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Sound Attenuation of Rotary-Wing Aviation Helmets with Oregon Aero™ Earcup Replacement Products

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Aircrew Protection Division

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14. ABSTRACT

The sound attenuation of the HGU-56/P Aircrew Integrated Helmet System (AIHS) and the HGU-84/P Rotary-Wing Helmet System (RWHS) configured with Oregon Aero™ replacement earcup products was evaluated in accordance with the American National Standard Methods for Measuring the Real-Ear Attenuation of Hearing Protectors [ANSI S12.6-1997 (R2002)], Method A: Experimenter-supervised fit. Sound attenuation of both the HGU-56/P AIHS and HGU-84/P RWHS configured with the Oregon Aero HushKit™ replacement earcup foam or SoftSeal™ replacement earcup seal was essentially equivalent to the helmet's standard configurations. However, the Oregon Aero™ SoftSeal/HushKit Combo™, soft replacement earcups provided significantly poorer sound attenuation than the standard configuration. As with the Army's current flight helmet/earcup combination, double protection (i.e., earplugs in addition to the sound-protective flight helmet) is required in certain high noise environments.

15. SUBJECT TERMS

Hearing, hearing protection, sound attenuation, noise protection, HGU-56/P, HGU-84/P, flight helmet, Oregon Aero

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Introduction

Oregon Aero, a manufacturer of replacement products for civilian and military vehicles and personal items such as helmets and headsets, has developed and is marketing several earcup replacement products for use in Gentex HGU-56/P Aircrew Integrated Helmet System (AIHS) and the Gentex HGU-84/P Rotary-Wing Helmet System (RWHS). These products include replacement earcup foam (HushKit™), replacement earcup seals (SoftSeal™) and replacement earcups (SoftSeal/HushKit Combo™) designed for use in a number of different helmet systems (see Figures 1 and 2). None of these products have been authorized for use with either helmet system. This report describes the sound attenuation and hearing protection provided by each of these earcup replacement products when used with the HGU-56/P AIHS and the HGU-84/P RWHS. Before airworthiness releases are promulgated, however, evaluations of blunt impact protection and helmet retention must be performed to ensure that the non-auditory injury protection of the helmets is not negatively affected by the replacement earcup products .

The Gentex HGU-56/P AIHS (Figure 1) and HGU-84/P (Figure 2) are designed to provide impact protection and noise attenuation to U.S. Army (HGU-56/P) and U.S. Navy (HGU-84/P) rotary-wing aircraft crewmembers. They replaced the 1980's-vintage SPH-4 and SPH-3C flight helmets and are used by most U.S. Army, U.S. Air Force, and U.S. Navy rotary-wing aircrew. Tables 1 and 2 present selected data from the manufacturer's product data sheets on these helmets.

Figure 1. Gentex HGU-56/P Aircrew Integrated Helmet System.

Figure 2. Gentex HGU-84/P Rotary-Wing Helmet System.

Table 1.
Manufacturer's description of the HGU-56/P Aircrew Integrated Helmet System.

Sound Attenuation

	Test frequency (kHz)								
	0.125	0.250	0.500	1.000	2.000	3.150	4.000	6.300	8.000
Decibels	17	14	20	21	26	38	37	44	42

Impact Resistance

Peak Gs	Velocity (ft/s)	Velocity (m/s)	Location	Environmental Conditions
<150	15.748	4.8	Crown	High, Ambient
<175	19.685	6.0	Headband	High, Ambient
<150	19.685	6.0	Earcup	High, Ambient

Table 2.
Manufacturer's description of the HGU-84/P Rotary-Wing Helmet System.

Sound Attenuation

	Test frequency (kHz)								
	0.125	0.250	0.500	1.000	2.000	3.150	4.000	6.300	8.000
Decibels	13	14	21	24	30	40	43	44	36

Impact Resistance

Peak Gs	Velocity (ft/s)	Velocity (m/s)	Anvil	Environmental Conditions
300	17.5	5.334	Flat	Cold, Hot, Wet
400	17.5	5.334	Hemispherical	Cold Hot, Wet

Method

Sound attenuation testing was performed in accordance with (IAW) the American National Standard Methods for Measuring the Real-Ear Attenuation of Hearing Protectors (REAT), Method A: Experimenter-supervised fit, described in ANSI S12.6-1997 (R2002). The fitting of the helmets for all conditions was performed by personnel trained by the U.S. Army Aeromedical Research Laboratory (USAARL) Aviation Life Support Equipment (ALSE) specialists.

Subjects

The USAARL recruited 11 volunteer subjects (10 male, 1 female) for evaluations of the HGU-56/P AIHS and HGU-84/P RWHS from tenant activities located at the U.S. Army Aviation Center, Fort Rucker, Alabama. The purpose of the study was explained to each subject. Each subject read and signed an informed consent form (Appendix A) and then completed a questionnaire regarding his/her hearing health (Appendix B). An otoscopic examination was performed and an audiogram collected on each subject before REAT testing. At any time during this preliminary process, if a subject failed to qualify for ANSI S12.6-1997 (R2002) testing, he/she was released. No subject failed to qualify for the study. Although subjects were permitted to withdraw from the study at any time, no subjects chose to withdraw from the study. Subject 9 did not complete the testing of all configurations of HGU-84/P RWHS and an eleventh subject was recruited to complete the evaluations. Investigators adhered to Army Regulation (AR) 70-25 (Department of the Army, 1990) and USAMRMC Regulation 70-25 (Department of Defense, 1990) on use of volunteers in research during the conduct of this study.

Devices tested

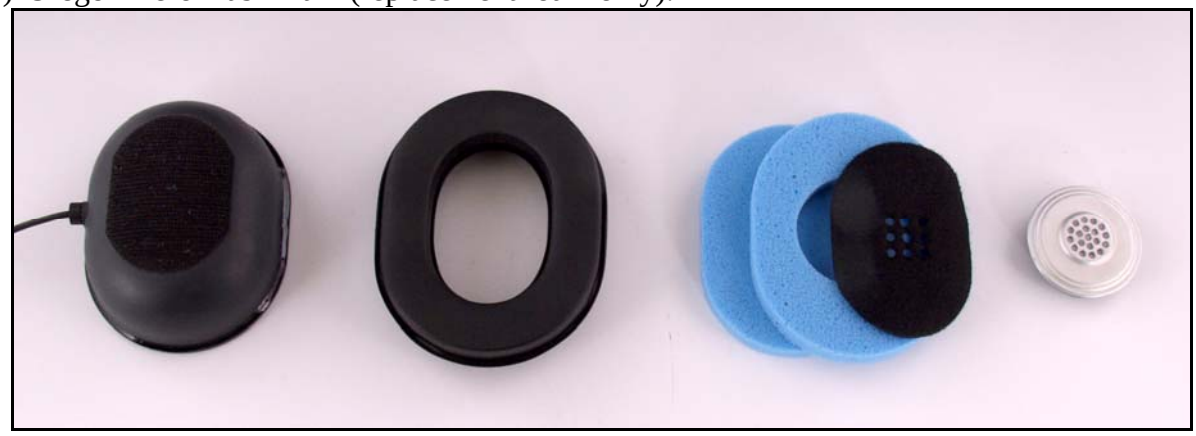
The earcup parts for the standard HGU-56/P AIHS are displayed in Figure 3. The earcup configurations with the HushKit™, SoftSeal™, and SoftSeal/HushKit™ Combo are displayed in Figure 4. To conserve test assets, four HGU-56/P AIHS units were acquired, sizes S, M, L, and XL. The earcups were removed and sets of replacement earcups were configured with HushKit™ and standard earcup seal, the SoftSeal™ and HushKit™, or the SoftSeal/HushKit Combo™. The standard speaker (earphone) used in the HGU-56/P AIHS was included in each configuration.

Figure 3. Earcup, earcup seal, insert foam, and speaker (earphone) used in the Gentex HGU-56/P Aircrew Integrated Helmet System.

Following helmet selection, sound attenuation was measured on the helmet system as configured by the manufacturer. All evaluations were made using normal fitting procedures. That is, subjects were told to wear the helmets secured with chinstrap tension that would be appropriate for use in flight and were not permitted to tighten the chinstrap to a degree that would result in helmet discomfort for the duration of a normal flight.

Following the evaluation of the standard helmet configuration, one of the three or four earcup configurations was installed into the HGU-56/P AIHS or HGU-84/P RWHS. The HGU-56/P was tested with the HushKit™ replacement earcup foam, with the SoftSeal™ replacement earcup seal with standard earcup foam, with the SoftSeal™ replacement earcup seal with HushKit™ replacement foam, and with the SoftSeal/HushKit Combo™, a soft replacement earcup with Oregon Aero foam earcup liner. The HGU-84/P RWHS also was evaluated with a triangular (Custom SoftSeal/HushKit Combo™) soft replacement earcup similar to the SoftSeal/HushKit Combo™. Test configurations were conducted in counterbalanced order.

(a) Oregon Aero HushKit™ (replacement foam only).



(b) Oregon Aero SoftSeal™ (replacement earcup seal) with HushKit™.

(c) Oregon Aero SoftSeal/HushKit Combo™ (soft, non-energy absorbing, replacement earcup).

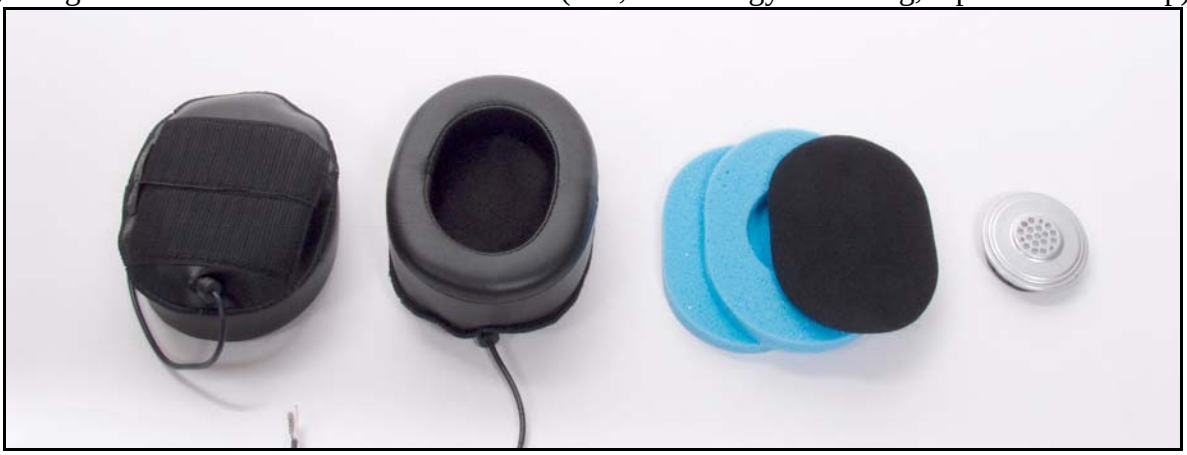
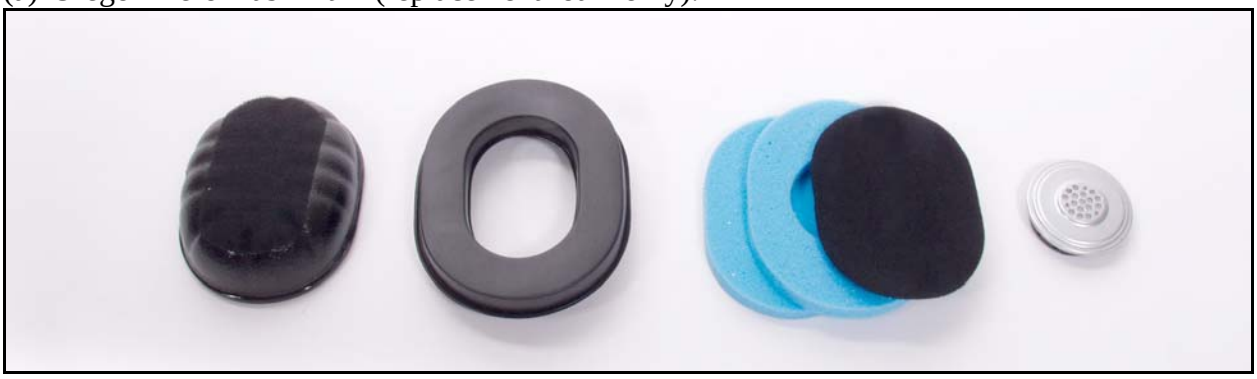


Figure 4. Gentex HGU-56/P Aircrew Integrated Helmet System earcup configuration displayed with the Oregon Aero earcup replacement products evaluated in this study. (a) Oregon Aero HushKit™, (b) Oregon Aero SoftSeal™ with Oregon Aero HushKit™, (c) Oregon Aero SoftSeal/HushKit Combo™

The earcup parts for the standard HGU-84/P RWHS are displayed in Figure 5. The earcup configurations with the HushKit™ and SoftSeal™ are displayed in Figure 6. The earcup configurations using complete earcup replacements (SoftSeal/HushKit Combo™ and custom SoftSeal/ HushKit Combo™) are shown in Figure 7. To conserve test assets, four HGU-84/P RWHS units were acquired, sizes M, L, XL, and XL (wide). The earcups were removed and sets of replacement earcups were configured with HushKit™ and standard earcup seal or with the SoftSeal™ and HushKit™. The speaker (earphone) used in the standard HGU-84/P RWHS was included in each configuration.

Figure 5. Earcup, earcup seal, insert foam, and speaker (earphone) found in the Gentex HGU-84/P Rotary-Wing Helmet System.

(a) Oregon Aero HushKit™ (replacement foam only).



(b) Oregon Aero SoftSeal™ (replacement earcup seal) with HushKit™.

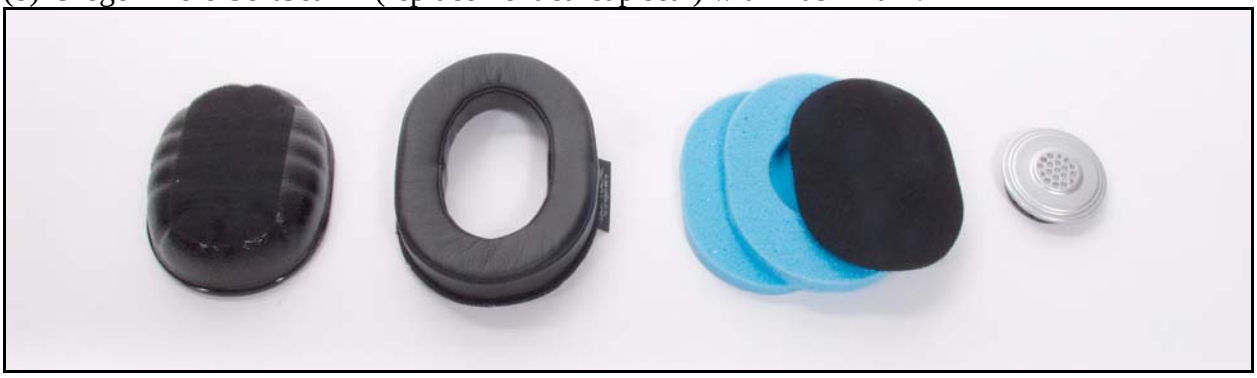


Figure 6. Gentex HGU-84/P Rotary-Wing Helmet System earcup configuration displayed with the (a) Oregon Aero HushKit™ and (b) Oregon Aero SoftSeal™ with Oregon Aero HushKit™.

(a) Oregon Aero SoftSeal/HushKit Combo™ (soft, non-energy absorbing, replacement earcup).

(b) Oregon Aero custom SoftSeal/HushKit Combo™. The replacement earcup fills the space in the HGU-84/P RWHS ear dome.

Figure 7. Gentex HGU-84/P Rotary-Wing Helmet System earcup configuration displayed with the (a) normal (oval) version of the Oregon Aero SoftSeal/HushKit Combo™ and (b) Oregon Aero custom SoftSeal/HushKit Combo™.

Upon completion of the informed-consent procedure and initial audiometric evaluation (see above), the subject selected the unmodified helmet that provided the best fit with regard to hearing protection and comfort. Following helmet selection, one of the four earcup configurations was installed into the HGU-56/P AIHS and the HGU-84/P RWHS. The fitting of the helmet for all conditions was performed by personnel trained by USAARL ALSE specialists.

Equipment

The REAT test procedure utilized Tucker-Davis Technologies (TDT) System II psychoacoustic test modules controlled by a general-purpose personal computer using custom-written software to control the real-ear procedure. Test stimuli were created by filtering the output of a WG2 Waveform Generator by a PF1 Programmable Filter and attenuating this signal with two PA2 Programmable Attenuators connected in series. The output of the WG2 was gated on and off using a TG6 Timing Generator with 400 ms cycle time (two-and-one-half times a second, 50 percent duty cycle). The output of the attenuators placed in series was connected to QSC Audio PLX3402 Professional Power Amplifiers and routed to a speaker system consisting of three Altec Model 612C speakers. The sound field created by the system described satisfied the stimulus conditions mandated by ANSI S12.6-1997 (R2002).

Procedure

After preliminary screening including audiometric and anthropometric measurements (presented in Appendix O), subjects were trained on the testing procedure. A custom TDT response box (RBOX) with six pushbuttons and two lights was used by the subjects to adjust the level of the signal (via the programmable attenuators). Subjects were given the instruction to "adjust the loudness of the signal until it is 'just barely audible'." Subjects satisfied the training and reliability requirements IAW ANSI S12.6-1997 (R2002) with at least three consecutive unoccluded third-octave audiograms with a range no greater than six decibels (dB). Threshold during training and data collection was determined as the average of four consecutive judgments at a single test signal, with the condition that the range of these four judgments be no greater than five decibels. If response variability was large and this criterion was not reached after 20 judgments, the testing was paused and the subject was instructed on the use of the response box and reminded of the listening strategy. Subjects seldom required more than 20 trials to reach criterion with the vast majority of thresholds collected with less than 6 responses.

During each REAT test, two occluded and two unoccluded thresholds for each of the seven specified third-octave bands of noise centered at octave frequencies from 125 Hz to 8000 Hz were obtained for each condition. A "trial" consisted of one occluded and one unoccluded measurement. The real-ear attenuation at threshold at each test center frequency was calculated as the average of the difference between the occluded and unoccluded thresholds for the two trials.

Statistical analyses were performed using STATISTICA® Release 6.1 from StatSoft®, Inc. Post-hoc analyses were performed using the Duncan multiple range test[*]. The probability of a Type I error was set at 0.05 for all analyses.

[*] The Duncan's multiple-range test was used for post-hoc comparisons because only a limited set of comparisons, those between real-ear attenuation at threshold at the same test frequencies, were of interest in these analyses (Keppel, 1973).

Results

HGU-56/P Aircrew Integrated Helmet System

The mean REAT results for the HGU-56/P AIHS are illustrated in Figure 8 and depicted in tabular form in Table 3. An asterisk in Table 3 represents a statistically significant post-hoc comparison of the mean at that test frequency with the corresponding mean for the standard helmet configuration. The summary tables for the mixed-model analyses of variance with repeated measures on one factor (frequency) are presented in Table 4. The main effect of frequency was statistically significant for all analyses and was not unexpected due to our knowledge of the frequency-specific performance of most hearing protective devices. Individual results are presented in tables in Appendix C. Unoccluded and occluded thresholds for each trial of the HGU-56/P AIHS are presented in Appendices D through G.

Results of our evaluations demonstrated that the HGU-56/P AIHS equipped with the HushKit™ earcup foam or the SoftSeal™ replacement earcup seal with HushKit™ provide equivalent or poorer sound attenuation/protection at frequencies below 4.0 kHz and marginal improvement at 4.0 kHz and above. The sound attenuation of the helmet with the Softseal/Hushkit Combo™ (soft replacement earcup) provide significantly less noise attenuation and hearing protection below 4.0 kHz than provided by the standard helmet configuration.

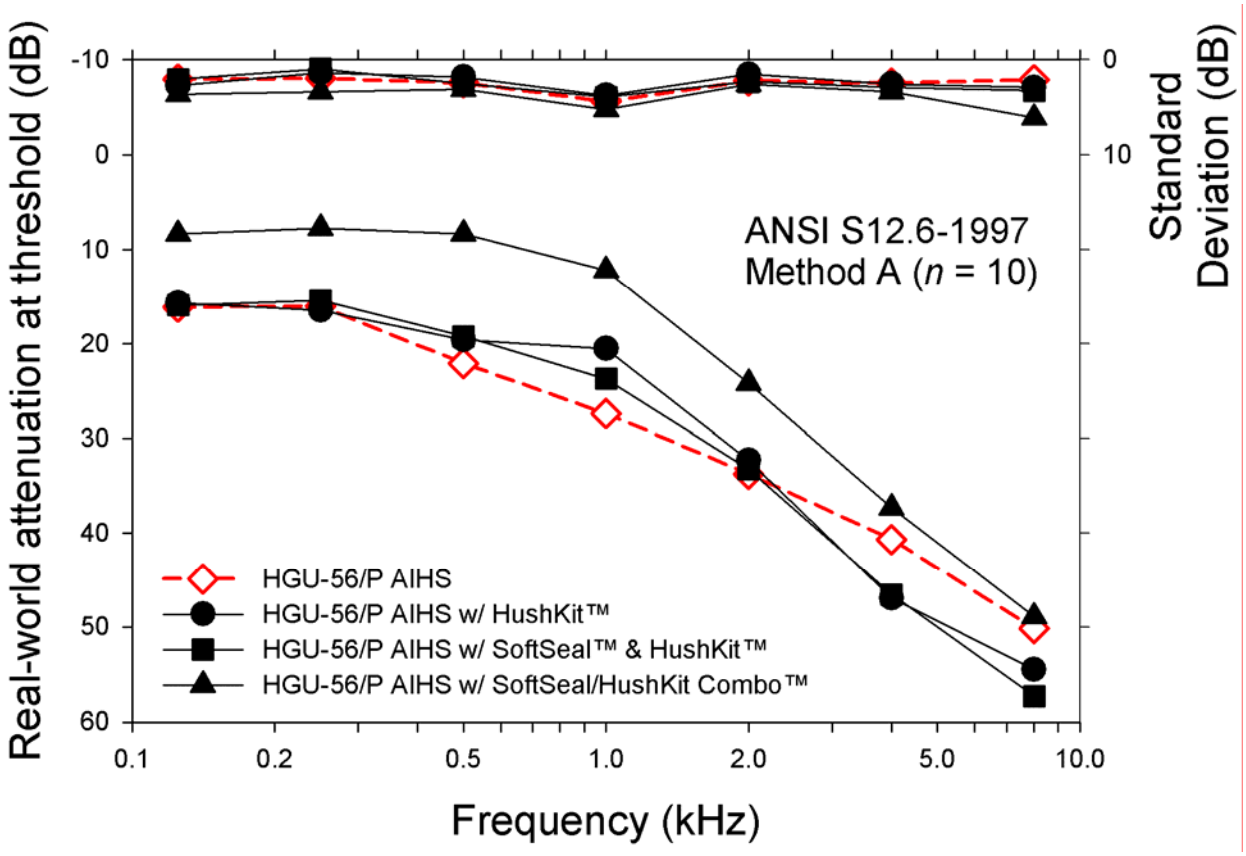


Figure 8. The mean (*n*=10) real-ear attenuation at threshold for the HGU-56/P AIHS with the HushKit™, SoftSeal™ with HushKit™, and SoftSeal/HushKit Combo™.

Table 3.
The mean (n=10) real-ear attenuation at threshold for the HGU-56/P Aircrew Integrated Helmet System with Oregon Aero earcup replacement products .

	Test frequency (kHz)						
	0.125	0.250	0.500	1.000	2.000	4.000	8.000
HGU-56/P Aircrew Integrated Helmet System Standard Configuration							
$\overline{X}$	16.15	16.05	22.10	27.40	33.79	40.70	50.18
s	2.11	2.00	2.46	4.43	2.26	2.51	2.16
HGU-56/P AIHS with HushKit™							
$\overline{X}$	15.68	16.49	19.61	20.53*	32.33	46.99*	54.52*
s	2.77	1.39	1.85	3.78	1.57	2.58	2.93
HGU-56/P AIHS with SoftSeal™ and HushKit™							
$\overline{X}$	16.31	15.79	19.14	24.09	33.55	46.45	56.85
s	2.11	1.00	2.52	3.98	2.35	2.94	3.29
HGU-56/P AIHS with SoftSeal/HushKit Combo™							
$\overline{X}$	8.36*	7.73*	8.33*	12.18*	24.20*	37.34	48.91
s	3.69	3.41	3.17	5.25	2.62	3.39	6.17

* $p < .05$

Table 4.

Analysis of Variance summary tables comparing the mean real-ear attenuation at threshold of the standard HGU-56/P Aircrew Integrated Helmet System with the same helmet configured with Oregon Aero replacement earphone products .

HGU-56/P Standard versus HGU-56/P with HushKit™

Source	*SS*	*df*	*MS*	*F*	*p*
Device	0.04	1	0.04	0.002	0.962
Error	274.36	18	15.24		
Frequency	24111.76	6	4018.63	742.841	0.000
Frequency × Device	572.02	6	95.34	17.623	0.000
Error	584.26	108	5.41		

HGU-56/P Standard versus HGU-56/P with SoftSeal™ and HushKit™

Source	*SS*	*df*	*MS*	*F*	*p*
Device	24.00	1	24.00	1.077	0.313
Error	400.86	18	22.27		
Frequency	24893.92	6	4148.99	865.277	0.000
Frequency × Device	463.19	6	77.20	16.100	0.000
Error	517.86	108	4.79		

HGU-56/P Standard versus HGU-56/P with SoftSeal/HushKit Combo™

Source	*SS*	*df*	*MS*	*F*	*p*
Device	2514.83	1	2514.83	48.569	0.000
Error	932.02	18	51.78		
Frequency	25437.30	6	4239.55	769.444	0.000
Frequency × Device	767.15	6	127.86	23.205	0.000
Error	595.07	108	5.51		

HGU-84/P Rotary-Wing Helmet System

The mean REAT results for the HGU-84/P RWHS are illustrated in Figures 9 and 10 and depicted in tabular form in Table 5. There was no statistically significant difference revealed in the post-hoc analyses. The summary tables for the mixed-model analyses of variance with repeated measures on one factor (frequency) are presented in Table 6. The main effect of frequency was statistically significant for all analyses and was expected due to our knowledge of the frequency-specific performance of most hearing protective devices. There was no statistically significant Device main effort or Frequency × Device interaction between the standard RWHS and the RWHS configured with Oregon Aero SoftSeal™ with standard foam. Individual results are presented in the tables in Appendix H. Unoccluded and occluded thresholds for each trial of the HGU-84/P RWHS are presented in Appendices I through N.

There were no statistically significant differences in real-ear attenuation at threshold between the standard HGU-84/P RWHS configuration and the helmet configured with either the Oregon Aero HushKit™ or the Oregon Aero SoftSeal™ with the main effect of Device and the Frequency × Device interaction not statistically significant in either analysis. The main effect of Device was statistically significant when comparing the standard HGU-84/P RWHS with the helmet configured with the SoftSeal™ with HushKit™, representing an approximate mean 4.2 dB improvement across all frequencies. The main effect of Device was not statistically significant when comparing the standard helmet with either the SoftSeal/HushKit Combo™ or custom SoftSeal/HushKit Combo™. The Frequency × Device interaction was statistically significant for both these analyses indicating a statistically significant difference between the standard and modified helmet at some test frequencies. Although multiple contrasts fail to reach statistical significance, it is apparent that these differences appear to be at the lowest two test frequencies (below 500 Hz).

Results of our evaluations demonstrated that the HGU-84/P RWHS equipped with either the HushKit™ earcup foam or the SoftSeal™ replacement earcup seal or the SoftSeal™ with the HushKit™ foam provides slightly greater noise attenuation and hearing protection (yet not statistically significant) than helmets equipped with the standard foam or standard earcup seal and foam. The Oregon Aero SoftSeal/ HushKit Combo™ and Custom SoftSeal/HushKit Combo™ provided slightly greater noise attenuation in the lower frequency region from 125 Hz to 250 Hz and marginally less noise attenuation in the lower frequency regions over that provided by the standard helmet earcup configuration. (These differences also failed to reach statistical significance.)

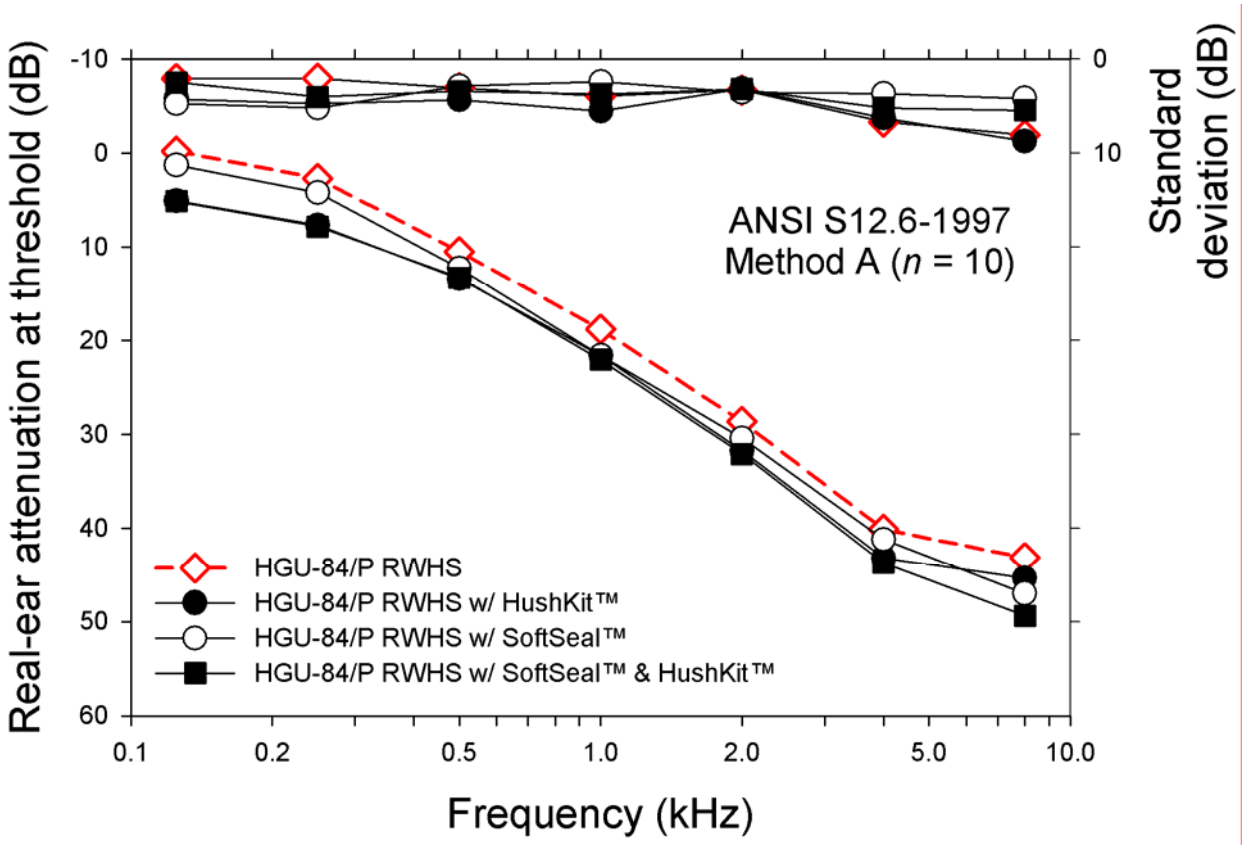


Figure 9. The mean (n=10) real-ear attenuation at threshold for the HGU-84/P RWHS with the HushKit™ and SoftSeal™ with HushKit™.

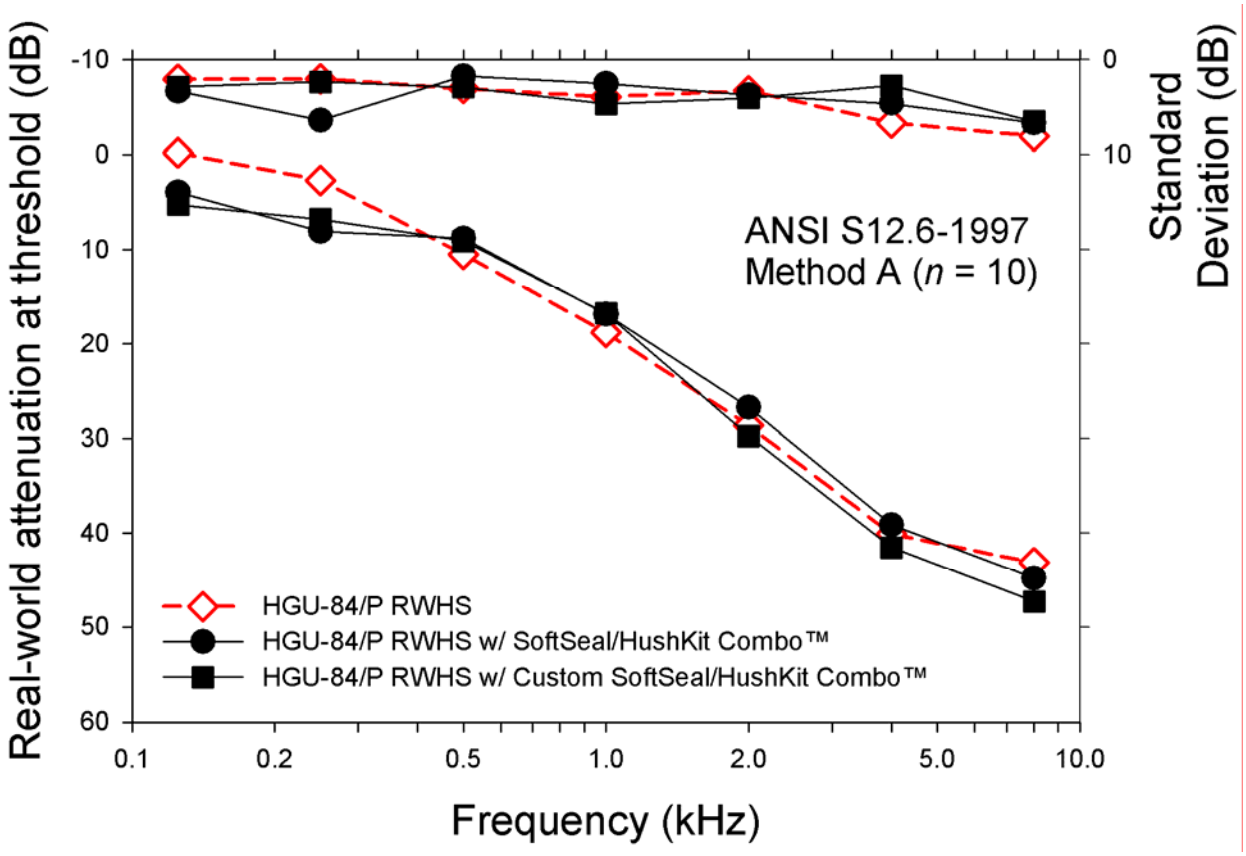


Figure 10. The mean (*n*=10) real-ear attenuation at threshold for the HGU-84/P RWHS with the SoftSeal/HushKit Combo™ and Custom SoftSeal/HushKit Combo™.

Table 5.

The mean (n=10) real-ear attenuation at threshold for the HGU-84/P Rotary Wing Helmet System with Oregon Aero earcup replacement products .

	Test frequency (kHz)						
	0.125	0.250	0.500	1.000	2.000	4.000	8.000
HGU-84/P Rotary-Wing Helmet System Standard Configuration							
$\overline{X}$	-0.19	2.70	10.49	18.84	28.68	40.15	43.19
s	2.09	2.07	3.07	3.95	3.28	6.68	8.06
HGU-84/P RWHS with HushKit™							
$\overline{X}$	5.10	7.70	13.41	21.61	31.79	43.22	45.39
s	4.25	4.73	4.36	5.53	3.16	6.29	8.72
HGU-84/P RWHS with SoftSeal™							
$\overline{X}$	1.32	4.24	12.30	21.65	30.40	41.24	47.00
s	4.78	5.20	2.88	2.42	3.56	3.70	4.19
HGU-84/P RWHS with SoftSeal™ and HushKit™							
$\overline{X}$	5.13	7.84	13.30	22.07	32.12	43.75	49.39
s	2.48	4.03	3.43	3.72	3.20	5.21	5.46
HGU-84/P RWHS with SoftSeal/HushKit Combo™							
$\overline{X}$	3.93	8.10	8.85	16.91	26.75	39.15	44.84
s	3.35	6.40	1.72	2.57	3.74	4.64	6.68
HGU-84/P RWHS with Custom SoftSeal/HushKit Combo™							
$\overline{X}$	5.26	6.78	9.11	16.78	29.79	41.59	47.33
s	2.88	2.36	2.93	4.70	4.06	2.76	6.52

* $p < .05$ (Note: there were no statistically significant post-hoc tests.)

Table 6.

Analysis of Variance summary tables comparing the mean real-ear attenuation at threshold of the standard HGU-84/P Rotary-Wing Helmet System with the same helmet configured with Oregon Aero replacement earphone products .

HGU-84/P Standard versus HGU-84/P with HushKit™

Source	*SS*	*df*	*MS*	*F*	*p*
Device	424.66	1	424.66	3.435	0.080
Error	2225.31	18	123.63		
Frequency	34398.88	6	5733.15	562.084	0.000
Frequency × Device	41.69	6	6.95	0.681	0.665
Error	1101.58	108	10.20		

HGU-84/P Standard versus HGU-84/P with SoftSeal™

Source	*SS*	*df*	*MS*	*F*	*p*
Device	145.73	1	145.73	2.399	0.139
Error	1093.42	18	60.75		
Frequency	37136.75	6	6189.46	528.572	0.000
Frequency × Device	26.67	6	4.45	0.380	0.891
Error	1264.66	108	11.71		

HGU-84/P Standard versus HGU-84/P with SoftSeal™ and HushKit™

Source	*SS*	*df*	*MS*	*F*	*p*
Device	633.17	1	633.17	8.455	0.009
Error	1347.93	18	74.89		
Frequency	36421.21	6	6070.20	609.324	0.000
Frequency × Device	49.55	6	8.26	0.829	0.550
Error	1075.92	108	9.96		

HGU-84/P Standard versus HGU-84/P with SoftSeal/HushKit Combo™

Source	*SS*	*df*	*MS*	*F*	*p*
Device	15.66	1	15.66	0.228	0.639
Error	1238.77	18	68.82		
Frequency	33400.10	6	5566.68	421.893	0.000
Frequency × Device	283.95	6	47.32	3.587	0.003
Error	1425.01	108	13.19		

Table 6 (continued).

HGU-84/P Standard versus HGU-84/P with SoftSeal/HushKit Custom Combo™

Source	*SS*	*df*	*MS*	*F*	*p*
Device	116.74	1	116.74	1.802	0.196
Error	1166.35	18	64.80		
Frequency	35809.39	6	5968.23	527.903	0.000
Frequency × Device	247.95	6	41.32	3.655	0.002
Error	1221.00	108	11.31		

Discussion

The replacement of the standard HGU-56/P AIHS earcup foam with the Oregon Aero HushKit™ replacement foam and the standard earcup seal with the Oregon Aero SoftSeal™ replacement earcup seal with HushKit™ foam provides essentially equivalent noise attenuation of the helmet system when measured by ANSI S12.6-1997 (R2002) Methods for Measuring the Real-Ear Attenuation of Hearing Protectors, Method A: Experimenter-supervised fit. Using the HushKit™ replacement foam, sound attenuation performance was improved at the highest test frequencies (where the noise hazard in rotary-wing aircraft is the lowest) and worse at 1.0 kHz. Helmets fitted with the Oregon Aero SoftSeal/HushKit Combo™ replacement earcup perform poorly (significantly less noise attenuation) compared to the standard HGU-56/P AIHS.

While the current results for the HGU-56/P AIHS are similar to those published by the manufacturer, there appear to be considerable differences in the HGU-84/P RWHS sound attenuation between the manufacturer's data and the current results at frequencies below 1.0 kHz (Figure 10). The standard employed by the manufacturer was an earlier standard (ANSI S12.6-1984), but the fitting method for that standard is essentially the same as the fitting method in the standard used in the current study (ANSI S12.6-1997 (R2002), Method A, Experimenter-supervised fit). The only appreciable differences in the two methods employed are that the earlier standard employed three occluded and three unoccluded measurements per test frequency and it mandated testing third-octave test bands centered at the half-octave frequencies of 3.15 and 6.3 kHz. The reasons for the discrepancies are not understood although a parallel insertion-loss evaluation of the HGU-84/P RWHS using a substantially different measurement technique (ANSI S12.42-1995 (R1999)) (depicted as the dashed line in the lower panel of Figure 11) also showed low sound attenuation at the lower frequency test bands (Ahroon et al., 2004). In fact, the real-ear attenuation at threshold results from the present study and the insertion loss data from the earlier evaluation are quite similar (see Figure 11).

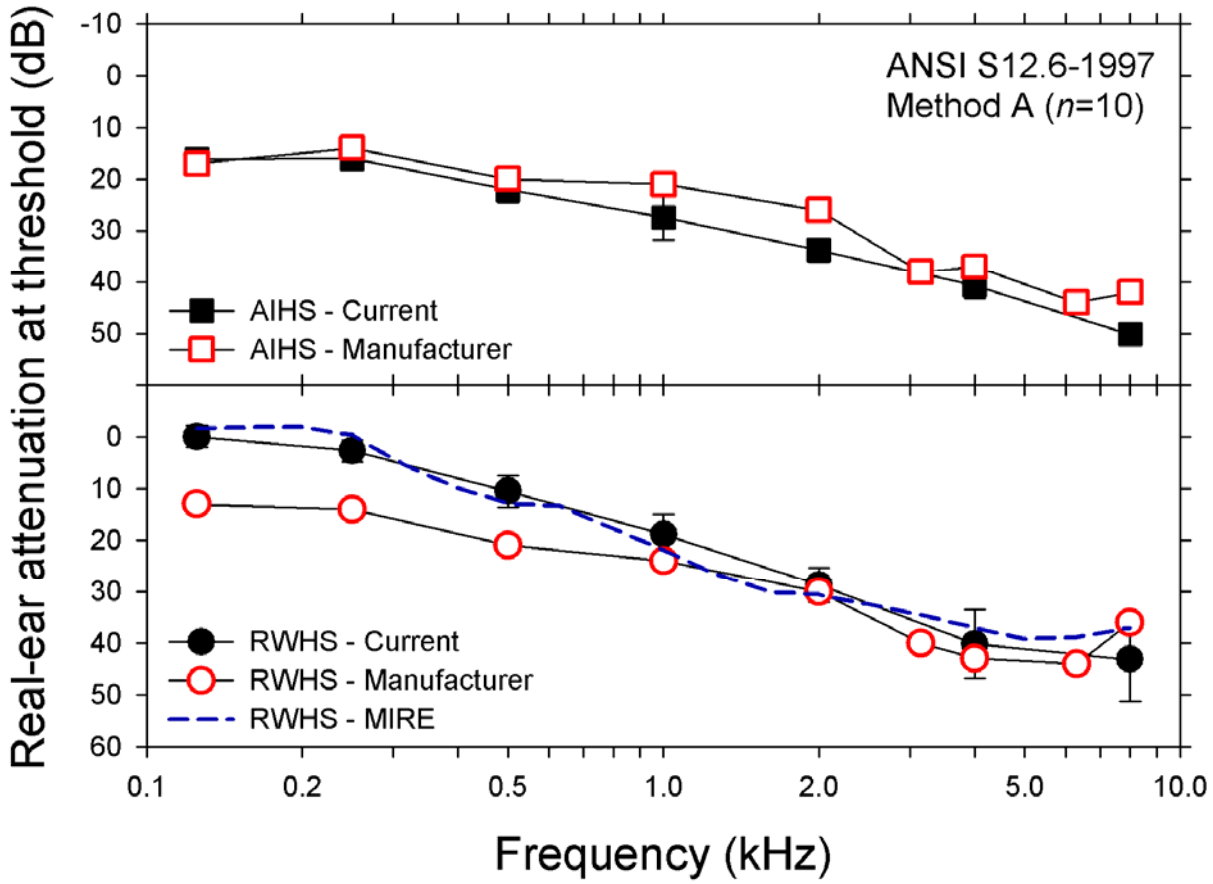


Figure 11. Comparison of current and manufacturer's sound attenuation results. (Top panel – HGU-56/P Aircrew Integrated Helmet System [AIHS]. Bottom panel – HGU-84/P Rotary-Wing Helmet System [RWHS]). Error bars represent one standard deviation. The dashed line in the lower figure depicts the insertion loss of the HGU-84/P published by Ahroon et al., 2004).

The replacement of the standard HGU-84/P RWHS earcup foam with the Oregon Aero HushKit™ replacement foam or the Oregon Aero SoftSeal™ replacement earcup seal provides no improvement in the hearing protection provided by the RWHS. When the SoftSeal™ and HushKit™ are used, there is a marginal (less than 5 dB) improvement in noise attenuation of the helmet system when measured by ANSI S12.6-1997 (R2002) Methods for Measuring the Real-Ear Attenuation of Hearing Protectors, Method A: Experimenter-supervised fit. Helmets fitted with the Oregon Aero SoftSeal/HushKit Combo™ replacement earcup and the Custom SoftSeal/HushKit Combo™ replacement earcup perform similarly to the standard HGU-84/P RWHS with only a small improvement at the lowest two test frequency bands.

The hearing protection provided by the flight helmet directly defines the operational limits for flight operations. Department of Defense Instruction 6055.12, (DODI 6055.12), Department of Defense, 1991, Hearing Conservation, defines an 85 dBA (A-weighted decibels) limit for a daily 8-hour exposure to continuous noise with a three-decibel doubling rule. That is, for every three decibels above 85 dBA, the maximum permissible exposure time is halved. Using the data presented in this report, Table 7 presents an example of the operational limits at the pilot's position of a UH-60A Black Hawk helicopter, traveling at 120 knots indicated air speed, with the doors open. There are no operational limit improvements when using Oregon Aero replacement earcup products for the HGU-56/P AIHS. In addition, while there were some improvements in noise attenuation from the HushKit™ and SoftSeal™ with HushKit™ configurations in the HGU-84/P RWHS, and these improvements result in appreciable increases in the maximum duration that a pilot can be exposed to the aircraft noise, the improvements still only permit a maximum of approximately one-half hour safe operational time.

If double hearing protection (in the form of expandable-foam, preformed, or custom-molded earplugs or communication augmentation systems such as the Communications Earplug [CEP], or Attenuating Custom Communications Earphone System [ACCES] for Aircrew) is used, any loss in hearing protection due to replacement of the standard earcup components would be minimal for either helmet system (Berger, 1984).

A second important caveat is in order. While it is possible that any replacement earcup foam or seal or earcup may improve sound attenuation, it is essential that these products not be authorized for use until evaluations of helmet retention and the blunt impact protection provided by the helmet when fitted with these earcup replacement products are performed. It is possible that the surface of replacement earcup seals may slip during an aircraft mishap, allowing the helmet to rotate on the head, exposing normally-protected areas of the skull to blunt impacts. Likewise, aviation helmet earcups often are designed with energy-absorbing characteristics which might not be part of a replacement earcup design. Reduced energy absorption to lateral impacts will place aircrew wearing a modified helmet at a higher, unacceptable risk of head injury. Complete helmet retention and blunt impact tests under different environmental conditions are necessary before fielding any earcup replacement product.

Table 7.

Noise reduction rating (NRR) and operational limits* for the various helmet configurations.

	HGU-56/P Aircrew Integrated Helmet System			
		Overall	Allowable Time (per day)	
	NRR (dB)	dBA	(min)	(hr)
Manufacturer Data	---	90.0	151	2.5
Standard Configuration	19.5	88.0	240	4.0
HushKit™	16.3	88.0	240	4.0
SoftSeal™ and HushKit™	17.6	88.8	200	3.3
SoftSeal/HushKit Combo™	4.4	97.1	29	0.5

	HGU-84/P Rotary-Wing Helmet System			
		Overall	Allowable Time (per day)	
	NRR (dB)	dBA	(min)	(hr)
Manufacturer Data	---	90.1	148	2.5
Standard Configuration	7.7	101.5	11	0.2
HushKit™	7.8	96.6	33	0.5
SoftSeal™	5.6	99.9	15	0.3
SoftSeal™ and HushKit™	10.0	96.5	34	0.6
SoftSeal/HushKit Combo™	6.7	97.0	30	0.5
Custom SoftSeal/HushKit Combo™	7.7	97.8	25	0.4

* Operational limits are calculated using noise exposure data for a UH-60A Black Hawk in the pilot's position, 120 KTS IAS, doors open.

Conclusions

The real-ear attenuation at threshold for the HGU-56/P AIHS used by most U.S. Army rotary-wing aircrew and the HGU-84/P RWHS used by U.S. Navy rotary-wing aircrew was measured in both standard configuration and in configurations using earcup replacement products manufactured by Oregon Aero, Inc. ANSI S12/6-1997 (R2002) Method A, Experimenter-supervised fit procedures were used. The Oregon Aero earcup replacement products provide essentially equivalent sound attenuation/protection in the HGU-56/P AIHS. Some of the Oregon Aero replacement product configurations provide marginal statistically significant improvement at some frequencies to the hearing protection provided by the HGU-84/P RWHS. Any improvement in protection provided by the use of Oregon Aero earcup replacement protects is not sufficient to eliminate the need to use double protection (i.e., earplugs in addition to the sound-protective flight helmet).

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Appendix A.

Volunteer agreement affidavit

VOLUNTEER AGREEMENT AFFIDAVIT

For use of this form, see AR 70-25 or AR 40-38; the proponent agency is OTSG.

PRIVACY ACT OF 1974

Authority: 10 USC 3013, 44 USC 3101, and 10 USC 1071-1087

Principal Purpose: To document voluntary participation in the Clinical Investigation and Research program. SSN and home address will be used for identification and locating purposes.

Routine Uses: The SSN and home address will be used for identification and locating purposes. Information derived from the study will be used to document the study; implementation of medical programs; adjudication of claims; and for the mandatory reporting of medical conditions as required by law. Information may be furnished to Federal, State, and local agencies.

Disclosure: The furnishing of your SSN and home address is mandatory and necessary to provide identification and to contact you if future information indicates that your health may be adversely affected. Failure to provide the information may preclude your voluntary participation in this investigational study.

PART A -- VOLUNTEER AFFIDAVIT

Volunteer Subjects in Approved Department of Army Research Studies

Volunteers under the provisions of AR 40-38 and AR 70-25 are authorized all necessary medical care for injury or diseases which is the proximate result of their participation in such studies.

I, _____ SSN _____ ,

having full capacity to consent and having attained my _____ birthday, do hereby

volunteer to participate in *the research protocol, Sound Attenuation of the HGU-56/P Aircrew Integrated Helmet System and HGU-84/P Rotary-Wing Helmet System with the Oregon Aero HushKit™, SoftSeal™, and Combo™"*

under the direction of *William A. Ahroon, Ph.D.*

conducted by *the United States Army Aeromedical Research Laboratory, Fort Rucker, AL 36362-0577*

The implications of my voluntary participation: duration and purpose of the research study; the methods and means by which it is to be conducted; and the inconveniences and hazards that may reasonably be expected have been explained to me by

Dr. William Ahroon, CPT Martin Robinette, Ms. Melinda Hill or Ms. Elmaree Gordon

I have been given an opportunity to ask questions concerning this investigational study. Any such questions were answered to my full and complete satisfaction. Should any further questions arise concerning my rights or study-related injury, I may contact

Dr. Patricia A. LeDuc

at Human Subject Review Committee, U.S. Army Aeromedical Research Laboratory,

Building 6901, P.O. Box 620577, Fort Rucker, Alabama 36362-0577 (334) 255-6872

I understand that I may at any time during the course of the study revoke my consent and withdraw from the study without further penalty or loss of benefits; however I may be required (military volunteer) or requested (civilian volunteer) to undergo certain examinations if, in the opinion of the attending physician, such examinations are necessary for my health and well-being. My refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled.

PART B -- TO BE COMPLETED BY INVESTIGATOR

INSTRUCTIONS FOR ELEMENTS OF INFORMED CONSENT: *(Provide a detailed explanation in accordance with Appendix C, AR 40-38 or AR 70-25.)*

You will be participating in a study to measure the sound attenuation of the HGU-56/P Aircrew Integrated Helmet System and HGU-84/P Rotary-Wing Helmet System with alternative earcup configurations. All testing is performed in accordance with standards promulgated by the American National Standards Institute (ANSI).

To participate in some aspects of this study, you must have normal hearing relative to the definitions set by ANSI You will be given a hearing test by a certified audiologist or hearing conservationist before your participation in the study. You also will complete a general health screening questionnaire which will include questions on your hearing. Following this introduction, you will be trained in the psychophysical procedure to be used in the evaluations of helmet.

The evaluation will be in two parts. The time required to complete all parts of the evaluation will be approximately 10 hours including training for the real-ear evaluation. (Approximately two hours for training and 90 minutes for each device tested.) Testing may be accomplished over several days.

Real-ear evaluation.—During the testing, you will be asked to adjust (using buttons on a control box) the loudness of a narrow band of noise (that sometimes may be like a “chirping” sound) so that the sound is just barely audible. When the sound is just barely audible, you will press the “SET” button and another trial will start. The number of trials for each stimulus type will depend on the stability of your responses. Seven different sounds will be used. At least five practice “audiograms” will be completed before actual data collection on any helmet configuration will begin. A total of four “audiograms” will be conducted for each device, alternating between devices in place and devices removed. For each condition, two measurements with the helmet on and two measurements with the helmet off will be made.

Microphone-in-Real-Ear evaluation.—You will be fitted with earplugs and a miniature microphone will be attached to the outer portion at the earplug. A brief, but loud, sound will be presented from which you will be protected by the earplugs. Next, you will don the helmet and the procedure will be repeated. You will don and doff the helmet three times.

No risk is anticipated for this study. Sounds presented in the real-ear evaluation (Part 1) are soft and present no risk. Noise exposures in the physical-ear evaluation (Part 2) are brief and are well within the allowable limits of 85 dBA L_{eq} for unprotected noise exposure set forth in DODI 6055.12 (1991). The earplugs worn during physical-ear evaluations provide an additional margin of protection from overexposure. Previous studies of this type have not resulted in any particular discomfort or ill effects to the subjects involved.

You will receive no personal benefit from participation in this study. Participation in this study is strictly voluntary, and you have the right to withdraw at any time without adverse consequences or loss of benefit.

The data from your participation in the study will be kept as confidential as possible. Representatives of the U.S. Army Medical Research and Materiel Command may inspect the records of this test and evaluation. Group data will be summarized in reports, but your name will never be identified with any specific data. None of the information obtained from this study which identifies you in any way will be released to a public forum without your express consent.

I have received a copy of this volunteer consent form and have read and fully understand its contents. I am signing this form voluntarily.

□ I do □ do not (*check one and initial*) consent to the inclusion of this form in my outpatient medical treatment record.

SIGNATURE OF VOLUNTEER DATE

PERMANENT ADDRESS OF VOLUNTEER PRINTED NAME OF WITNESS

SIGNATURE OF WITNESS DATE

Appendix B.

General health screening questionnaire.

Volunteer Screening Questionnaire

Name _____ SSN: _____

Age: _____ DOB: _____ Height _____ Weight _____

General Health

Do you feel that you are currently in good health?	NO	YES
Do you have any medical waivers or profiles?	NO	YES
Have you ever had any problems with hearing?	NO	YES
Have you ever had any problems with balance, dizziness, motion sickness, ear pain or ear discharge?	NO	YES
Do you have any allergies?	NO	YES
Are you currently suffering from any illnesses?	NO	YES
Have you taken any medication within the past three days?	NO	YES

Following to be completed by audiologist or audiometric technician only

Earcanal Size: _____ Bitragion width: _____ mm. Head height: _____ mm

Audiometric Screening

Frequency	125	250	500	1000	2000	4000	8000
Pre-test	_____	_____	_____	_____	_____	_____	_____

_____
Audiologist/CAOHC Tech Signature & Date

Following to be completed by aeromedical monitor only

Anatomical Features	GO	NO-GO	Reason for disqualification:
Otoscopic Inspection	GO	NO-GO	
Pretest Audiogram	GO	NO-GO	

_____ _____
Principal Investigator's Signature & Date Medical Monitor's Signature & Date

Appendix C.

Means and standard deviations of the real-ear attenuation threshold of the HGU-56/P Aircrew Integrated Helmet System for all subjects.

Table C-1. Means and standard deviations of the real-ear attenuation at threshold of the HGU-56/P Aircrew Integrated Helmet System (*n*=10).

Table C-2. Means and standard deviations of the real-ear attenuation at threshold of the HGU-56/P Aircrew Integrated Helmet System with the Oregon Aero HushKit™ (*n*=10)**.**

Table C-3. Means and standard deviations of the real-ear attenuation at threshold of the HGU-56/P Aircrew Integrated Helmet System with the Oregon Aero SoftSeal™ with HushKit™ (*n*=10).

Table C-4. Means and standard deviations of the real-ear attenuation at threshold of the HGU-56/P Aircrew Integrated Helmet System with the Oregon Aero SoftSeal/HushKit Combo™ (*n*=10).

Table C-1.

Means and standard deviations of the real-ear attenuation at threshold of the HGU-56/P Aircrew Integrated Helmet System (*n*=10).

	Third-octave band center frequency (kHz)						
Subject	0.125	0.250	0.500	1.000	2.000	4.000	8.000
01	16.75	16.75	24.88	31.38	34.75	45.38	51.50
02	14.75	15.75	21.50	22.38	36.00	42.00	46.63
03	18.00	18.88	22.75	33.25	37.38	43.50	50.50
04	16.63	17.63	23.38	27.38	32.00	38.88	50.13
05	18.13	12.38	21.50	24.63	29.88	38.50	47.75
06	11.63	13.13	17.38	26.63	32.13	39.38	48.63
07	13.88	15.50	20.88	19.50	33.63	37.88	51.25
08	17.25	17.63	26.38	31.13	33.00	38.63	53.25
09	18.01	16.50	21.38	26.38	33.13	42.75	52.95
10	16.50	16.38	21.00	31.38	36.00	40.13	49.25
Mean	16.15	16.05	22.10	27.40	33.79	40.70	50.18
s	2.12	2.01	2.46	4.43	2.26	2.54	2.16

Table C-2.

Means and standard deviations of the real-ear attenuation at threshold of the HGU-56/P Aircrew Integrated Helmet System with the Oregon Aero HushKit™ (*n*=10)**.**

	Third-octave band center frequency (kHz)						
Subject	0.125	0.250	0.500	1.000	2.000	4.000	8.000
01	17.13	18.13	19.25	20.63	33.88	52.63	58.63
02	17.75	18.13	17.38	12.88	33.50	45.88	52.38
03	20.09	18.00	22.75	18.50	34.25	46.50	56.25
04	15.00	17.88	22.25	21.63	31.88	42.75	51.50
05	17.25	15.25	19.00	15.88	29.00	45.75	55.25
06	13.38	15.00	19.25	24.63	32.00	46.38	56.63
06	13.38	15.00	19.25	24.63	32.00	46.38	56.63
08	10.38	15.25	17.00	21.38	32.50	49.25	56.63
09	16.88	16.13	19.25	22.00	33.38	46.38	50.25
10	15.63	16.13	20.75	23.13	30.88	48.00	51.13
Mean	15.68	16.49	19.61	20.53	32.33	46.99	54.53
s	2.77	1.39	1.85	3.78	1.57	2.58	2.93

Table C-3.

Means and standard deviations of the real-ear attenuation at threshold of the HGU-56/P Aircrew Integrated Helmet System with the Oregon Aero SoftSeal™ with HushKit™ (*n*=10).

Subject	0.125	0.250	0.500	1.000	2.000	4.000	8.000
01	18.00	16.50	19.63	30.38	34.50	48.63	59.25
02	15.63	14.38	14.38	18.25	33.38	45.13	53.50
03	19.13	16.25	19.88	24.00	34.25	48.13	59.00
04	14.00	15.38	22.00	24.00	30.00	43.88	53.13
05	16.13	15.88	18.88	22.25	29.63	42.00	54.38
06	16.25	15.75	22.50	27.88	33.00	47.75	61.25
07	12.38	13.50	18.00	19.63	36.13	45.88	57.00
08	15.88	15.75	18.63	23.50	35.25	51.25	60.88
09	16.94	18.13	18.75	21.63	31.63	46.63	52.25
10	18.75	16.38	18.75	29.38	37.75	45.25	57.88
Mean	16.31	15.79	19.14	24.09	33.55	46.45	56.85
s	2.11	1.00	2.52	3.98	2.35	2.94	3.29

Table C-4.

Means and standard deviations of the real-ear attenuation at threshold of the HGU-56/P Aircrew Integrated Helmet System with the Oregon Aero SoftSeal/HushKit Combo™ (*n*=10).

	Third-octave band center frequency (kHz)						
Subject	0.125	0.250	0.500	1.000	2.000	4.000	8.000
01	9.38	8.88	7.25	9.13	24.38	39.50	47.00
02	5.00	4.75	2.25	6.13	22.00	33.00	39.25
03	11.88	9.38	10.88	13.25	24.38	40.50	51.50
04	10.00	10.13	10.38	11.50	22.00	36.00	52.63
05	10.00	8.13	6.75	12.88	26.13	36.38	49.13
06	5.88	7.00	8.88	18.00	21.75	36.25	43.50
07	-0.13	-0.63	4.13	2.13	20.13	31.75	45.25
08	10.63	9.38	11.63	17.13	26.38	42.88	62.38
09	10.75	9.38	10.38	13.13	27.50	37.75	48.75
10	10.25	10.88	10.75	18.50	27.38	39.38	49.75
Mean	8.36	7.73	8.33	12.18	24.20	37.34	48.91
s	3.69	3.41	3.17	5.25	2.62	3.39	6.17

Appendix D.

Occluded and unoccluded thresholds for each trial of the HGU-56/P Aircrew Integrated Helmet System with standard earcup foam and earcup seals.

			Third-octave frequency band (kHz)						
Condition	Subject	Trial	0.125	0.250	0.500	1.000	2.000	4.000	8.000
Unoccluded	1	1	42.75	37.50	23.25	-6.75	-6.25	-2.50	42.75
Occluded	1	1	57.00	54.00	46.00	22.00	27.25	43.25	57.00
Unoccluded	1	2	41.75	36.75	20.25	-10.25	-6.25	-2.50	41.75
Occluded	1	2	61.00	53.75	47.25	23.75	29.75	42.50	61.00
Occluded	2	1	60.25	52.25	44.25	18.75	32.25	45.25	60.25
Unoccluded	2	1	45.75	33.50	19.75	-2.25	-3.50	5.25	45.75
Occluded	2	2	59.75	46.75	37.25	21.25	32.00	47.25	59.75
Unoccluded	2	2	44.75	34.00	18.75	-2.50	-4.25	3.25	44.75
Unoccluded	3	1	40.00	33.50	17.25	-9.50	-4.00	2.50	40.00
Occluded	3	1	58.50	53.25	42.25	25.25	32.50	46.50	58.50
Unoccluded	3	2	42.50	34.25	21.50	-8.25	-1.75	3.25	42.50
Occluded	3	2	60.00	52.25	42.00	23.50	36.50	46.25	60.00
Unoccluded	4	1	39.25	33.50	18.50	-11.50	-7.00	-7.00	39.25
Occluded	4	1	56.50	50.75	41.50	15.00	23.50	32.25	56.50
Unoccluded	4	2	39.25	33.75	17.75	-12.50	-7.75	-6.75	39.25
Occluded	4	2	55.25	51.75	41.50	15.75	25.75	31.75	55.25
Occluded	5	1	59.00	49.75	40.75	18.25	27.50	39.75	59.00
Unoccluded	5	1	40.50	35.25	19.00	-6.50	-1.25	2.25	40.50
Occluded	5	2	58.00	47.00	40.50	18.00	29.75	40.75	58.00
Unoccluded	5	2	40.25	36.75	19.25	-6.50	-1.25	1.25	40.25
Unoccluded	6	1	45.25	35.75	19.00	-14.50	-6.50	-6.50	45.25
Occluded	6	1	55.00	47.50	33.25	13.00	25.75	33.00	55.00
Unoccluded	6	2	40.25	33.00	14.00	-13.00	-5.00	-5.75	40.25
Occluded	6	2	53.75	47.50	34.50	12.75	27.00	33.50	53.75
Occluded	7	1	52.00	47.25	37.50	9.25	28.50	37.50	52.00
Unoccluded	7	1	39.75	32.75	18.25	-10.75	-5.25	0.25	39.75
Occluded	7	2	51.25	47.75	37.75	11.50	29.00	36.00	51.25
Unoccluded	7	2	35.75	31.25	15.25	-7.50	-4.50	-2.50	35.75
Unoccluded	8	1	35.25	31.25	17.25	-15.75	-3.00	-8.00	35.25
Occluded	8	1	53.00	47.50	40.75	16.50	29.75	30.50	53.00
Unoccluded	8	2	39.75	31.00	13.50	-14.00	-1.25	-5.25	39.75
Occluded	8	2	56.50	50.00	42.75	16.00	32.00	33.50	56.50
Occluded	9	1	59.13	53.25	43.25	23.50	40.00	49.25	59.13
Unoccluded	9	1	41.25	36.00	21.75	-3.00	6.25	7.25	41.25
Occluded	9	2	58.88	52.00	41.25	26.00	38.50	48.50	58.88
Unoccluded	9	2	40.75	36.25	20.00	-0.25	6.00	5.00	40.75
Unoccluded	10	1	47.25	39.25	21.75	-5.25	0.50	-0.75	47.25
Occluded	10	1	62.75	55.00	41.50	27.00	35.00	39.75	62.75
Unoccluded	10	2	46.50	39.25	20.50	-4.25	-2.25	1.75	46.50
Occluded	10	2	64.00	56.25	42.75	26.25	35.25	41.50	64.00

Appendix E.

Occluded and unoccluded thresholds for each trial of the HGU-56/P Aircrew Integrated Helmet System with Oregon Aero HushKit™.

			Third-octave frequency band (kHz)						
Condition	Subject	Trial	0.125	0.250	0.500	1.000	2.000	4.000	8.000
Unoccluded	1	1	42.00	36.50	22.50	-6.50	-5.25	-3.50	6.25
Occluded	1	1	59.75	54.25	40.50	13.00	28.00	49.75	65.25
Unoccluded	1	2	44.00	35.75	23.50	-8.00	-5.00	-2.00	9.25
Occluded	1	2	60.50	54.25	44.00	13.75	29.50	50.00	67.50
Occluded	2	1	60.00	51.25	37.25	6.00	30.50	51.75	69.25
Unoccluded	2	1	40.25	31.00	17.00	-7.00	-4.00	2.75	15.25
Occluded	2	2	57.50	47.50	32.50	5.25	28.00	48.50	66.25
Unoccluded	2	2	41.75	31.50	18.00	-7.50	-4.50	5.75	15.50
Unoccluded	3	1	41.50	35.00	18.50	-8.00	-1.50	7.00	8.25
Occluded	3	1	60.43	52.25	41.25	11.50	32.25	52.50	64.50
Unoccluded	3	2	40.50	34.25	18.50	-9.00	-2.00	4.00	6.00
Occluded	3	2	61.75	53.00	41.25	8.50	32.75	51.50	62.25
Unoccluded	4	1	40.00	33.75	20.75	-11.00	-5.75	-4.00	7.50
Occluded	4	1	54.50	51.50	41.75	12.00	25.50	39.75	57.00
Unoccluded	4	2	35.50	31.75	15.50	-11.25	-8.25	-6.50	1.25
Occluded	4	2	51.00	49.75	39.00	9.00	24.25	35.25	54.75
Occluded	5	1	58.00	50.50	37.75	9.50	28.00	46.00	66.75
Unoccluded	5	1	41.00	35.25	17.75	-7.75	-0.75	1.25	11.50
Occluded	5	2	58.50	50.50	38.00	11.00	28.50	45.75	67.25
Unoccluded	5	2	41.00	35.25	20.00	-3.50	-0.75	-1.00	12.00
Unoccluded	6	1	46.25	37.25	20.00	-16.25	-4.50	-3.75	10.25
Occluded	6	1	57.50	51.75	38.50	10.75	28.00	41.50	65.25
Unoccluded	6	2	43.25	37.25	18.75	-10.25	-5.00	-4.25	9.50
Occluded	6	2	58.75	52.75	38.75	12.00	26.50	43.25	67.75
Occluded	7	1	53.25	47.50	36.75	7.50	28.00	41.00	62.75
Unoccluded	7	1	39.00	33.25	19.25	-6.25	-2.50	-1.25	11.00
Occluded	7	2	57.75	49.25	38.00	8.00	28.50	41.50	62.25
Unoccluded	7	2	41.50	33.75	19.00	-5.75	-4.00	1.25	11.25
Unoccluded	8	1	39.25	31.00	18.75	-14.50	-2.50	-9.50	4.75
Occluded	8	1	52.00	48.75	37.75	11.50	31.75	41.00	63.50
Unoccluded	8	2	38.75	30.25	17.50	-8.25	0.25	-6.50	6.50
Occluded	8	2	46.75	43.00	32.50	8.50	31.00	41.50	61.00
Occluded	9	1	59.50	53.50	40.50	19.25	39.50	55.50	54.25
Unoccluded	9	1	41.50	35.25	21.00	-1.75	3.50	5.50	5.25
Occluded	9	2	57.50	51.50	42.75	22.75	38.25	51.25	59.00
Unoccluded	9	2	41.75	37.50	23.75	-0.25	7.50	8.50	7.50
Unoccluded	10	1	46.25	39.75	22.25	-4.75	0.25	1.00	7.50
Occluded	10	1	61.00	54.75	42.50	17.25	32.75	48.00	54.50
Unoccluded	10	2	46.00	38.25	20.00	-4.00	4.75	-0.75	7.50
Occluded	10	2	62.50	55.50	41.25	20.25	34.00	48.25	62.75

Appendix F.

Occluded and unoccluded thresholds for each trial of the HGU-56/P Aircrew Integrated Helmet System with Oregon Aero SoftSeal™ and HushKit™.

			Third-octave frequency band (kHz)						
Condition	Subject	Trial	0.125	0.250	0.500	1.000	2.000	4.000	8.000
Unoccluded	1	1	43.25	37.25	23.25	-7.25	-4.00	0.75	9.75
Occluded	1	1	62.00	55.25	45.00	24.25	31.75	50.75	68.50
Unoccluded	1	2	43.75	39.50	25.75	-6.00	1.75	4.00	12.75
Occluded	1	2	61.00	54.50	43.25	23.25	35.00	51.25	72.50
Occluded	2	1	58.00	44.50	33.00	11.50	29.25	50.00	68.00
Unoccluded	2	1	44.00	30.00	18.75	-8.50	-4.50	4.25	16.50
Occluded	2	2	58.25	44.25	32.00	11.25	28.50	48.75	67.75
Unoccluded	2	2	41.00	30.00	17.50	-5.25	-4.50	4.25	12.25
Unoccluded	3	1	41.50	33.00	18.50	-11.50	-6.00	2.75	6.00
Occluded	3	1	58.75	50.50	38.50	13.50	30.25	51.00	64.00
Unoccluded	3	2	41.00	35.50	17.75	-9.25	-2.50	3.50	7.00
Occluded	3	2	62.00	50.50	37.50	13.75	29.75	51.50	67.00
Unoccluded	4	1	37.50	32.75	16.50	-12.00	-8.00	-7.50	2.25
Occluded	4	1	51.50	47.50	39.00	12.00	21.25	38.00	58.00
Unoccluded	4	2	39.75	34.00	17.75	-10.00	-7.50	-5.25	3.50
Occluded	4	2	53.75	50.00	39.25	14.00	23.25	37.00	54.00
Occluded	5	1	55.75	48.25	38.00	16.00	30.25	43.75	66.00
Unoccluded	5	1	39.25	33.75	18.00	-6.25	-1.00	-0.25	11.25
Occluded	5	2	56.00	50.25	35.25	14.00	30.75	42.25	66.75
Unoccluded	5	2	40.25	33.00	17.50	-8.25	2.75	2.25	12.75
Unoccluded	6	1	40.25	33.75	11.50	-14.75	-5.25	-6.00	5.25
Occluded	6	1	57.75	49.25	36.00	12.75	26.25	40.50	67.00
Unoccluded	6	2	44.25	35.75	16.00	-11.75	-5.75	-6.50	7.00
Occluded	6	2	59.25	51.75	36.50	16.50	28.75	42.50	67.75
Occluded	7	1	52.25	46.25	37.25	13.25	31.75	44.75	67.50
Unoccluded	7	1	39.75	33.25	19.75	-6.50	-4.50	-2.00	10.00
Occluded	7	2	53.50	46.50	37.25	13.50	29.75	43.50	66.50
Unoccluded	7	2	41.25	32.50	18.75	-6.00	-6.25	-1.50	10.00
Unoccluded	8	1	36.75	33.25	18.00	-10.50	-2.25	-8.50	6.50
Occluded	8	1	51.25	48.75	37.75	14.50	33.50	41.75	65.75
Unoccluded	8	2	37.75	30.00	18.75	-11.50	-5.00	-11.00	2.50
Occluded	8	2	55.00	46.00	36.25	10.50	29.75	41.25	65.00
Occluded	9	1	56.38	53.00	40.00	19.00	37.25	51.00	61.50
Unoccluded	9	1	40.50	36.00	20.00	2.25	7.50	5.25	5.00
Occluded	9	2	58.00	55.75	40.25	21.25	41.25	56.75	55.75
Unoccluded	9	2	40.00	36.50	22.75	-5.25	7.75	9.25	7.75
Unoccluded	10	1	47.00	40.25	21.25	-5.75	2.00	1.25	6.50
Occluded	10	1	65.00	56.50	38.50	23.50	38.00	45.00	64.50
Unoccluded	10	2	46.00	39.50	20.00	-5.75	0.25	1.50	8.50
Occluded	10	2	65.50	56.00	40.25	23.75	39.75	48.25	66.25

Appendix G.

Occluded and unoccluded thresholds for each trial of the HGU-56/P Aircrew Integrated Helmet System with Oregon Aero SoftSeal/HushKit Combo™.

			Third-octave frequency band (kHz)						
Condition	Subject	Trial	0.125	0.250	0.500	1.000	2.000	4.000	8.000
Unoccluded	1	1	47.00	40.50	27.25	0.75	0.50	2.50	10.75
Occluded	1	1	55.25	51.00	37.00	8.00	26.50	43.75	57.25
Unoccluded	1	2	44.75	42.00	29.75	-1.75	3.00	5.75	12.00
Occluded	1	2	55.25	49.25	34.50	9.25	25.75	43.50	59.50
Occluded	2	1	48.75	37.25	20.00	0.75	15.50	37.75	55.75
Unoccluded	2	1	41.25	30.00	16.75	-9.00	-9.75	4.75	12.50
Occluded	2	2	44.50	32.25	19.00	-4.25	13.25	37.25	50.25
Unoccluded	2	2	42.00	30.00	17.75	-6.75	-5.50	4.25	15.00
Unoccluded	3	1	40.50	32.75	16.50	-9.00	-4.00	3.00	6.25
Occluded	3	1	52.25	41.50	27.25	4.75	19.75	41.75	58.75
Unoccluded	3	2	42.00	32.50	17.75	-8.25	-2.75	2.75	8.50
Occluded	3	2	54.00	42.50	28.75	4.50	22.25	45.00	59.00
Unoccluded	4	1	36.50	32.25	17.00	-11.75	-8.75	-6.00	3.50
Occluded	4	1	45.75	41.50	28.75	0.75	13.50	28.50	57.25
Unoccluded	4	2	36.50	31.75	17.00	-12.25	-7.50	-7.75	5.50
Occluded	4	2	47.25	42.75	26.00	-1.75	14.25	29.75	57.00
Occluded	5	1	47.75	42.00	23.50	1.50	21.75	35.00	61.75
Unoccluded	5	1	40.75	34.50	17.50	-7.75	-3.25	-3.50	11.25
Occluded	5	2	52.50	43.25	26.25	9.25	25.50	36.00	61.00
Unoccluded	5	2	39.50	34.50	18.75	-7.25	-1.75	1.75	13.25
Occluded	6	1	44.75	37.00	16.25	-13.25	-5.50	-5.25	9.25
Unoccluded	6	1	50.50	43.50	25.75	4.25	20.75	31.50	57.00
Occluded	6	2	44.25	36.50	17.50	-13.50	-5.00	-4.75	9.75
Occluded	6	2	50.25	44.00	25.75	5.00	12.25	31.00	49.00
Unoccluded	7	1	41.75	33.50	22.50	-4.75	16.00	30.50	56.00
Occluded	7	1	41.75	34.50	19.50	-7.50	-7.50	-2.75	10.25
Unoccluded	7	2	41.50	32.00	24.25	-5.25	14.50	28.50	55.25
Unoccluded	7	2	41.75	32.25	19.00	-6.75	-2.25	-1.75	10.50
Occluded	8	1	36.75	29.00	13.50	-14.25	-7.50	-10.00	2.50
Unoccluded	8	1	45.00	37.00	25.25	3.00	21.75	33.75	65.50
Occluded	8	2	36.00	28.25	14.00	-13.00	-5.00	-9.50	1.50
Occluded	8	2	49.00	39.00	25.50	4.00	18.50	32.50	63.25
Unoccluded	9	1	53.75	46.25	33.00	13.25	35.00	46.25	58.00
Occluded	9	1	42.75	35.50	22.00	2.25	8.25	7.25	6.75
Unoccluded	9	2	52.25	47.25	31.50	13.50	33.75	44.50	51.25
Unoccluded	9	2	41.75	39.25	21.75	-1.75	5.50	8.00	5.00
Occluded	10	1	48.00	40.00	25.25	-4.25	0.75	1.75	8.75
Unoccluded	10	1	58.75	53.00	34.75	15.25	27.00	40.50	58.50
Occluded	10	2	48.25	41.75	23.00	-2.50	1.50	2.25	10.25
Occluded	10	2	58.00	50.50	35.00	15.00	30.00	42.25	60.00

Appendix H.

Means and standard deviations of the real-ear attenuation at threshold of the HGU-84/P Rotary-Wing Helmet System for all subjects.

Table H-1.
Means and standard deviations of the real-ear attenuation at threshold of the HGU-84/P Rotary-Wing Helmet System (*n*=10).

	Third-octave band center frequency (kHz)						
Subject	0.125	0.250	0.500	1.000	2.000	4.000	8.000
01	-4.63	5.00	13.88	21.75	31.00	44.25	51.50
02	2.00	4.50	10.50	18.00	30.50	45.50	54.25
03	-0.13	1.75	11.63	18.75	28.38	42.88	42.75
04	-0.75	4.13	10.63	17.63	33.75	43.38	48.75
05	1.75	1.75	12.75	16.25	29.13	43.88	44.50
06	1.63	5.50	15.25	26.75	28.38	48.00	48.38
07	-0.38	-0.38	5.00	13.13	27.13	34.38	36.63
08	-0.88	0.38	8.00	15.38	21.63	26.13	27.25
10	1.63	3.38	8.00	22.75	30.63	34.63	39.38
11	-2.13	1.00	9.25	18.00	26.25	38.50	38.50
Mean	-0.19	2.70	10.49	18.84	28.68	40.15	43.19
s	2.09	2.07	3.07	3.95	3.28	6.68	8.06

Table H-2.

Means and standard deviations of the real-ear attenuation at threshold of the HGU- 84/P Rotary-Wing Helmet System with the Oregon Aero HushKit™ (*n*=10).

	Third-octave band center frequency (kHz)						
Subject	0.125	0.250	0.500	1.000	2.000	4.000	8.000
01	2.63	10.63	13.38	25.38	29.75	45.25	49.00
02	10.00	9.63	14.50	24.13	35.13	47.25	55.13
03	7.13	12.13	17.50	20.88	32.50	44.13	48.25
04	8.00	9.38	16.75	26.00	36.50	46.75	54.13
05	10.50	10.63	19.38	27.25	32.63	48.50	54.00
06	7.13	14.38	17.00	28.13	31.13	49.38	48.50
07	0.00	0.88	6.50	11.75	26.63	38.38	34.63
08	-0.75	1.88	9.00	15.75	28.88	34.00	33.38
10	0.13	2.75	8.63	16.38	29.63	31.63	33.38
11	6.25	4.75	11.50	20.50	35.13	47.00	43.50
Mean	5.10	7.70	13.41	21.61	31.79	43.23	45.39
s	4.25	4.73	4.36	5.53	3.16	6.29	8.72

Table H-3.

Means and standard deviations of the real-ear attenuation at threshold of the HGU-84/P Rotary-Wing Helmet System with the Oregon Aero SoftSeal™ (*n*=10).

	Third-octave band center frequency (kHz)						
Subject	0.125	0.250	0.500	1.000	2.000	4.000	8.000
01	-3.69	1.00	13.50	25.00	28.75	43.13	50.75
02	-0.25	1.00	9.00	20.00	32.38	41.00	49.50
03	-1.50	0.50	11.38	21.38	25.25	38.13	43.50
04	-1.13	1.88	10.88	17.50	30.25	41.25	51.25
05	-2.25	0.50	11.75	21.50	29.13	44.00	49.38
06	-2.38	4.13	9.88	24.38	35.00	44.00	48.88
07	9.38	14.50	17.38	23.38	36.50	43.50	47.75
08	9.63	13.13	17.13	22.50	30.88	35.63	45.75
10	2.50	3.50	10.25	18.50	25.88	35.50	37.25
11	2.88	2.25	11.88	22.38	30.00	46.25	46.00
Mean	1.32	4.24	12.30	21.65	30.40	41.24	47.00
s	4.78	5.20	2.88	2.42	3.56	3.70	4.19

Table H-4.

Means and standard deviations of the real-ear attenuation at threshold of the HGU-84/P Rotary-Wing Helmet System with the Oregon Aero SoftSeal™ with HushKit ™ (*n*=10).

	Third-octave band center frequency (kHz)						
Subject	0.125	0.250	0.500	1.000	2.000	4.000	8.000
01	5.38	11.50	16.88	21.38	31.75	47.50	51.63
02	8.75	6.88	13.50	24.50	31.75	44.63	56.13
03	8.13	9.00	17.50	19.13	30.25	43.00	48.00
04	6.25	11.63	15.50	29.63	38.38	46.88	54.13
06	5.75	10.63	14.13	24.13	33.88	48.13	52.88
06	5.75	10.63	14.13	24.13	33.88	48.13	52.88
07	1.88	1.13	8.00	19.75	32.13	44.25	45.88
08	5.25	9.50	15.13	22.38	33.25	39.88	46.38
10	3.25	6.88	10.38	16.63	26.00	30.88	37.25
11	1.00	0.63	7.88	19.13	30.00	44.25	48.75
Mean	5.14	7.84	13.30	22.08	32.13	43.75	49.39
s	2.48	4.03	3.43	3.72	3.20	5.21	5.46

Table H-5.

Means and standard deviations of the real-ear attenuation at threshold of the HGU-84/P Rotary-Wing Helmet System with the Oregon Aero SoftSeal/HushKit Combo™ (*n*=10).

	Third-octave band center frequency (kHz)						
Subject	0.125	0.250	0.500	1.000	2.000	4.000	8.000
01	0.63	24.50	10.63	18.13	26.25	38.63	48.13
02	7.75	4.38	7.88	13.38	25.38	42.75	53.50
03	3.25	4.88	6.88	15.25	20.50	38.38	34.50
04	5.88	6.50	9.38	21.00	30.38	41.25	49.88
05	8.13	7.63	11.50	15.13	24.63	42.38	49.63
06	7.50	8.50	7.50	18.63	31.13	43.38	48.25
07	3.00	10.25	7.75	18.75	31.38	39.00	39.75
08	3.50	9.38	11.25	19.13	27.13	35.25	43.75
10	-1.88	1.13	7.25	13.63	22.00	28.13	34.00
11	1.50	3.88	8.50	16.13	28.75	42.38	47.00
Mean	3.93	8.10	8.85	16.91	26.75	39.15	44.84
s	3.35	6.40	1.72	2.57	3.74	4.64	6.68

Table H-6.

Means and standard deviations of the real-ear attenuation at threshold of the HGU-84/P Rotary-Wing Helmet System with the Oregon Aero Custom SoftSeal/HushKit Combo™ (*n*=10).

	Third-octave band center frequency (kHz)						
Subject	0.125	0.250	0.500	1.000	2.000	4.000	8.000
01	6.88	7.13	8.88	15.38	25.38	38.63	45.88
02	7.88	5.63	7.88	15.75	26.75	41.63	57.00
03	8.25	8.38	9.25	16.00	25.13	41.13	48.63
04	6.25	11.63	15.50	29.63	38.38	46.88	54.13
05	6.25	8.63	9.88	14.63	33.63	42.25	52.38
06	4.13	4.75	3.88	17.00	27.75	44.00	45.63
07	6.50	7.50	7.00	15.63	28.50	42.50	35.50
08	5.88	5.75	9.63	16.63	31.25	37.13	49.50
10	1.38	3.88	10.50	12.25	31.00	39.50	39.50
11	-0.75	4.50	8.75	14.88	30.13	42.25	45.13
Mean	5.26	6.78	9.11	16.78	29.79	41.59	47.33
s	2.88	2.36	2.93	4.70	4.06	2.76	6.52

Appendix I.

Occluded and unoccluded thresholds for each trial of the HGU-84/P Rotary Wing Helmet System with standard earcup foam and earcup seals.

			Third-octave frequency band (kHz)						
Condition	Subject	Trial	0.125	0.250	0.500	1.000	2.000	4.000	8.000
Occluded	1	1	40.25	40.75	30.50	5.50	25.75	43.75	60.75
Unoccluded	1	1	42.50	35.00	17.00	-15.25	-6.00	-2.75	8.25
Occluded	1	2	39.50	38.50	32.50	9.50	28.75	40.25	60.25
Unoccluded	1	2	46.50	34.25	18.25	-13.25	-1.50	-1.75	9.75
Unoccluded	2	1	37.25	32.25	17.75	-7.00	-2.00	0.00	9.75
Occluded	2	1	39.50	38.50	29.50	10.00	27.75	44.00	64.25
Unoccluded	2	2	39.25	33.25	19.00	-9.00	-2.25	-0.25	10.75
Occluded	2	2	41.00	36.00	28.25	10.00	29.00	46.75	64.75
Occluded	3	1	37.50	36.25	30.00	8.00	22.50	45.25	57.25
Unoccluded	3	1	39.75	33.50	19.00	-11.00	-9.00	1.50	14.00
Occluded	3	2	39.25	35.50	33.50	7.75	18.75	47.25	57.75
Unoccluded	3	2	37.25	34.75	21.25	-10.75	-6.50	5.25	15.50
Unoccluded	4	1	38.75	34.50	22.00	-2.00	-0.25	-1.75	9.75
Occluded	4	1	39.25	37.25	32.50	14.75	33.75	41.50	59.00
Occluded	4	2	37.50	40.25	32.50	14.50	33.00	41.00	57.50
Unoccluded	4	2	39.50	34.75	21.75	-4.00	-0.50	-2.50	9.25
Occluded	5	1	36.50	32.25	27.25	7.25	29.25	40.25	49.75
Unoccluded	5	1	32.75	29.00	13.50	-6.00	-0.50	-3.75	3.00
Occluded	5	2	36.00	32.25	25.50	8.75	27.00	37.25	43.50
Unoccluded	5	2	36.25	32.00	13.75	-10.50	-1.50	-6.50	1.25
Unoccluded	6	1	49.00	37.50	21.00	-5.00	-4.75	-1.50	14.00
Occluded	6	1	50.75	41.50	34.50	18.75	23.50	46.25	60.75
Unoccluded	6	2	51.75	37.75	22.25	-6.25	-3.75	0.50	11.50
Occluded	6	2	53.25	44.75	39.25	23.50	24.75	48.75	61.50
Occluded	7	1	43.50	37.75	27.25	11.75	26.50	38.75	50.25
Unoccluded	7	1	44.25	38.75	23.00	-3.25	-1.00	3.50	10.00
Occluded	7	2	46.00	39.25	26.50	8.25	26.75	37.00	41.25
Unoccluded	7	2	46.00	39.00	20.75	-3.00	0.00	3.50	8.25
Unoccluded	8	1	42.25	32.00	15.25	-9.00	-0.75	-4.75	6.50
Occluded	8	1	41.75	33.75	24.50	8.00	22.50	23.75	35.25
Unoccluded	8	2	41.75	32.25	17.00	-8.75	0.75	-5.00	6.50
Occluded	8	2	40.50	31.25	23.75	5.00	20.75	18.75	32.25
Occluded	10	1	46.00	37.50	29.75	18.25	30.50	35.00	45.25
Unoccluded	10	1	42.25	34.25	20.50	-8.50	-1.00	-0.25	5.25
Occluded	10	2	41.00	37.50	26.50	14.50	29.25	34.00	43.75
Unoccluded	10	2	41.50	34.00	19.75	-4.25	-0.50	0.00	5.00
Unoccluded	11	1	47.00	39.75	22.75	-6.25	-0.25	2.25	14.25
Occluded	11	1	45.50	41.50	33.00	12.75	27.25	40.00	59.00
Unoccluded	11	2	47.00	38.75	21.50	-4.00	0.75	3.50	17.00
Occluded	11	2	44.25	39.00	29.75	13.00	25.75	42.75	49.25

Appendix J.

Occluded and unoccluded thresholds for each trial of the HGU-84/P Rotary-Wing Helmet System with Oregon Aero HushKit™.

			Third-octave frequency band (kHz)						
Condition	Subject	Trial	0.125	0.250	0.500	1.000	2.000	4.000	8.000
Occluded	1	1	47.50	44.00	34.00	15.75	30.50	44.50	61.00
Unoccluded	1	1	43.75	32.75	21.25	-12.25	-2.25	-1.25	9.75
Occluded	1	2	46.75	46.75	35.75	13.00	26.00	43.75	55.75
Unoccluded	1	2	45.25	36.75	21.75	-9.75	-0.75	-1.00	9.00
Unoccluded	2	1	39.50	34.25	18.50	-10.25	-1.00	1.00	10.50
Occluded	2	1	50.50	44.25	32.25	15.75	33.50	49.00	66.75
Unoccluded	2	2	40.50	33.25	18.25	-7.50	-0.50	2.25	11.25
Occluded	2	2	49.50	42.50	33.50	14.75	35.25	48.75	65.25
Occluded	3	1	47.50	47.00	38.25	10.75	27.50	49.50	64.75
Unoccluded	3	1	40.00	32.00	20.25	-8.25	-5.75	3.00	14.50
Occluded	3	2	46.25	42.50	36.25	12.50	24.00	46.75	61.50
Unoccluded	3	2	39.50	33.25	19.25	-10.25	-7.75	5.00	15.25
Unoccluded	4	1	41.25	34.50	21.25	-5.00	-1.50	-1.75	10.25
Occluded	4	1	49.25	43.75	39.25	22.50	36.25	43.75	64.50
Unoccluded	4	2	40.00	34.50	21.75	-2.50	2.50	0.75	11.25
Occluded	4	2	48.00	44.00	37.25	22.00	37.75	48.75	65.25
Occluded	5	1	44.75	38.50	29.00	13.25	28.25	42.00	55.25
Unoccluded	5	1	36.25	29.25	11.50	-15.50	-5.00	-6.75	1.50
Occluded	5	2	45.25	38.75	31.00	14.00	30.00	42.25	56.25
Unoccluded	5	2	32.75	26.75	9.75	-11.75	-2.00	-6.00	2.00
Unoccluded	6	1	47.00	35.00	22.00	-8.00	-0.25	2.50	15.25
Occluded	6	1	56.50	47.25	35.25	20.00	30.25	51.50	61.00
Unoccluded	6	2	48.00	33.25	16.00	-10.25	-5.25	0.00	10.75
Occluded	6	2	52.75	49.75	36.75	18.00	26.50	49.75	62.00
Occluded	7	1	48.75	38.75	29.50	9.75	29.00	41.00	44.75
Unoccluded	7	1	46.75	39.25	21.00	-0.50	4.00	4.00	11.00
Occluded	7	2	48.75	43.75	28.25	12.25	32.50	43.75	44.00
Unoccluded	7	2	50.75	41.50	23.75	-1.00	4.25	4.00	8.50
Unoccluded	8	1	41.00	31.25	16.75	-10.00	-4.25	-6.25	4.25
Occluded	8	1	41.00	33.50	25.75	8.00	25.75	27.75	39.75
Unoccluded	8	2	41.00	32.75	15.50	-7.00	-4.25	-5.75	5.50
Occluded	8	2	39.50	34.25	24.50	6.50	23.50	28.25	36.75
Occluded	10	1	41.75	35.50	25.00	8.75	28.25	28.25	37.25
Unoccluded	10	1	44.25	31.75	15.50	-6.00	-2.75	0.25	5.75
Occluded	10	2	46.00	37.00	26.75	11.75	27.75	35.00	40.50
Unoccluded	10	2	43.25	35.25	19.00	-6.25	-0.50	-0.25	5.25
Unoccluded	11	1	42.25	38.25	21.25	-3.25	3.50	1.50	15.00
Occluded	11	1	49.00	41.25	33.00	14.50	36.25	46.50	52.75
Unoccluded	11	2	43.50	37.75	20.00	-5.25	0.25	1.00	13.25
Occluded	11	2	49.25	44.25	31.25	18.00	37.75	50.00	62.50

Appendix K.

Occluded and unoccluded thresholds for each trial of the HGU-84/P Rotary-Wing Helmet System with Oregon Aero SoftSeal™.

			Third-octave frequency band (kHz)						
Condition	Subject	Trial	0.125	0.250	0.500	1.000	2.000	4.000	8.000
Unoccluded	01	1	40.75	37.25	31.50	13.00	26.50	42.75	62.00
Occluded	01	1	44.75	35.75	19.00	-11.75	-2.50	-0.50	13.00
Unoccluded	01	2	43.50	38.75	33.00	14.25	26.00	40.75	64.25
Unoccluded	01	2	46.88	38.25	18.50	-11.00	-2.50	-2.25	11.75
Occluded	02	1	40.25	34.00	17.50	-10.75	-1.00	2.25	11.00
Unoccluded	02	1	41.00	35.00	26.75	10.50	32.00	43.00	58.75
Occluded	02	2	39.50	35.00	18.75	-8.00	0.00	2.50	10.50
Occluded	02	2	38.25	36.00	27.50	10.75	31.75	43.75	61.75
Unoccluded	03	1	35.25	34.25	32.00	12.00	19.50	41.75	58.25
Occluded	03	1	36.75	33.25	20.75	-10.50	-8.00	4.50	13.50
Unoccluded	03	2	37.00	33.25	31.50	11.00	17.25	42.75	57.50
Unoccluded	03	2	38.50	33.25	20.00	-9.25	-5.75	3.75	15.25
Occluded	04	1	39.50	35.00	23.00	-0.50	2.75	2.00	9.75
Unoccluded	04	1	39.25	38.50	33.00	16.50	33.75	44.25	62.50
Occluded	04	2	40.75	36.25	22.75	-1.50	5.50	2.25	12.25
Occluded	04	2	38.75	36.50	34.50	16.50	35.00	42.50	62.00
Unoccluded	05	1	35.50	32.50	27.25	11.75	26.25	37.75	52.00
Occluded	05	1	37.25	32.75	13.75	-13.00	-4.00	-8.00	-1.75
Unoccluded	05	2	36.50	33.25	25.25	7.25	24.00	35.75	45.75
Unoccluded	05	2	39.25	32.00	15.25	-11.00	-4.00	-6.50	0.75
Occluded	06	1	49.50	37.75	21.25	-7.50	-5.25	2.25	13.75
Unoccluded	06	1	46.75	39.25	29.75	17.75	26.75	45.50	61.75
Occluded	06	2	47.00	41.00	31.25	15.50	31.00	45.75	62.75
Occluded	06	2	49.00	34.25	20.00	-8.00	-7.00	1.00	13.00
Unoccluded	07	1	54.50	51.25	39.00	17.75	37.50	46.00	55.25
Occluded	07	1	47.00	38.50	21.75	-4.25	0.25	3.00	7.75
Unoccluded	07	2	58.25	54.25	40.25	21.25	38.50	48.50	55.50
Unoccluded	07	2	47.00	38.00	22.75	-3.50	2.75	4.50	7.50
Occluded	08	1	38.25	29.75	16.50	-7.75	-1.25	-5.00	4.75
Unoccluded	08	1	50.75	45.00	34.25	15.25	29.25	31.00	51.75
Occluded	08	2	41.50	32.00	16.50	-9.75	-2.00	-4.50	6.00
Occluded	08	2	48.25	43.00	33.00	12.25	29.25	30.75	50.50
Unoccluded	10	1	43.75	36.75	26.75	12.75	26.50	33.00	37.75
Occluded	10	1	42.50	33.75	20.50	-5.75	0.00	2.00	5.25
Unoccluded	10	2	48.00	39.00	33.50	15.00	28.00	41.50	49.00
Unoccluded	10	2	44.25	35.00	19.25	-3.50	2.75	1.50	7.00
Occluded	11	1	44.50	38.50	20.75	-6.25	2.50	2.00	15.00
Unoccluded	11	1	49.00	41.25	32.00	17.00	34.25	48.00	66.50
Occluded	11	2	44.50	37.75	19.50	-4.00	2.00	2.25	15.00
Unoccluded	11	2	45.75	39.50	32.00	17.50	30.25	48.75	55.50

Appendix L.

Occluded and unoccluded thresholds for each trial of the HGU-84/P Rotary-Wing Helmet System with Oregon Aero SoftSeal™ and HushKit™.

			Third-octave frequency band (kHz)						
Condition	Subject	Trial	0.125	0.250	0.500	1.000	2.000	4.000	8.000
Unoccluded	1	1	48.00	46.25	36.00	10.50	27.50	45.75	62.50
Occluded	1	1	44.00	33.25	17.00	-11.00	-2.25	-2.00	11.00
Unoccluded	1	2	52.25	43.25	32.75	12.25	31.75	47.00	62.50
Unoccluded	1	2	45.50	33.25	18.00	-9.00	-2.00	-0.25	10.75
Occluded	2	1	36.25	34.25	15.75	-10.75	-2.75	0.75	11.25
Unoccluded	2	1	44.50	41.25	31.50	14.00	29.75	46.75	68.25
Occluded	2	2	38.50	34.50	19.25	-11.50	-2.00	1.75	12.00
Occluded	2	2	47.75	41.25	30.50	12.75	29.00	45.00	67.25
Unoccluded	3	1	45.50	42.25	36.50	11.75	23.75	47.75	64.00
Occluded	3	1	38.00	33.75	19.25	-7.50	-4.25	6.75	16.00
Unoccluded	3	2	48.25	42.75	36.00	13.50	28.00	50.50	65.50
Unoccluded	3	2	39.50	33.25	18.25	-5.50	-4.50	5.50	17.50
Occluded	4	1	40.00	32.75	20.50	-5.25	-1.00	-1.00	9.75
Unoccluded	4	1	46.00	44.00	37.00	25.00	36.25	46.25	64.50
Occluded	4	2	41.25	35.00	23.25	-3.25	0.25	0.00	10.50
Occluded	4	2	47.75	47.00	37.75	25.75	39.75	46.50	64.00
Unoccluded	5	1	42.25	37.50	27.00	8.00	30.50	44.50	52.00
Occluded	5	1	33.25	27.00	9.25	-10.25	-3.50	-3.50	1.00
Unoccluded	5	2	39.00	36.00	27.50	10.25	32.50	42.50	56.75
Unoccluded	5	2	34.00	28.50	11.00	-12.25	-4.75	-5.25	4.00
Occluded	6	1	45.25	33.50	18.75	-13.50	-7.75	-2.00	9.25
Unoccluded	6	1	52.25	45.25	32.75	10.75	27.75	47.25	64.25
Occluded	6	2	47.25	35.00	19.00	-10.75	-6.50	1.75	13.00
Occluded	6	2	51.75	44.50	33.25	13.25	25.75	48.75	63.75
Unoccluded	7	1	46.25	41.75	32.75	19.50	36.50	47.75	57.00
Occluded	7	1	45.25	41.50	26.00	-0.25	2.50	3.25	11.25
Unoccluded	7	2	50.75	44.75	35.25	19.25	35.50	49.75	58.75
Unoccluded	7	2	48.00	42.75	26.00	-0.50	5.25	5.75	12.75
Occluded	8	1	40.50	32.00	14.75	-9.25	-3.75	-6.25	5.25
Unoccluded	8	1	45.00	40.00	30.50	13.25	30.75	32.25	48.00
Occluded	8	2	44.00	33.00	15.75	-10.75	-1.25	-6.25	4.25
Occluded	8	2	50.00	44.00	30.25	11.50	30.75	35.00	54.25
Unoccluded	10	1	45.75	40.50	29.00	13.00	29.00	32.75	40.75
Occluded	10	1	43.75	34.00	19.50	-3.25	1.00	1.25	5.50
Unoccluded	10	2	48.00	39.75	30.00	13.25	24.75	32.25	46.75
Unoccluded	10	2	43.50	32.50	18.75	-3.75	0.75	2.00	7.50
Occluded	11	1	46.25	39.00	23.25	-7.00	2.75	2.50	15.00
Unoccluded	11	1	48.25	40.75	31.75	12.75	33.00	48.00	63.75
Occluded	11	2	45.00	38.50	21.25	-4.25	3.00	3.00	11.75
Unoccluded	11	2	45.00	38.00	28.50	14.25	32.75	46.00	60.50

Appendix M.

Occluded and unoccluded thresholds for each trial of the HGU-84/P Rotary-Wing Helmet System with Oregon Aero SoftSeal/HushKit Combo™.

			Third-octave frequency band (kHz)						
Condition	Subject	Trial	0.125	0.250	0.500	1.000	2.000	4.000	8.000
Occluded	1	1	45.50	42.25	26.50	10.50	26.50	41.00	57.00
Unoccluded	1	1	46.25	0.00	17.50	-5.25	1.25	1.50	10.00
Occluded	1	2	44.75	43.25	27.00	14.75	27.50	40.00	58.75
Unoccluded	1	2	42.75	36.50	14.75	-5.75	0.25	2.25	9.50
Unoccluded	2	1	38.75	33.75	18.75	-7.25	4.75	3.25	12.75
Occluded	2	1	45.75	38.75	25.50	6.25	28.50	46.25	66.50
Unoccluded	2	2	38.25	35.50	18.00	-8.25	1.25	1.75	11.75
Occluded	2	2	46.75	39.25	27.00	5.00	28.25	44.25	65.00
Occluded	3	1	42.50	37.50	25.75	7.50	16.50	43.00	52.50
Unoccluded	3	1	38.75	33.00	20.00	-7.75	-4.00	4.00	16.75
Occluded	3	2	40.00	38.25	26.75	6.75	17.00	43.75	52.00
Unoccluded	3	2	37.25	33.00	18.75	-8.50	-3.50	6.00	18.75
Unoccluded	4	1	40.25	35.75	24.00	-3.50	1.00	1.50	11.00
Occluded	4	1	45.50	42.50	33.00	17.50	30.75	42.25	63.50
Unoccluded	4	2	39.00	36.00	23.25	-3.50	2.25	0.25	11.50
Occluded	4	2	45.50	42.25	33.00	17.50	33.25	42.00	58.75
Occluded	5	1	43.00	39.00	24.50	2.75	24.50	38.25	54.25
Unoccluded	5	1	36.75	29.75	11.75	-10.00	0.75	-5.00	-0.25
Occluded	5	2	43.00	35.00	23.75	5.50	26.25	37.50	48.00
Unoccluded	5	2	33.00	29.00	13.50	-12.00	0.75	-4.00	3.25
Unoccluded	6	1	47.00	35.25	23.00	-7.25	-7.00	2.50	13.50
Occluded	6	1	52.75	44.75	29.50	10.50	25.50	46.75	61.25
Unoccluded	6	2	44.25	32.50	17.75	-10.75	-7.25	1.00	10.50
Occluded	6	2	53.50	40.00	26.25	8.75	22.50	43.50	59.25
Occluded	7	1	51.50	51.25	33.75	15.75	35.75	43.50	51.50
Unoccluded	7	1	49.25	39.25	25.50	-2.50	4.00	3.75	10.50
Occluded	7	2	49.00	48.75	32.00	15.00	32.25	42.00	49.25
Unoccluded	7	2	45.25	40.25	24.75	-4.25	1.25	3.75	10.75
Unoccluded	8	1	39.75	31.75	18.00	-8.75	-2.50	-6.50	3.75
Occluded	8	1	43.25	38.50	26.75	11.00	22.50	28.75	48.50
Unoccluded	8	2	42.75	27.75	15.00	-10.50	-5.75	-6.75	2.00
Occluded	8	2	46.25	39.75	28.75	8.00	23.50	28.50	44.75
Occluded	10	1	43.25	34.25	24.25	11.50	23.50	27.50	40.00
Unoccluded	10	1	43.25	33.25	18.50	-4.50	2.00	-2.00	3.75
Occluded	10	2	40.75	35.00	26.50	6.25	22.75	28.00	38.00
Unoccluded	10	2	44.50	33.75	17.75	-5.00	0.25	1.25	6.25
Unoccluded	11	1	48.25	37.25	20.50	-7.00	1.50	-0.25	13.25
Occluded	11	1	50.00	42.50	30.75	9.75	28.75	43.25	64.25
Unoccluded	11	2	48.50	40.75	22.25	-3.75	1.50	5.25	15.00
Occluded	11	2	49.75	43.25	29.00	11.75	31.75	46.50	58.00

Appendix N.

Occluded and unoccluded thresholds for each trial of the HGU-84/P Rotary-Wing Helmet System with Oregon Aero Custom SoftSeal/HushKit Combo™.

			Third-octave frequency band (kHz)						
Condition	Subject	Trial	0.125	0.250	0.500	1.000	2.000	4.000	8.000
Occluded	1	1	50.00	39.50	28.50	5.50	26.75	39.50	55.25
Unoccluded	1	1	42.25	37.50	20.75	-11.75	3.75	0.75	11.50
Occluded	1	2	45.25	44.00	26.50	8.75	24.00	37.25	60.25
Unoccluded	1	2	39.25	31.75	16.50	-4.75	-3.75	-1.25	12.25
Unoccluded	2	1	39.00	33.75	18.50	-9.00	0.00	1.25	9.75
Occluded	2	1	46.00	38.25	26.75	7.75	24.75	42.25	65.50
Unoccluded	2	2	37.75	33.50	17.50	-10.25	-0.75	1.75	10.25
Occluded	2	2	46.50	40.25	25.00	4.50	28.00	44.00	68.50
Occluded	3	1	47.50	43.50	31.00	8.75	23.50	47.50	65.25
Unoccluded	3	1	38.00	33.25	21.00	-6.75	-3.00	5.00	14.75
Occluded	3	2	47.50	41.00	30.00	7.00	21.00	44.25	61.25
Unoccluded	3	2	40.50	34.50	21.50	-9.50	-2.75	4.50	14.50
Unoccluded	4	1	38.75	32.25	22.50	-3.00	0.25	-2.75	9.75
Occluded	4	1	47.75	41.25	32.25	15.25	29.25	45.25	61.50
Unoccluded	4	2	39.50	33.75	24.25	-3.00	2.00	0.75	11.50
Occluded	4	2	45.25	44.50	34.00	14.25	29.25	43.25	62.00
Occluded	5	1	43.50	37.50	22.00	4.75	31.75	38.25	55.25
Unoccluded	5	1	36.50	30.50	11.75	-9.25	-2.50	-3.50	2.75
Occluded	5	2	42.50	39.75	22.00	4.75	30.00	39.50	56.25
Unoccluded	5	2	37.00	29.50	12.50	-10.50	-3.00	-3.25	4.00
Unoccluded	6	1	48.75	37.50	22.25	-11.00	-4.75	2.25	15.25
Occluded	6	1	53.50	44.00	24.00	7.75	23.00	48.50	61.75
Unoccluded	6	2	47.25	37.00	21.50	-9.00	-8.25	-1.25	12.75
Occluded	6	2	50.75	40.00	27.50	6.25	19.50	40.50	57.50
Occluded	7	1	53.25	49.75	34.00	15.00	36.50	47.50	51.75
Unoccluded	7	1	46.00	42.75	26.50	-0.75	3.75	3.50	13.00
Occluded	7	2	52.75	48.50	32.75	15.25	31.75	46.75	44.50
Unoccluded	7	2	47.00	40.50	26.25	-0.25	7.50	5.75	12.25
Unoccluded	8	1	39.25	31.25	13.50	-11.50	-4.50	-6.75	2.00
Occluded	8	1	45.25	35.75	24.75	5.75	28.00	33.25	52.75
Unoccluded	8	2	38.50	30.75	16.25	-13.50	-4.25	-5.75	2.00
Occluded	8	2	44.25	37.75	24.25	2.50	25.75	28.50	50.25
Occluded	10	1	44.50	37.50	29.25	9.25	32.00	39.00	47.25
Unoccluded	10	1	42.50	34.75	17.50	-1.75	1.00	-1.25	5.50
Occluded	10	2	44.75	39.25	27.25	9.75	32.75	39.00	43.50
Unoccluded	10	2	44.00	34.25	18.00	-3.75	1.75	0.25	6.25
Unoccluded	11	1	46.50	39.00	21.00	-3.00	4.50	5.25	16.75
Occluded	11	1	48.00	44.75	29.00	13.50	36.25	46.75	61.50
Unoccluded	11	2	48.75	40.25	20.25	0.25	6.25	5.75	15.75
Occluded	11	2	45.75	43.50	29.75	13.50	34.75	48.75	61.25

Appendix O.

Subject head and ear measurement demographics and fitting notes.

Subject demographics and helmet fitting notes.

Subject	Gender	Bitragion width (mm)	Head height (mm)	Ear canal size	HGU-56/P size	Helmet Spacers
1	M	145	140	L / L	S	1 / 1
2	M	138	138	M / M	M	1 / 1
3	M	142	136	M l M	M	1 / 1
4	M	142	148	L / M	M	2 / 2*
5	F	138	136	M / M	M	1, 2T / 1, 2T**
6	M	143	142	ML / ML	M	2 / 3
7	M	139	134	ML / ML	M	2 / 3
8	M	142	142	L / L	L	1 / 2
9	M	159	154	L / L	M	2 ½ / 2
10	M	155	145	L / L	L	1 / 1
11	F	138	136	M / M	M	0 / 0

* Plus an additional thick pad for the SoftSeal/HushKit Combo™, left and right.

** Pads for the HGU-56/P AIHS have standard (2 mm) or thick (4 mm) sizes. All pads except those followed by the "T" are standard-size pads. Measurements do not include the width of the hook and pile attachment.

Subject	Gender	Bitragion width (mm)	Head height (mm)	Ear canal size (L / R)	HGU-84/P size	Helmet Spacers (L / R)
1	M	144	148	L / L	XL	1 / 1
2	M	142	142	L / L	XL	1 / 1
3	M	140	140	L / R	L	1 / 1
4	M	138	138	L / L	L	0 / 0
5	M	140	140	L / L	L	0 / 0
6	F	135	137	M / M	M	2 / 1
7	M	140	142	M / M	L	0 / 0
8	M	142	144	M / L	L	0 / 0
9	M	144	148	L / L	XL	1 / 1
10	M	142	144	L / L	XL	0 / 0
11	M	140	142	L / L	L	0 / 0