise reduced by hearing protector attenuation and A-weighting for all standard frequencies. This yields a single number representing exposure in dBA. The Army's procedure for determining a noise exposure hazard is to reduce hearing protector mean attenuation by one standard deviation.

Estimates of EELs are a way of looking at the effectiveness of a hearing protector and an indication of noise exposure the aviator is accumulating while flying in that particular noise environment. Noise levels from several aircraft for various positions and flight conditions were used to evaluate the effective noise exposure for an aviator wearing each of the test devices. Estimates of the effective exposure in dBA of the CRDA devices for several Army helicopters are shown in appendix C. Each of the resultant A-weighted and protected octave band levels are shown to give the reader a sense of how sound levels arriving at the ear are distributed. Differences in overall means of the device worn alone when compared to being worn with CB mask and with spectacles are an indication of the loss of effectiveness caused by ancillary devices. The increased variability introduces a negative bias on results of the EEL evaluation since mean values are reduced by one standard deviation in the algorithm. Certainly, the larger standard deviation does indicate there is some factor in the device which affects the fitting of the device on different heads.

The sound attenuation data for each device, as measured by their respective techniques, were used to calculate the EEL in dBA for typical Army aircraft noise levels. Each individual set of attenuation values for each subject for each device condition was used to calculate the EEL for the UH-60 pilot's position at 120 knot cruise and the CH-47 between the pilots during 100 knot cruise. EEL values for test conditions and subjects were used in the analysis of variance (ANOVA). Independent variables were helmet/protective type (six levels) and ancillary device (three levels) with EEL being the dependent variable. Results of the ANOVA indicate significant main effects and significant effects for the interactions. The UH-60 analysis shows results of the main effects, ancillary ($F = 139.4$, d.f. = 2/349, $p < 0.001$) and helmet/protective type ($F = 95.4$, d.f. = 6/349, $p < 0.001$). Interactions show ($F = 10.8$, d.f. = 12/349, $p < 0.001$). The CH-47 analysis shows results of the main effects, ancillary ($F = 174.0$, d.f. = 2/349, $p < 0.001$) and helmet/protective type ($F=99.0$, d.f. = 6/349, $p < 0.001$). Interactions show ($F = 13.8$, d.f. = 12/349, $p < 0.001$). Tables 12 and 13 show results of Tukey's post hoc tests for the UH-60 and CH-47 EEL analysis. The test was used to evaluate the mean EEL for each device for each of the ancillary conditions. The mean EEL values are arrayed in the table in ascending order. The mean differences which are determined to be significant are shown with letters to indicate their relationship with all other means for similar conditions.

Table 12.
Devices shown in ascending order of mean EEL for UH-60 noise. (Significant differences are shown, using letters to indicate the various mean levels.)

Alone			Spectacles			CB Mask		
E-A-R	70.5	a	Bose	73.6	a	E-A-R	73.8	a
Bose	70.6	a	CEP	73.9	a	CEP	74.6	a
Gentex	72.1	a	E-A-R	74.6	a	Bose	88.8	b
CEP	73.7	a	Gentex	77.6	a	Gentex	91.7	b
Grumman	77.7	a	Grumman	82.7	b	Grumman	93.9	b c
HGU-56/P	86.0	b	HGU-56/P	91.0	c	HGU-56/P	98.8	c

Table 13.
Devices shown in ascending order of mean EEL for CH-47C noise. (Significant differences are shown, using letters to indicate the various mean levels.)

Alone			Spectacles			CB Mask		
E-A-R	73.2	a	CEP	75.7	a	E-A-R	75.5	a
Bose	73.6	a	E-A-R	75.8	a	CEP	75.8	a
CEP	75.2	a	Bose	76.6	a	Bose	92.1	b
Grumman	80.5	b	Gentex	84.7	b	Grumman	95.2	b
Gentex	81.0	b	Grumman	85.3	b	Gentex	95.2	b
HGU-56/P	82.0	b	HGU-56/P	86.7	b	HGU-56/P	96.1	b

Results of the sound attenuation evaluation indicate E-A-R, CEP, and the ANR devices perform better than the standard HGU-56/P helmet worn alone. CEP and E-A-R perform better than ANR when wearing the CB mask. ANR and the HGU-56/P sound attenuation characteristics are reduced when the helmet earseal is compromised or leakage paths occur. The differences in levels of significance between the CH-47 and UH-60 calculations are driven by the spectral characteristics of the noise in each helicopter. The CH-47 has a characteristic high level noise component at about 1600 hertz which is caused by the forward and aft transmissions. The attenuation provided by the Gentex device shows lower sound attenuation in that region of the spectrum.

Speech intelligibility

Voltage levels required to produce 85 dB at 1000 Hertz for each of the DUTs are shown in Table 14. The attenuator settings required to produce 85 dB output from the DUTs also are shown in Table 14. The attenuator setting for the E-A-R presentation is 20 dB less than the HGU-56/P to compensate for attenuation of the speech signal. The speech signal-to- noise ratio in the earcup should be increased by 20 dB over the speech signal-to-noise ratio of the HGU-56/P worn alone.

Table 14.
Mean drive level in millivolts required to produce 85 dB at 1000 Hertz and the attenuator settings used to produce a speech level of 85 dB.

Manufacturer	Drive level (mv)	Attenuator setting (dB)
Bose	87	41
Grumman	133	39
Gentex	127	41
HGU-56/P	457	41
CEP	370	30
E-A-R	1270	21

Electro-acoustic (sensitivity response) levels which are used to establish attenuator settings to estimate 85 dB speech levels are included in appendix B. The response levels are shown for one third octave center frequencies between 200 hertz and 4000 hertz and overall dBA and dB linear levels. Speech signals were input into the device at a level which produced 85 dB linear weighting as measured by HATS. The attenuator level also was used to reproduce speech for the 85 dB and reduced by 10 dB for the 95 dB presentation levels.

Results of the speech intelligibility evaluation conditions are shown in Tables 15 and 16. Standard deviations are larger as the mean value decreases indicating the uncertainty of the listener's understanding of the PB words. As the mean SI level decreases, the difference between 85 and 95 dB speech level increases indicating the levels are not asymptotic to the 100 percent SI level. The sound attenuation test results from the first subject for the CB mask condition indicated a potential noise safety hazard existed when the subject did not have the additional protection provided by the insert protector. The interface between the subject's head and the

HGU-56/P helmet earseal was greatly compromised by the CB mask. A decision was made to reduce the sound field noise by 10 dB for all SI test conditions which did not utilize an insert protector. This creates a problem in analyzing the data because of the two different treatments of the ambient noise used in the SI evaluation. The ANR and HGU-56/P worn with CB mask are given a 10 dB noise advantage over E-A-R and CEP. However, an ANOVA was completed without considering the change in ambient noise level. The implication is that if there are significant differences in the results between the insert devices and the circumaural devices, then differences would be even greater if measurements were made at the same noise level. The speech reception threshold (attenuator settings) of the CRDA test devices are shown in Table 16. These tests are an indication of the fit and consistency of the speech signals presented to the listener.

Table 15.
Speech intelligibility of the CRDA devices worn alone, with CB mask, and with spectacles.

Mfg.	Level	% Correct Mean	% Correct S.D.	Level	% Correct Mean	% Correct S.D.
Alone						
Bose	**85**	93	3.6	**95**	97	4.1
CEP	**85**	89	7.6	**95**	95	3.4
E-A-R	**85**	72	14.4	**95**	86	9.1
Gentex	**85**	88	8.2	**95**	95	4.1
Grumman	**85**	83	17.5	**95**	90	10.3
HGU-56	**85**	57	15.2	**95**	85	9.1
CB mask (* Ambient noise decreased 10 dB)						
Bose	* **85**	75	23.3	**95**	88	14.7
CEP	**85**	84	12.1	**95**	96	3.8
E-A-R	**85**	48	12.6	**95**	78	6.4
Gentex	* **85**	73	23.0	**95**	86	13.6
Grumman	* **85**	71	27.5	**95**	82	21.8
HGU-56	* **85**	39	24.4	**95**	68	24.4
Spectacles						
Bose	**85**	87	10.0	**95**	97	2.6
CEP	**85**	89	5.4	**95**	95	4.1
E-A-R	**85**	67	14.2	**95**	84	10.1
Gentex	**85**	82	10.3	**95**	91	4.9
Grumman	**85**	72	15.7	**95**	86	10.9
HGU-56	**85**	38	20.7	**95**	74	14.5

Table 16.
Speech reception threshold (attenuator setting) of the CRDA test devices worn alone, with CB mask, and spectacles.

Mfg.	Ancillary	Level	Avg SRT	Min	Max	Level	Avg SRT	Min	Max
Bose	1	**85**	64	58	69	**95**	65	59	70
CEP	1	**85**	56	42	68	**95**	58	45	94
E-A-R	1	**85**	38	26	45	**95**	37	23	46
Gentex	1	**85**	64	57	96	**95**	65	59	72
Grumman	1	**85**	60	45	68	**95**	59	41	70
HGU-56	1	**85**	48	41	78	**95**	48	36	58
Bose	*2	**85**	60	46	72	**95**	59	42	69
CEP	2	**85**	52	45	62	**95**	53	42	63
E-A-R	2	**85**	31	23	38	**95**	32	22	40
Gentex	*2	**85**	57	0	66	**95**	56	38	67
Grumman	*2	**85**	55	42	64	**95**	54	35	66
HGU-56	*2	**85**	46	32	64	**95**	46	31	63
Bose	3	**85**	62	54	68	**95**	63	57	68
CEP	3	**85**	56	45	67	**95**	56	45	66
E-A-R	3	**85**	35	22	50	**95**	36	25	46
Gentex	3	**85**	60	52	68	**95**	61	51	68
Grumman	3	**85**	54	43	65	**95**	54	40	67
HGU-56	3	**85**	46	38	54	**95**	48	39	58

Ancillary: 1=Alone
2=CB mask * Noise reduced 10 dB
3=Spectacles

The results of the SI with ANOVA are shown in Table 17. Independent variables were ancillary device and helmet/protective type with the SI score being the dependent variable. All main effects, ancillary (F=28.0, d.f.=2/625, p<0.001) and helmet/protective type (F=56.7, d.f.=1/625, p<0.001) indicate significant differences. The ancillary helmet/protective type (F=1.7, d.f.=10,625, p<.07) interactions indicate differences are not significant. The mean SI values shown in Table 17 are arrayed in descending order for the ancillary conditions. The mean differences which are determined to be significant using Tukey's honestly significant difference procedure are shown with letters to indicate their relationship with the other mean values for a similar condition.

Table 17.
Devices shown in descending order of mean SI for combined speech.
(Significant differences are shown using letters to indicate
the various mean levels.)

Alone			Spectacles			CB mask		
Bose	94.7	a	CEP	92.2	a	CEP	90.1	a
CEP	92.0	a b	Bose	91.8	a	Bose	81.6	a b
Gentex	91.3	a b	Gentex	87.0	a b	Gentex	79.7	a b
Grumman	86.8	a b	Grumman	79.5	a b	Grumman	76.3	b c
E-A-R	78.9	b c	E-A-R	75.2	b	E-A-R	62.9	c d
HGU-56/P	71.1	c	HGU-56/P	55.8	c	HGU-56/P	53.6	d

In order to overcome the differences in ambient noise levels used in the CB mask conditions, the data also were compared using 95 dB speech level for the CEP and the E-A-R conditions, and 85 dB speech level for the ANR and HGU-56/P conditions. This comparison places the systems on a more equal basis when considering the speech signal-to-noise ratio. Table 18 shows this comparison which indicates there are significant differences in the CEP and the circumaural devices. In this case, even the E-A-R performs as well as the ANR systems.

Table 18.
Devices shown in descending order of mean SI for the CB mask condition
using 95 dB speech level for CEP and EAR, and 85 dB speech
level for the remaining conditions. (Significant differences
are shown using letters to indicate the various mean levels.)

CB mask		
CEP(95)	95.8	a
E-A-R(95)	78.0	a b
Bose(85)	75.2	b
Gentex(85)	72.9	b
Grumman(85)	70.7	b
HGU-56/P(85)	39.4	c

Conclusions

The results of this study show that ANR and CEP are techniques which enhance hearing protection and voice communications for the aviator. The study also shows there are effects on performance of the ANR and HGU-56/P helmets when worn in combination with spectacles or CB mask. The CB mask, in particular, degrades the performance and protective characteristics of the circumaural devices to a point of rendering them inadequate for Army noise environments. Other considerations for use of these techniques in the U.S. Army are weight, aircraft modification, cost, lateral impact protection, impulse noise attenuation, donning, and others.

There are obvious differences in the two techniques to be considered when making a fielding decision. The areas relative to performance and safety become of primary importance. While user acceptance and cost are of secondary importance, they are critical to the decision process. Safety must be considered, not only for the auditory performance enhancements, but for other mechanical factors designed to protect the aviator during normal missions and during events which are unexpected and unplanned. Side impacts in the helicopter environment have been shown to produce significant head injuries during crashes and, in many cases, are preventable with energy-absorbing earcups (Shanahan, 1985).

The weight of the helmet is a significant factor for increased injury during a crash and adds to the burden supported by the aviator during flight. In recent years, the aviator's helmet has become a mounting platform for systems which integrate the aviator into the environment or into the weapon system. Night-vision goggles and heads-up-displays are becoming commonplace and enable the aviator to carry out mission requirements in a more efficient manner. However, the added head-supported mass of these systems becomes a significant contributor to the level of injury in case of mishap. Any weight reduction while maintaining performance of the helmet provides a significant advantage for weapon system developers, and techniques to reduce that burden must be explored.

Fielding considerations must include all aspects of how the user wears the helmet system and how various wearer configurations affect the performance of the system. For example, the ANR system typically is installed in a circumaural device, so the effects of equipment which compromise the earseal must be considered. CB protective hoods used by U.S. Army personnel are placed between the head and earseal and cause a significant loss in performance of the protective and communication characteristics of the helmet system. The effects of other ancillary equipment, such as spectacles, also are important to the issue of compromised earseal.

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Appendix A.

Photographs of devices under test

Photographs of the HGU-56/P

Figure A-1. Front

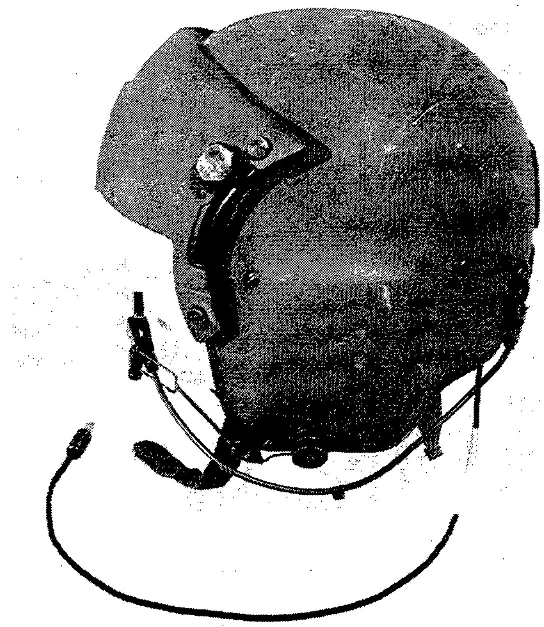

Figure A-2. Side

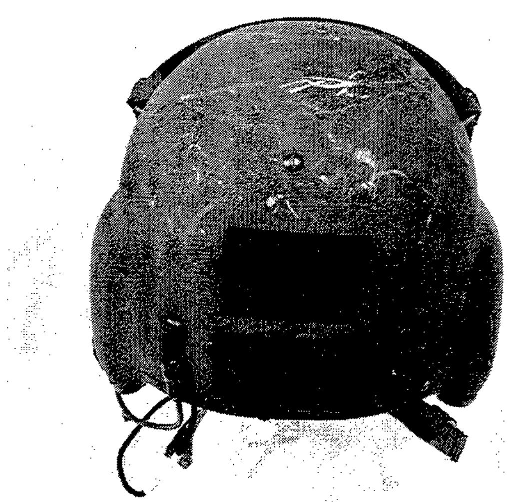

Figure A-3. Back

A-4. Earcup

Photographs of the Bose ANR system

Figure A-5. Front

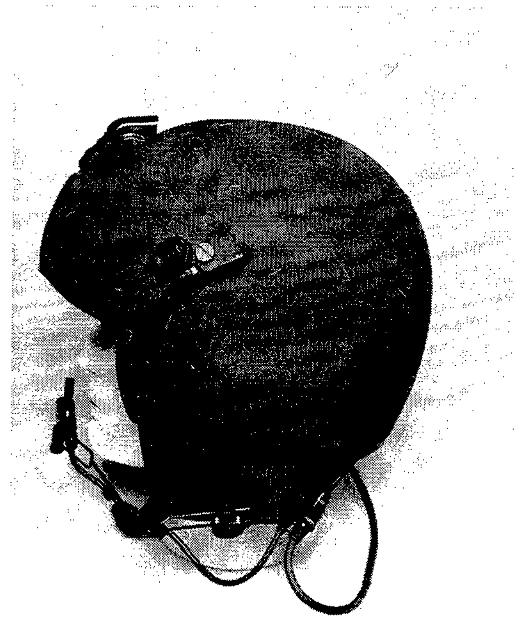

Figure A-6. Side

Figure A-7. Back

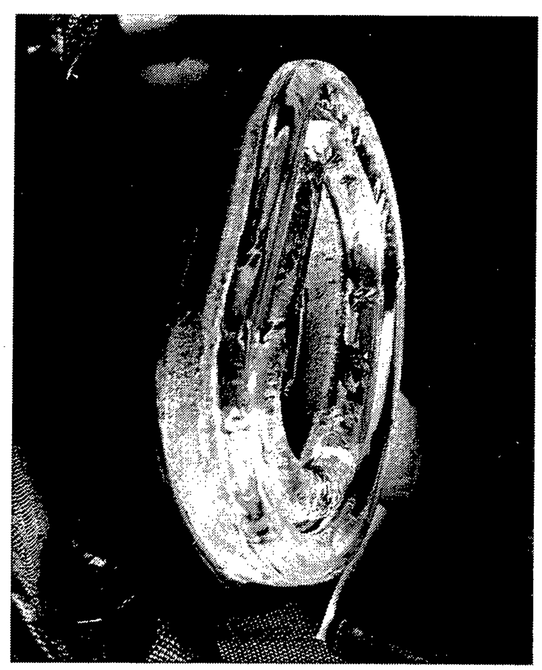

Figure A-8. Earcup

Photographs of the Grumman ANR system


Figure A-9. Front


Figure A-10. Side

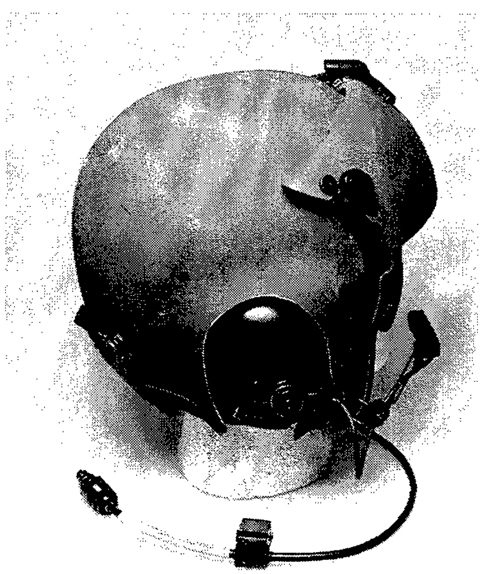
Figure A-11. Side w/ microphone

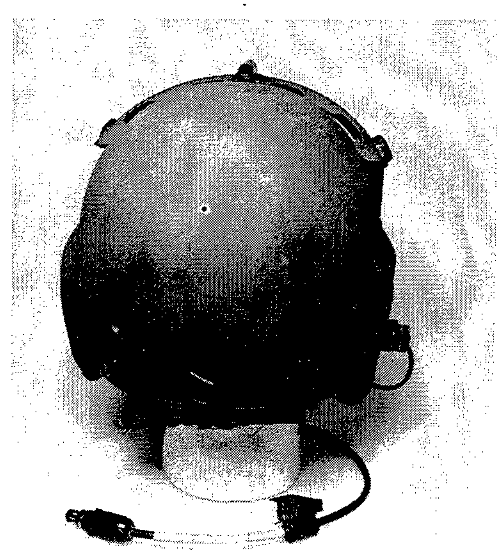
Figure A-12. Back

Photographs of the Grumman ANR system

Figure A-13. Front

Figure A-14. Side w/ microphone

Figure A-15. Back

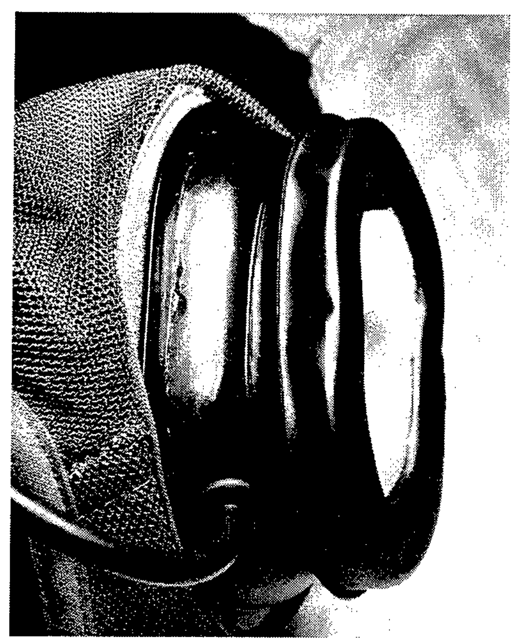

Figure A-16. Earcup

Photographs of the Gentex ANR system

Figure A-17. Front

Figure A-18. Side

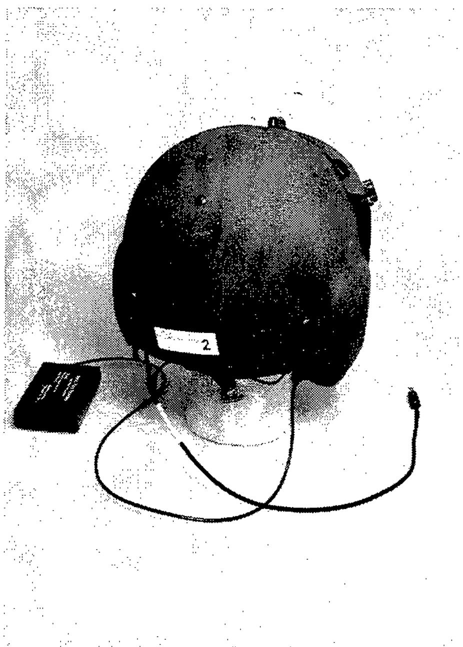

Figure A-19. Back

Figure A-20. Earcup

Photographs of the Communications Earplug system

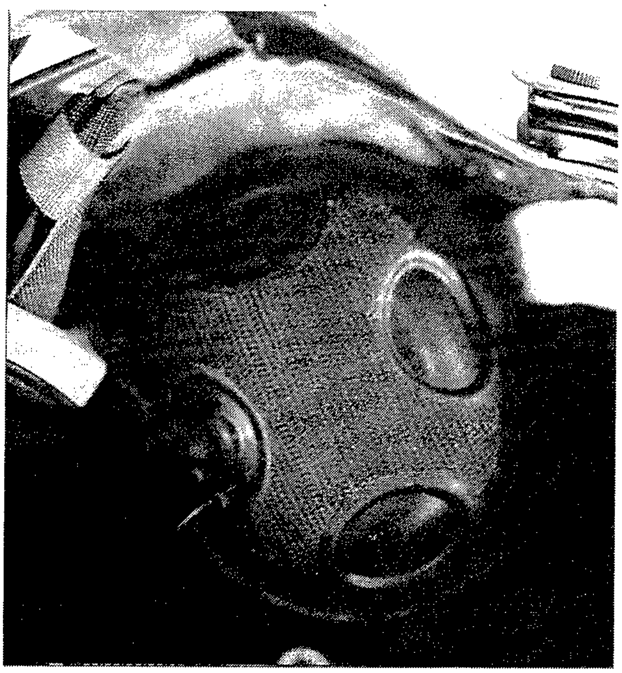
Figure A-21. Earcup


Figure A-22. Back

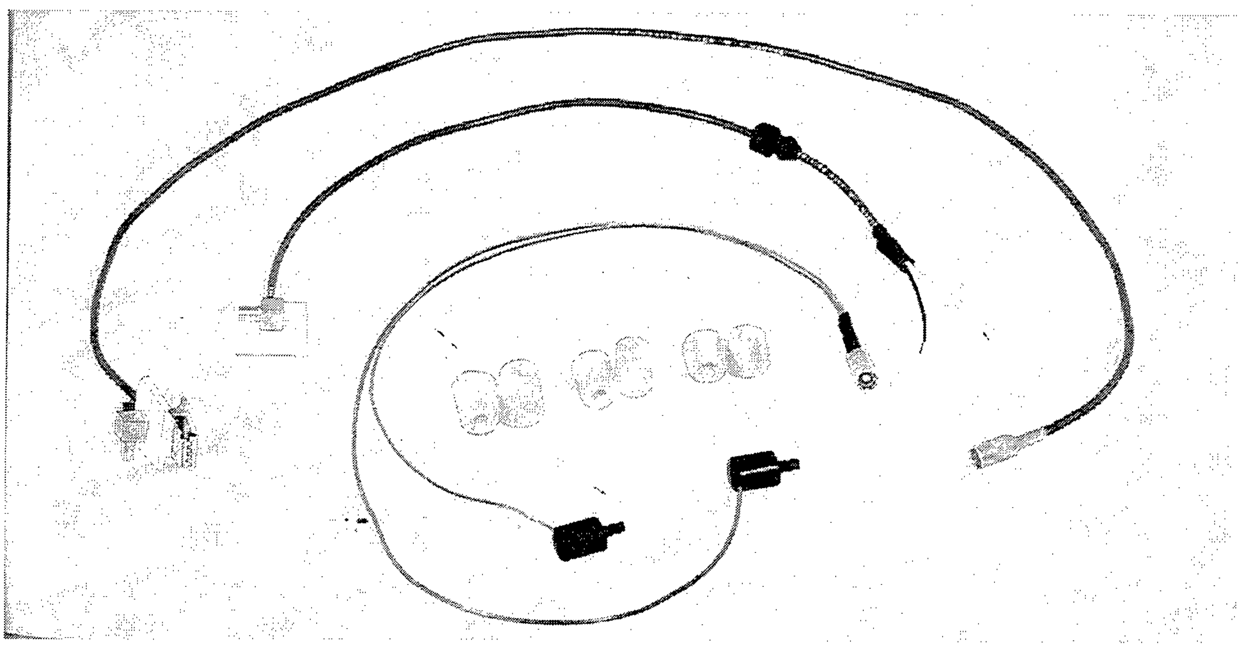
Figure A-23. CEP w/ interface cable and extension cable

Photographs of the HGU-56/P w/ ancillary devices

Figure A-24. Spectacles

Figure A-25. Helmet w /CB mask

Figure A-26. CB mask

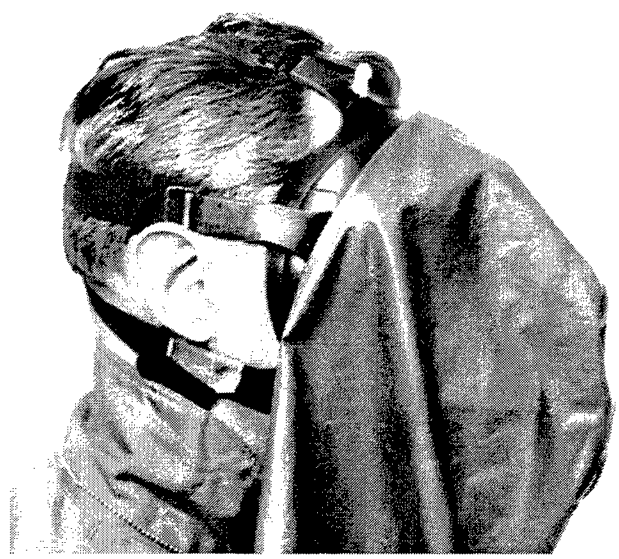

Figure A-27. CB mask harness

Appendix B.

Sensitivity responses that determine attenuator settings for 85 dB speech output levels for the CRDA devices.

Table B-1.

Sensitivity responses that determine attenuator settings for 85 dB speech output levels for the CRDA devices.

Mfg	Helmet	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	dBA	dBLin
Bose																	
	1	61.7	66.3	72.0	76.7	77.6	69.4	62.8	66.3	67.3	74.8	74.1	75.1	77.0	75.3	84	85
	1	62.2	66.7	72.3	76.9	77.7	69.4	63.2	67.0	68.1	75.0	73.2	73.9	75.0	74.8	84	85
	Mean	**62.0**	**66.5**	**72.2**	**76.8**	**77.7**	**69.4**	**63.0**	**66.7**	**67.7**	**74.9**	**73.7**	**74.5**	**76.0**	**75.1**	**84**	**85**
	2	62.2	66.7	72.3	77.0	77.7	69.2	63.4	66.9	67.8	75.2	74.4	74.4	78.0	77.8	85	86
	2	61.5	66.0	71.7	76.6	77.7	69.3	62.4	65.7	66.5	74.3	74.0	75.2	77.0	75.6	84	85
	Mean	**61.9**	**66.3**	**72.0**	**76.8**	**77.7**	**69.3**	**62.9**	**66.3**	**67.2**	**74.8**	**74.2**	**74.8**	**77.5**	**76.7**	**85**	**85**
	3	61.0	65.4	71.0	75.7	76.3	68.2	62.3	65.5	67.0	75.0	75.3	77.6	81.0	78.1	86	86
	3	60.7	65.1	70.6	75.3	76.1	67.9	61.9	65.3	66.9	75.4	75.1	76.3	78.0	76.4	85	85
	Mean	**60.9**	**65.3**	**70.8**	**75.5**	**76.2**	**68.1**	**62.1**	**65.4**	**67.0**	**75.2**	**75.2**	**76.9**	**79.5**	**77.3**	**86**	**86**
Gentex																	
	1	54.4	59.4	66.2	72.9	76.0	70.5	64.6	64.3	68.3	77.2	74.1	68.9	81.0	77.1	86	85
	1	54.0	58.7	65.2	72.3	75.5	71.3	65.6	65.2	69.9	77.1	73.7	68.0	78.0	74.9	84	84
	Mean	**54.2**	**59.1**	**65.7**	**72.6**	**75.8**	**70.9**	**65.1**	**64.8**	**69.1**	**77.2**	**73.9**	**68.5**	**79.5**	**76.0**	**85**	**85**
	2	53.6	58.4	65.3	72.6	76.5	72.4	63.6	61.5	65.2	76.0	68.9	65.3	80.0	77.4	85	85
	2	54.5	60.0	67.4	74.4	77.9	72.1	62.5	66.1	72.6	78.2	73.4	68.2	79.0	74.4	85	85
	Mean	**54.1**	**59.2**	**66.3**	**73.5**	**77.2**	**72.3**	**63.1**	**63.8**	**68.9**	**77.1**	**71.2**	**66.8**	**79.5**	**75.9**	**85**	**85**
	3	54.4	60.2	67.6	75.3	79.6	76.4	64.2	64.9	70.6	76.1	73.4	70.0	82.0	76.9	87	87
	3	53.7	58.5	65.0	71.3	74.6	69.9	65.6	65.9	69.9	76.2	72.4	67.3	79.0	75.2	84	84
	Mean	**54.1**	**59.4**	**66.3**	**73.3**	**77.1**	**73.2**	**64.9**	**65.4**	**70.3**	**76.2**	**72.9**	**68.7**	**80.5**	**76.1**	**86**	**85**

Table B-1 (Continued).

Mfg	Helmet	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	dBA	dBLin
Grumman																	
	1	71.4	73.1	76.6	79.1	79.5	71.8	65.0	65.1	64.5	71.6	68.7	65.9	67.0	61.8	81	86
	1	71.2	73.1	76.6	79.5	79.9	72.2	65.5	65.6	65.3	73.3	71.5	67.6	70.0	66.6	82	86
	Mean	**71.3**	**73.1**	**76.6**	**79.3**	**79.7**	**72.0**	**65.3**	**65.3**	**64.9**	**72.4**	**70.1**	**66.8**	**68.5**	**64.2**	**82**	**86**
	2	70.1	72.2	75.6	78.6	78.8	71.3	65.0	65.6	65.5	71.8	68.7	66.0	69.0	67.6	81	85
	2	69.3	71.4	75.0	77.9	78.3	70.7	64.5	65.0	65.2	72.9	70.9	67.0	70.0	65.2	81	85
	Mean	**69.7**	**71.8**	**75.3**	**78.3**	**78.6**	**71.0**	**64.8**	**65.3**	**65.3**	**72.3**	**69.8**	**66.5**	**69.5**	**66.4**	**81**	**85**
	3	73.4	75.3	78.8	81.2	81.4	73.4	66.7	66.8	66.1	72.4	70.2	67.1	69.0	65.5	83	87
	3	68.8	70.5	74.0	76.4	76.6	69.0	62.6	62.8	62.2	68.3	67.4	66.4	69.0	64.8	79	83
	Mean	**71.1**	**72.9**	**76.4**	**78.8**	**79.0**	**71.2**	**64.7**	**64.8**	**64.2**	**70.3**	**68.8**	**66.8**	**69.0**	**65.2**	**81**	**85**
HGU-56/P																	
	1	64.2	67.5	71.8	74.3	74.1	65.1	57.3	55.6	57.3	68.2	71.6	71.4	82.0	78.7	86	85
	1	63.9	67.2	71.4	74.1	74.0	64.8	54.6	53.6	60.0	72.2	69.6	70.6	80.0	79.8	85	85
	Mean	**64.1**	**67.3**	**71.6**	**74.2**	**74.1**	**64.9**	**56.0**	**54.6**	**58.7**	**70.2**	**70.6**	**71.0**	**81.0**	**79.3**	**86**	**85**
	2	64.9	67.8	71.9	74.9	75.0	66.9	58.9	56.0	55.3	67.9	66.7	62.9	79.0	79.1	84	84
	2	64.9	68.3	72.5	75.6	75.6	66.8	56.9	53.2	57.7	68.8	67.2	67.8	80.0	80.3	85	85
	Mean	**64.9**	**68.1**	**72.2**	**75.3**	**75.3**	**66.8**	**57.9**	**54.6**	**56.5**	**68.3**	**67.0**	**65.3**	**79.5**	**79.7**	**85**	**85**
	3	63.0	65.6	70.0	72.9	72.8	64.1	56.6	55.0	57.8	68.8	68.9	66.0	82.0	80.1	85	85
	3	62.6	65.9	70.4	73.4	73.4	64.7	55.0	50.7	53.0	63.6	66.6	69.9	81.0	81.1	85	85
	Mean	**62.8**	**65.8**	**70.2**	**73.2**	**73.1**	**64.4**	**55.8**	**52.9**	**55.4**	**66.2**	**67.8**	**68.0**	**81.5**	**80.6**	**85**	**85**
CEP																	
	3	70.2	72.7	76.6	79.3	79.2	70.0	63.1	64.0	62.9	70.0	70.6	69.5	68.0	70.0	82	85
	3	70.3	73.0	77.0	80.0	80.3	72.0	64.2	64.4	63.9	71.1	71.4	69.2	68.0	69.7	82	86
	Mean	**70.3**	**72.8**	**76.8**	**79.7**	**79.8**	**71.0**	**63.7**	**64.2**	**63.4**	**70.6**	**71.0**	**69.3**	**68.0**	**69.8**	**82**	**86**

Appendix C.

Estimates of the effective exposure level in dBA of the CRDA test devices for Army noise environments.

Table C-1.
Estimates of the effective exposure level in dBA of the CRDA test devices for Army noise environments.

Aircraft	125	250	500	1000	2000	4000	8000	EEL
CH-47C helicopter								
				Between pilots 100 KT CRS 245 rotor RPM				
Alone								
Bose ANR on	63.7	66.1	60.2	65.6	69.3	52.3	39.1	**73.6**
Gentex ANR on	60.2	62.1	63.8	61.6	80.7	55.1	41.7	**81.0**
Grumman ANR on	66.3	65.6	69.8	70.2	78.9	56.7	53.1	**80.5**
HGU-56/P	74.7	72.8	78.4	68.1	74.1	55.7	50.2	**82.0**
CB mask								
Bose ANR on	82.3	79.4	79.0	82.4	89.6	67.3	56.2	**92.1**
Gentex ANR on	85.9	81.5	82.0	81.9	93.4	68.7	57.3	**95.2**
Grumman ANR on	85.1	81.7	85.3	87.9	91.5	66.9	57.4	**95.2**
HGU-56/P	87.6	82.9	91.2	81.2	91.1	68.9	59.3	**96.1**
Spectacles								
Bose ANR on	67.0	68.0	63.6	67.0	72.8	58.7	43.2	**76.6**
Gentex ANR on	69.3	65.0	69.1	64.4	84.2	61.6	51.3	**84.7**
Grumman ANR on	73.6	69.3	74.5	73.6	83.6	63.3	59.8	**85.3**
HGU-56/P	81.8	75.9	83.2	70.0	76.2	59.4	59.1	**86.7**

Table C-1 (Continued).

Aircraft	125	250	500	1000	2000	4000	8000	EEL
CH-47C								
				Station 482				
				100 KT CRS 245 rotor RPM				
Alone								
Bose ANR on	67.7	72.1	66.2	73.6	71.3	66.3	53.1	**78.9**
Gentex ANR on	64.2	68.1	69.8	69.6	82.7	69.1	55.7	**83.6**
Grumman ANR on	70.3	71.6	75.8	78.2	80.9	70.7	67.1	**84.7**
HGU-56/P	78.7	78.8	84.4	76.1	76.1	69.7	64.2	**87.4**
CB mask								
Bose ANR on	86.3	85.4	85.0	90.4	91.6	81.3	70.2	**96.5**
Gentex ANR on	89.9	87.5	88.0	89.9	95.4	82.7	71.3	**98.8**
Grumman ANR on	89.1	87.7	91.3	95.9	93.5	80.9	71.4	**100.2**
HGU-56/P	91.6	88.9	97.2	89.2	93.1	82.9	73.3	**100.8**
Spectacles								
Bose ANR on	71.0	74.0	69.6	75.0	74.8	72.7	57.2	**81.9**
Gentex ANR on	73.3	71.0	75.1	72.4	86.2	75.6	65.3	**87.6**
Grumman ANR on	77.6	75.3	80.5	81.6	85.6	77.3	73.8	**89.4**
HGU-56/P	85.8	81.9	89.2	78.0	78.2	73.4	73.1	**92.0**

Table C-1 (Continued).

Aircraft	125	250	500	1000	2000	4000	8000	EEL
CH-47D								
				AFT cabin 90 knot cruise				
Alone								
Bose ANR on	69.7	67.1	66.2	72.6	63.3	59.3	52.1	**76.7**
Gentex ANR on	66.2	63.1	69.8	68.6	74.7	62.1	54.7	**77.6**
Grumman ANR on	72.3	66.6	75.8	77.2	72.9	63.7	66.1	**81.9**
HGU-56/P	80.7	73.8	84.4	75.1	68.1	62.7	63.2	**86.8**
CB mask								
Bose ANR on	88.3	80.4	85.0	89.4	83.6	74.3	69.2	**94.2**
Gentex ANR on	91.9	82.5	88.0	88.9	87.4	75.7	70.3	**96.3**
Grumman ANR on	91.1	82.7	91.3	94.9	85.5	73.9	70.4	**98.6**
HGU-56/P	93.6	83.9	97.2	88.2	85.1	75.9	72.3	**99.8**
Spectacles								
Bose ANR on	73.0	69.0	69.6	74.0	66.8	65.7	56.2	**79.4**
Gentex ANR on	75.3	66.0	75.1	71.4	78.2	68.6	64.3	**82.5**
Grumman ANR on	79.6	70.3	80.5	80.6	77.6	70.3	72.8	**86.7**
HGU-56/P	87.8	76.9	89.2	77.0	70.2	66.4	72.1	**92.0**

Table C-1 (Continued).

Aircraft	125	250	500	1000	2000	4000	8000	EEL
CH-47D								
				Left cockpit seat 90 knot cruise				
Alone								
Bose ANR on	57.7	59.1	53.2	59.6	57.3	55.3	34.1	**66.0**
Gentex ANR on	54.2	55.1	56.8	55.6	68.7	58.1	36.7	**69.9**
Grumman ANR on	60.3	58.6	62.8	64.2	66.9	59.7	48.1	**71.3**
HGU-56/P	68.7	65.8	71.4	62.1	62.1	58.7	45.2	**74.8**
CB mask								
Bose ANR on	76.3	72.4	72.0	76.4	77.6	70.3	51.2	**83.6**
Gentex ANR on	79.9	74.5	75.0	75.9	81.4	71.7	52.3	**86.0**
Grumman ANR on	79.1	74.7	78.3	81.9	79.5	69.9	52.4	**87.0**
HGU-56/P	81.6	75.9	84.2	75.2	79.1	71.9	54.3	**88.2**
Spectacles								
Bose ANR on	61.0	61.0	56.6	61.0	60.8	61.7	38.2	**69.2**
Gentex ANR on	63.3	58.0	62.1	58.4	72.2	64.6	46.3	**74.3**
Grumman ANR on	67.6	62.3	67.5	67.6	71.6	66.3	54.8	**76.3**
HGU-56/P	75.8	68.9	76.2	64.0	64.2	62.4	54.1	**79.9**

Table C-1 (Continued).

Aircraft	125	250	500	1000	2000	4000	8000	EEL
MH-53E (ambient noise-nonattenuated)								
				MK-103 TOW				
				Pilot				
Alone								
Bose ANR on	69.7	64.1	59.2	59.1	45.5	30.3	10.1	**71.6**
Gentex ANR on	66.2	60.1	62.8	55.1	56.9	33.1	12.7	**69.2**
Grumman ANR on	72.3	63.6	68.8	63.7	55.1	34.7	24.1	**75.1**
HGU-56/P	80.7	70.8	77.4	61.6	50.3	33.7	21.2	**82.8**
CB mask								
Bose ANR on	88.3	77.4	78.0	75.9	65.8	45.3	27.2	**89.6**
Gentex ANR on	91.9	79.5	81.0	75.4	69.6	46.7	28.3	**92.7**
Grumman ANR on	91.1	79.7	84.3	81.4	67.7	44.9	28.4	**92.9**
HGU-56/P	93.6	80.9	90.2	74.7	67.3	46.9	30.3	**95.7**
Spectacles								
Bose ANR on	73.0	66.0	62.6	60.5	49.0	36.7	14.2	**74.5**
Gentex ANR on	75.3	63.0	68.1	57.9	60.4	39.6	22.3	**76.6**
Grumman ANR on	79.6	67.3	73.5	67.1	59.8	41.3	30.8	**81.2**
HGU-56/P	87.8	73.9	82.2	63.5	52.4	37.4	30.1	**89.0**
				STBD ramp				
Alone								
Bose ANR on	82.2	82.6	80.8	76.1	63.5	47.8	35.8	**87.4**
Gentex ANR on	78.7	78.6	84.4	72.1	74.9	50.6	38.4	**87.0**
Grumman ANR on	84.8	82.1	90.4	80.7	73.1	52.2	49.8	**92.5**
HGU-56/P	93.2	89.3	99.0	78.6	68.3	51.2	46.9	**100.5**
CB mask								
Bose ANR on	100.8	95.9	99.6	92.9	83.8	62.8	52.9	**104.9**
Gentex ANR on	104.4	98.0	102.6	92.4	87.6	64.2	54.0	**107.7**
Grumman ANR on	103.6	98.2	105.9	98.4	85.7	62.4	54.1	**109.2**
HGU-56/P	106.1	99.4	111.8	91.7	85.3	64.4	56.0	**113.3**
Spectacles								
Bose ANR on	85.5	84.5	84.2	77.5	67.0	54.2	39.9	**90.2**
Gentex ANR on	87.8	81.5	89.7	74.9	78.4	57.1	48.0	**92.7**
Grumman ANR on	92.1	85.8	95.1	84.1	77.8	58.8	56.5	**97.7**
HGU-56/P	100.3	92.4	103.8	80.5	70.4	54.9	55.8	**105.7**

Table C-1 (Continued).

Aircraft	125	250	500	1000	2000	4000	8000	EEL
OH-58D								
	Inside cockpit between crewmembers-doors off 80 KT IN							
Alone								
Bose ANR on	63.7	59.3	56.4	55.0	48.8	33.6	24.0	**66.4**
Gentex ANR on	60.2	55.3	60.0	51.0	60.2	36.4	26.6	**65.8**
Grumman ANR on	66.3	58.8	66.0	59.6	58.4	38.0	38.0	**70.7**
HGU-56/P	74.7	66.0	74.6	57.5	53.6	37.0	35.1	**78.1**
CB mask								
Bose ANR on	82.3	72.6	75.2	71.8	69.1	48.6	41.1	**84.4**
Gentex ANR on	85.9	74.7	78.2	71.3	72.9	50.0	42.2	**87.4**
Grumman ANR on	85.1	74.9	81.5	77.3	71.0	48.2	42.3	**88.0**
HGU-56/P	87.6	76.1	87.4	70.6	70.6	50.2	44.2	**91.0**
Spectacles								
Bose ANR on	67.0	61.2	59.8	56.4	52.3	40.0	28.1	**69.3**
Gentex ANR on	69.3	58.2	65.3	53.8	63.7	42.9	36.2	**72.1**
Grumman ANR on	73.6	62.5	70.7	63.0	63.1	44.6	44.7	**76.4**
HGU-56/P	81.8	69.1	79.4	59.4	55.7	40.7	44.0	**84.0**
	60 KT IN							
Alone								
Bose ANR on	60.6	57.6	54.6	54.0	47.1	32.5	22.9	**64.0**
Gentex ANR on	57.1	53.6	58.2	50.0	58.5	35.3	25.5	**63.7**
Grumman ANR on	63.2	57.1	64.2	58.6	56.7	36.9	36.9	**68.5**
HGU-56/P	71.6	64.3	72.8	56.5	51.9	35.9	34.0	**75.8**
CB mask								
Bose ANR on	79.2	70.9	73.4	70.8	67.4	47.5	40.0	**81.9**
Gentex ANR on	82.8	73.0	76.4	70.3	71.2	48.9	41.1	**84.8**
Grumman ANR on	82.0	73.2	79.7	76.3	69.3	47.1	41.2	**85.6**
HGU-56/P	84.5	74.4	85.6	69.6	68.9	49.1	43.1	**88.7**
Spectacles								
Bose ANR on	63.9	59.5	58.0	55.4	50.6	38.9	27.0	**66.8**
Gentex ANR on	66.2	56.5	63.5	52.8	62.0	41.8	35.1	**69.7**
Grumman ANR on	70.5	60.8	68.9	62.0	61.4	43.5	43.6	**74.0**
HGU-56/P	78.7	67.4	77.6	58.4	54.0	39.6	42.9	**81.5**

Table C-1 (Continued).

Aircraft	125	250	500	1000	2000	4000	8000	EEL
UH-60A Black Hawk								
				Left rear				
				120 KT CRS doors closed				
ALONE								
Bose ANR on	57.7	61.1	55.2	56.6	52.3	41.3	30.1	**65.0**
Gentex ANR on	54.2	57.1	58.8	52.6	63.7	44.1	32.7	**66.4**
Grumman ANR on	60.3	60.6	64.8	61.2	61.9	45.7	44.1	**69.5**
HGU-56/P	68.7	67.8	73.4	59.1	57.1	44.7	41.2	**75.8**
CB mask								
Bose ANR on	76.3	74.4	74.0	73.4	72.6	56.3	47.2	**82.1**
Gentex ANR on	79.9	76.5	77.0	72.9	76.4	57.7	48.3	**84.6**
Grumman ANR on	79.1	76.7	80.3	78.9	74.5	55.9	48.4	**85.9**
HGU-56/P	81.6	77.9	86.2	72.2	74.1	57.9	50.3	**88.5**
Spectacles								
Bose ANR on	61.0	63.0	58.6	58.0	55.8	47.7	34.2	**67.6**
Gentex ANR on	63.3	60.0	64.1	55.4	67.2	50.6	42.3	**71.0**
Grumman ANR on	67.6	64.3	69.5	64.6	66.6	52.3	50.8	**74.4**
HGU-56/P	75.8	70.9	78.2	61.0	59.2	48.4	50.1	**80.8**
				120KT CRS doors open				
Alone								
Bose ANR on	72.7	69.1	66.2	63.6	56.3	44.3	40.1	**75.6**
Gentex ANR on	69.2	65.1	69.8	59.6	67.7	47.1	42.7	**74.7**
Grumman ANR on	75.3	68.6	75.8	68.2	65.9	48.7	54.1	**79.9**
HGU-56/P	83.7	75.8	84.4	66.1	61.1	47.7	51.2	**87.5**
CB mask								
Bose ANR on	91.3	82.4	85.0	80.4	76.6	59.3	57.2	**93.5**
Gentex ANR on	94.9	84.5	88.0	79.9	80.4	60.7	58.3	**96.5**
Grumman ANR on	94.1	84.7	91.3	85.9	78.5	58.9	58.4	**97.2**
HGU-56/P	96.6	85.9	97.2	79.2	78.1	60.9	60.3	**100.4**
Spectacles								
Bose ANR on	76.0	71.0	69.6	65.0	59.8	50.7	44.2	**78.5**
Gentex ANR on	78.3	68.0	75.1	62.4	71.2	53.6	52.3	**81.1**
Grumman ANR on	82.6	72.3	80.5	71.6	70.6	55.3	60.8	**85.6**
HGU-56/P	90.8	78.9	89.2	68.0	63.2	51.4	60.1	**93.3**

Table C-1 (Continued).

Aircraft	125	250	500	1000	2000	4000	8000	EEL
UH-60A Black Hawk								
				Pilot				
				120 KT CRS doors closed				
Alone								
Bose ANR on	64.7	63.1	67.2	56.6	49.3	38.3	35.1	**70.6**
Gentex ANR on	61.2	59.1	70.8	52.6	60.7	41.1	37.7	**72.1**
Grumman ANR on	67.3	62.6	76.8	61.2	58.9	42.7	49.1	**77.7**
HGU-56/P	75.7	69.8	85.4	59.1	54.1	41.7	46.2	**86.0**
CB mask								
Bose ANR on	83.3	76.4	86.0	73.4	69.6	53.3	52.2	**88.8**
Gentex ANR on	86.9	78.5	89.0	72.9	73.4	54.7	53.3	**91.7**
Grumman ANR on	86.1	78.7	92.3	78.9	71.5	52.9	53.4	**93.9**
HGU-56/P	88.6	79.9	98.2	72.2	71.1	54.9	55.3	**98.8**
Spectacles								
Bose ANR on	68.0	65.0	70.6	58.0	52.8	44.7	39.2	**73.6**
Gentex ANR on	70.3	62.0	76.1	55.4	64.2	47.6	47.3	**77.6**
Grumman ANR on	74.6	66.3	81.5	64.6	63.6	49.3	55.8	**82.7**
HGU-56/P	82.8	72.9	90.2	61.0	56.2	45.4	55.1	**91.0**
				120KT CRS doors open				
Alone								
Bose ANR on	70.7	69.1	72.2	59.6	52.3	40.3	40.1	**76.0**
Gentex ANR on	67.2	65.1	75.8	55.6	63.7	43.1	42.7	**77.1**
Grumman ANR on	73.3	68.6	81.8	64.2	61.9	44.7	54.1	**82.8**
HGU-56/P	81.7	75.8	90.4	62.1	57.1	43.7	51.2	**91.1**
CB mask								
Bose ANR on	89.3	82.4	91.0	76.4	72.6	55.3	57.2	**94.2**
Gentex ANR on	92.9	84.5	94.0	75.9	76.4	56.7	58.3	**97.1**
Grumman ANR on	92.1	84.7	97.3	81.9	74.5	54.9	58.4	**99.0**
HGU-56/P	94.6	85.9	103.2	75.2	74.1	56.9	60.3	**104.0**
Spectacles								
Bose ANR on	74.0	71.0	75.6	61.0	55.8	46.7	44.2	**79.0**
Gentex ANR on	76.3	68.0	81.1	58.4	67.2	49.6	52.3	**82.8**
Grumman ANR on	80.6	72.3	86.5	67.6	66.6	51.3	60.8	**87.9**
HGU-56/P	88.8	78.9	95.2	64.0	59.2	47.4	60.1	**96.2**

Table C-2.
Estimates of the effective exposure level in dBA of the CRDA test devices for Army noise environments.

Aircraft	125	250	500	1000	2000	4000	8000	EEL
CH-47C								
	Between pilots 100 KT CRS 245 rotor RPM							
Alone								
CEP	55.8	65.4	62.8	69.4	69.1	44.4	34.4	**75.2**
E-A-R	55.0	62.0	60.2	68.7	68.6	45.6	34.0	**73.2**
HGU56	69.2	76.7	75.8	76.1	81.4	59.4	44.5	**85.3**
CB mask								
CEP	58.3	66.4	64.8	68.2	68.9	42.9	31.4	**75.8**
E-A-R	58.0	65.2	62.5	69.3	69.6	42.2	31.0	**75.5**
HGU56	75.8	81.9	81.2	82.7	83.6	64.1	54.6	**90.3**
Spectacles								
CEP	59.4	65.3	60.6	70.2	69.8	47.7	34.2	**75.7**
E-A-R	60.5	66.2	63.1	69.0	70.1	46.3	35.8	**75.8**
HGU56	74.3	78.8	76.6	76.0	83.3	62.3	60.5	**87.1**
	Station 482 100 KT CRS 245 rotor RPM							
Alone								
CEP	59.8	71.4	68.8	77.4	71.1	58.4	48.4	**81.2**
E-A-R	59.0	68.0	66.2	76.7	70.6	59.6	48.0	**79.2**
HGU56	73.2	82.7	81.8	84.1	83.4	73.4	58.5	**90.5**
CB mask								
CEP	62.3	72.4	70.8	76.2	70.9	56.9	45.4	**81.5**
E-A-R	62.0	71.2	68.5	77.3	71.6	56.2	45.0	**81.2**
HGU56	79.8	87.9	87.2	90.7	85.6	78.1	68.6	**96.2**
Spectacles								
CEP	63.4	71.3	66.6	78.2	71.8	61.7	48.2	**81.7**
E-A-R	64.5	72.2	69.1	77.0	72.1	60.3	49.8	**81.5**
HGU56	78.3	84.8	82.6	84.0	85.3	76.3	74.5	**92.1**

Table C-2 (Continued).

Aircraft	125	250	500	1000	2000	4000	8000	EEL
CH-47D								
				Aft cabin 90 knot cruise				
Alone								
CEP	61.8	71.4	63.8	76.4	63.1	51.4	47.4	**79.6**
E-A-R	61.0	68.0	61.2	75.7	62.6	52.6	47.0	**77.5**
HGU56	75.2	82.7	76.8	83.1	75.4	66.4	57.5	**88.2**
CB mask								
CEP	64.3	72.4	65.8	75.2	62.9	49.9	44.4	**79.4**
E-A-R	64.0	71.2	63.5	76.3	63.6	49.2	44.0	**79.4**
HGU56	81.8	87.9	82.2	89.7	77.6	71.1	67.6	**94.5**
Spectacles								
CEP	65.4	71.3	61.6	77.2	63.8	54.7	47.2	**80.3**
E-A-R	66.5	72.2	64.1	76.0	64.1	53.3	48.8	**80.0**
HGU56	80.3	84.8	77.6	83.0	77.3	69.3	73.5	**90.0**
				Left cockpit seat 90 knot cruise				
Alone								
CEP	49.8	58.4	55.8	63.4	57.1	47.4	29.4	**67.7**
E-A-R	49.0	55.0	53.2	62.7	56.6	48.6	29.0	**65.6**
HGU56	63.2	69.7	68.8	70.1	69.4	62.4	39.5	**77.1**
CB mask								
CEP	52.3	59.4	57.8	62.2	56.9	45.9	26.4	**68.1**
E-A-R	52.0	58.2	55.5	63.3	57.6	45.2	26.0	**67.8**
HGU56	69.8	74.9	74.2	76.7	71.6	67.1	49.6	**82.9**
Spectacles								
CEP	53.4	58.3	53.6	64.2	57.8	50.7	29.2	**68.3**
E-A-R	54.5	59.2	56.1	63.0	58.1	49.3	30.8	**68.3**
HGU56	68.3	71.8	69.6	70.0	71.3	65.3	55.5	**78.9**

Table C-2 (Continued).

Aircraft	125	250	500	1000	2000	4000	8000	EEL
MH-53E (ambient noise-nonattenuated)								
				MK-103 TOW				
				Pilot				
Alone								
CEP	61.8	64.4	60.8	62.9	45.3	22.4	5.4	**70.3**
E-A-R	61.0	61.0	58.2	62.2	44.8	23.6	5.0	**68.0**
HGU56	75.2	75.7	73.8	69.6	57.6	37.4	15.5	**81.0**
CB mask								
CEP	64.3	65.4	62.8	61.7	45.1	20.9	2.4	**71.3**
E-A-R	64.0	64.2	60.5	62.8	45.8	20.2	2.0	**70.8**
HGU56	81.8	80.9	79.2	76.2	59.8	42.1	25.6	**87.2**
Spectacles								
CEP	65.4	64.3	58.6	63.7	46.0	25.7	5.2	**71.5**
E-A-R	66.5	65.2	61.1	62.5	46.3	24.3	6.8	**72.3**
HGU56	80.3	77.8	74.6	69.5	59.5	40.3	31.5	**84.1**
				STBD ramp				
Alone								
CEP	74.3	86.0	79.3	79.9	63.3	39.9	31.1	**89.2**
E-A-R	73.5	82.6	76.7	79.2	62.8	41.1	30.7	**86.2**
HGU56	87.7	97.3	92.3	86.6	75.6	54.9	41.2	**99.8**
CB mask								
CEP	76.8	87.0	81.3	78.7	63.1	38.4	28.1	**89.8**
E-A-R	76.5	85.8	79.0	79.8	63.8	37.7	27.7	**89.3**
HGU56	94.3	102.5	97.7	93.2	77.8	59.6	51.3	**105.6**
Spectacles								
CEP	77.9	85.9	77.1	80.7	64.0	43.2	30.9	**89.4**
E-A-R	79.0	86.8	79.6	79.5	64.3	41.8	32.5	**90.0**
HGU56	92.8	99.4	93.1	86.5	77.5	57.8	57.2	**102.0**

Table C-2 (Continued).

Aircraft	125	250	500	1000	2000	4000	8000	EEL
OH-58D								
			Inside cockpit between crewmembers--doors off					
			80 KT IN					
Alone								
CEP	55.8	61.6	56.0	58.8	48.6	25.7	19.3	**66.4**
E-A-R	55.0	58.2	53.4	58.1	48.1	26.9	18.9	**63.9**
HGU56	69.2	72.9	69.0	65.5	60.9	40.7	29.4	**77.0**
CB mask								
CEP	58.3	62.6	58.0	57.6	48.4	24.2	16.3	**67.3**
E-A-R	58.0	61.4	55.7	58.7	49.1	23.5	15.9	**66.8**
HGU56	75.8	78.1	74.4	72.1	63.1	45.4	39.5	**82.9**
Spectacles								
CEP	59.4	61.5	53.8	59.6	49.3	29.0	19.1	**67.2**
E-A-R	60.5	62.3	56.3	58.4	49.6	27.6	20.7	**68.0**
HGU56	74.3	75.0	69.8	65.4	62.8	43.6	45.4	**79.7**
			60 KT IN					
Alone								
CEP	52.7	59.8	54.3	57.8	46.9	24.6	18.2	**64.8**
E-A-R	51.9	56.4	51.7	57.1	46.4	25.8	17.8	**62.2**
HGU56	66.1	71.1	67.3	64.5	59.2	39.6	28.3	**75.0**
CB mask								
CEP	55.2	60.8	56.3	56.6	46.7	23.1	15.2	**65.4**
E-A-R	54.9	59.6	54.0	57.7	47.4	22.4	14.8	**65.0**
HGU56	72.7	76.3	72.7	71.1	61.4	44.3	38.4	**81.0**
Spectacles								
CEP	56.3	59.7	52.1	58.6	47.6	27.9	18.0	**65.4**
E-A-R	57.4	60.5	54.6	57.4	47.9	26.5	19.6	**66.0**
HGU56	71.2	73.2	68.1	64.4	61.1	42.5	44.3	**77.5**

Table C-2 (Continued).

Aircraft	125	250	500	1000	2000	4000	8000	EEL
UH-60A Black Hawk								
			Left rear 120 KT CRS doors closed.					
Alone								
CEP	49.8	60.4	57.8	60.4	52.1	33.4	25.4	**66.7**
E-A-R	49.0	57.0	55.2	59.7	51.6	34.6	25.0	**64.0**
HGU56	63.2	71.7	70.8	67.1	64.4	48.4	35.5	**76.6**
CB mask								
CEP	52.3	61.4	59.8	59.2	51.9	31.9	22.4	**67.1**
E-A-R	52.0	60.2	57.5	60.3	52.6	31.2	22.0	**66.6**
HGU56	69.8	76.9	76.2	73.7	66.6	53.1	45.6	**82.5**
Spectacles								
CEP	53.4	60.3	55.6	61.2	52.8	36.7	25.2	**66.8**
E-A-R	54.5	61.2	58.1	60.0	53.1	35.3	26.8	**67.2**
HGU56	68.3	73.8	71.6	67.0	66.3	51.3	51.5	**78.4**
			120KT CRS doors open					
Alone								
CEP	64.8	71.4	65.8	67.4	56.1	36.4	35.4	**75.8**
E-A-R	64.0	68.0	63.2	66.7	55.6	37.6	35.0	**73.1**
HGU56	78.2	82.7	78.8	74.1	68.4	51.4	45.5	**86.4**
CB mask								
CEP	67.3	72.4	67.8	66.2	55.9	34.9	32.4	**76.6**
E-A-R	67.0	71.2	65.5	67.3	56.6	34.2	32.0	**76.1**
HGU56	84.8	87.9	84.2	80.7	70.6	56.1	55.6	**92.3**
Spectacles								
CEP	68.4	71.3	63.6	68.2	56.8	39.7	35.2	**76.4**
E-A-R	69.5	72.2	66.1	67.0	57.1	38.3	36.8	**77.2**
HGU56	83.3	84.8	79.6	74.0	70.3	54.3	61.5	**89.1**

Table C-2 (Continued).

Aircraft	125	250	500	1000	2000	4000	8000	EEL
UH-60A Black Hawk								
				Pilot				
				120 KT CRS doors closed				
Alone								
CEP	56.8	72.4	59.8	60.4	49.1	30.4	30.4	**73.7**
E-A-R	56.0	69.0	57.2	59.7	48.6	31.6	30.0	**70.5**
HGU56	70.2	83.7	72.8	67.1	61.4	45.4	40.5	**84.7**
CB Mask								
CEP	59.3	73.4	61.8	59.2	48.9	28.9	27.4	**74.6**
E-A-R	59.0	72.2	59.5	60.3	49.6	28.2	27.0	**73.8**
HGU56	76.8	88.9	78.2	73.7	63.6	50.1	50.6	**90.2**
Spectacles								
CEP	60.4	72.3	57.6	61.2	49.8	33.7	30.2	**73.9**
E-A-R	61.5	73.2	60.1	60.0	50.1	32.3	31.8	**74.6**
HGU56	75.3	85.8	73.6	67.0	63.3	48.3	56.5	**87.0**
				120KT CRS doors open				
Alone								
CEP	62.8	77.4	65.8	63.4	52.1	32.4	35.4	**78.6**
E-A-R	62.0	74.0	63.2	62.7	51.6	33.6	35.0	**75.4**
HGU56	76.2	88.7	78.8	70.1	64.4	47.4	45.5	**89.7**
CB mask								
CEP	65.3	78.4	67.8	62.2	51.9	30.9	32.4	**79.6**
E-A-R	65.0	77.2	65.5	63.3	52.6	30.2	32.0	**78.7**
HGU56	82.8	93.9	84.2	76.7	66.6	52.1	55.6	**95.3**
Spectacles								
CEP	66.4	77.3	63.6	64.2	52.8	35.7	35.2	**78.8**
E-A-R	67.5	78.2	66.1	63.0	53.1	34.3	36.8	**79.7**
HGU56	81.3	90.8	79.6	70.0	66.3	50.3	61.5	**92.1**

Appendix D.

List of manufacturers.

Auditec
Suite 2E, 156 W. Argonne
St. Louis, MO 63122

Bose Corporation
The Mountain
Framingham, MA 01701-9168

Bruel and Kjaer Instruments, Inc.
2364 Park Central Blvd.
Decatur, GA 30035-3987

Electro Scientific Industries
13900 NW Science Park Drive
Portland, OR 97229

Gentex Corporation
P.O. Box 315
Carbondale, PA 18407

Grumman Aerospace Corporation
South Oyster Bay Road
Bethpage, NY 11714

Larson Davis
1681 W. 820 North
Provo, UT 84601

Simpson Electric Company
5200 W Kinzie Street
Chicago, IL 60644

Statsoft
2300 East 14th Street
Tulsa, OK 74104

Tektronix Inc.
P.O. Box 1700
Beaverton, OR 97075

Tucker-Davis Technologies
4550 NW 6th Street
Gainesville, FL 32609

Appendix E.

List of abbreviations/acronyms.

ANSI	American National Standards Institute
ANOVA	analysis of variance
ANR	active noise reduction
CB	chemical biological
CEP	communications earplug
CRDA	Cooperative Research and Development Agreement
CVC	combat vehicle crewman
DUT	device under test
EEL	effective exposure level
FFT	fast Four transform
HATS	head and torso simulator
HPD	hearing protective devices
IHADSS	integrated helmet and display sighting system
MANOVA	multivariate analysis of variance
MIL-STD	Military Standard
PC	personal computer
PEAT	physical-ear attenuation test
PM-ACIS	Program Manager-Aircrew Integrated Systems
PM-ALSE	Program Manager-Aviation Life Support Equipment
REAT	real-ear attenuation test
RTA	real time analyzer
SEL	sound exposure level
SI	speech intelligibility
SPL	sound pressure levels
SRT	speech recognition threshold
TPL™	thermoplastic liner
USAARL	U.S. Army Aeromedical Research Laboratory

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DEPARTMENT OF THE ARMY
U.S. ARMY AEROMEDICAL RESEARCH LABORATORY
POST OFFICE BOX 620577
FORT RUCKER ALABAMA 36362-0577

REPLY TO ATTENTION OF

March 18, 2003

Office of the Commander

Defense Technical Information Center
DTIC-OCQ, Attn: Larry Downing
STE 0930
8725 John J. Kingman Road
Fort Belvoir, VA 22060-6218

Dear Mr. Downing:

This letter serves as an official request to change the distribution statement from "U.S. Government Only" to "Approved for Public Release" for the following reports:

(1) ADB222028, Assessment of Sound Attenuation and Speech Intelligibility of Selected Active Noise Reduction Devices and the Communications Earplug When Used with the HGU-56/P Aviator Helmet

(2) ADB220453, Operational Test to Evaluate the Effectiveness of the Communication Earplug and Active Noise Reduction Devices When Used with the HGU-56/P Aviator Helmet

Point of contact for this matter is Ms. Diana L. Hemphill, telephone DSN 558-6907, (334) 255-6907 or by e-mail at diana.hemphill@se.amedd.army.mil.

Sincerely,

Brian S. Campbell
Colonel, Medical Corps
Commander, U.S. Army Aeromedical
Research Laboratory

Copies furnished:
Dr. William Ahroon
Mr. Ben Mozo