



AFRL-RH-WP-TR-2013-0074

**Noise Attenuation Performance of Flight Helmets in Combination with
the Stealth Cup and the
Fully-Articulating Air Bladder System (FAABS)**

**Hilary L. Gallagher
Warfighter Interface Division
Battlespace Acoustics Branch**

**Melissa A. Theis
Oak Ridge Institute for Science and Education
Oak Ridge, TN**

April 2013

Interim Report

Distribution A: Approved for public release; distribution unlimited.

**AIR FORCE RESEARCH LABORATORY
711 HUMAN PERFORMANCE WING,
HUMAN EFFECTIVENESS DIRECTORATE,
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433
AIR FORCE MATERIEL COMMAND
UNITED STATES AIR FORCE**

NOTICE AND SIGNATURE PAGE

Using Government drawings, specifications, or other data included in this document for any purpose other than Government procurement does not in any way obligate the U.S. Government. The fact that the Government formulated or supplied the drawings, specifications, or other data does not license the holder or any other person or corporation; or convey any rights or permission to manufacture, use, or sell any patented invention that may relate to them.

This report was cleared for public release by the 88th Air Base Wing Public Affairs Office and is available to the general public, including foreign nationals.

Qualified requestors may obtain copies of this report from the Defense Technical Information Center (DTIC) (<http://www.dtic.mil>).

AFRL-RH-WP-TR-2013-0074 HAS BEEN REVIEWED AND IS APPROVED FOR PUBLICATION IN ACCORDANCE WITH ASSIGNED DISTRIBUTION STATEMENT.

//signed//

Richard L. McKinley
Work Unit Manager
Battlespace Acoustics Branch

//signed//

Robert C. McKinley
Chief, Battlespace Acoustics Branch
Warfighter Interface Division

//signed//

William E. Russell, Acting Chief
Warfighter Interface Division
Human Effectiveness Directorate
711 Human Performance Wing

This report is published in the interest of scientific and technical information exchange, and its publication does not constitute the Government's approval or disapproval of its ideas or findings.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

1. REPORT DATE (DD-MM-YYYY) 17-04-2013			2. REPORT TYPE Interim		3. DATES COVERED (From - To) July – August 2010	
4. TITLE AND SUBTITLE Noise Attenuation Performance of Flight Helmets in Combination with the Stealth Cup and the Fully-Articulating Air Bladder System (FAABS)					5a. CONTRACT NUMBER FA8650-08-D-6801-0027	
					5b. GRANT NUMBER	
					5c. PROGRAM ELEMENT NUMBER 62202F	
6. AUTHOR(S) Hilary L. Gallagher Melissa A. Theis*					5d. PROJECT NUMBER 7184	
					5e. TASK NUMBER 718416	
					5f. WORK UNIT NUMBER 71841620	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Warfighter Interface Division Battlespace Acoustics Branch Wright-Patterson AFB OH 45433					8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Materiel Command *Oak Ridge Institute for Science Air Force Research Laboratory and Education 711 Human Performance Wing Oak Ridge, TN 37831 Human Effectiveness Directorate Warfighter Interface Division Battlespace Acoustics Branch Wright-Patterson AFB OH 45433					10. SPONSOR/MONITOR'S ACRONYM(S) 711 HPW/RHCB	
					11. SPONSOR/MONITOR'S REPORT NUMBER(S) AFRL-RH-WP-TR-2013-0074	
12. DISTRIBUTION / AVAILABILITY STATEMENT Distribution A: Approved for public release; distribution unlimited.						
13. SUPPLEMENTARY NOTES 88 ABW/PA Cleared 08/26/2013; 88ABW-2013-3824.						
14. ABSTRACT Noise attenuation performance measurements were conducted on the HGU-55/P, HGU-68/P, and HGU-84/P flight helmets in combination with the Stealth Cup and the Fully-Articulating Air Bladder System (FAABS), developed by SPEAR Labs. Measurements were also collected on the helmets' most commonly used earcups and regular shims to facilitate a direct comparison among the same sample of subjects. Passive insertion loss was measured in accordance with ANSI S12.42 while passive noise attenuation was measured in accordance with ANSI S12.6. Four ear cups, including the Stealth Cup, were tested in combination with the HGU-55/P helmet and FAABS. The Stealth Cup was also tested in combination with the HGU-68/P and HGU-84/P flight helmets. The Stealth Cup was an equal, if not better, performer in comparison to currently used earcups across all frequencies. The FAABS was also an equal performer when compared to the currently used shims.						
15. SUBJECT TERMS HGU-55/P, HGU-68/P, HGU-84/P, noise attenuation, passive insertion loss, hearing protection, earcup						
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Hilary Gallagher	
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			SAR	17

THIS PAGE IS INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

1.0	INTRODUCTION.....	1
2.0	METHODS	2
2.1	Subjects	2
2.2	Test Matrix	2
2.3	MIRE – Passive Insertion Loss	3
2.4	REAT – Passive Noise Attenuation	4
3.0	RESULTS	5
3.1	MIRE – Passive Insertion Loss	5
3.2	REAT – Passive Noise Attenuation	8
4.0	DISCUSSION	11
5.0	CONCLUSIONS	11
6.0	REFERENCES.....	11

LIST OF FIGURES

Figure 1. a. Stealth Cup b. Fully-Articulating Air Bladder System (FAABS) 2

Figure 2. Flight Helmets (left to right HGU-55/P, HGU-84/P, and HGU-68/P) and Passive Earcups (left to right Stealth Cup, H-154/AIC, OA Softseal Oval, and the HGU-68/P Standard earcup)..... 3

Figure 3. a. FAABS b. Shim 3

Figure 4. Male subject sitting in test facility at AFRL for MIRE measurement 4

Figure 5. Female subject in REAT facility, open ear condition 4

Figure 6. Mean passive insertion loss comparison of the HGU-55/P and FAABS with four different earcups 5

Figure 7. Mean passive insertion loss comparison of the HGU-55/P with the Stealth Cup and the H-154/AIC..... 6

Figure 8. Mean passive insertion loss comparison of the HGU-68/P with the Stealth Cup and the standard earcup..... 7

Figure 9. Mean passive insertion loss comparison of the HGU-84/P with the Stealth Cup and the standard earcup..... 7

Figure 10. Mean passive insertion loss comparison of the HGU-55/P and the Stealth Cup with and without FAABS 8

Figure 11. Mean passive noise attenuation comparison of the HGU-55/P and Stealth Cup with and without the FAABS..... 9

Figure 12. Mean passive noise attenuation comparison of the HGU-68/P and Stealth Cup with and without the FAABS..... 10

Figure 13. Mean passive noise attenuation comparison of the HGU-84/P and Stealth Cup with and without the FAABS..... 10

LIST OF TABLES

Table 1. Mean and standard deviation noise attenuation data on the HGU-55/P, HGU-68/P, and HGU-84/P and the Stealth Cup with and without FAABS..... 9

EXECUTIVE SUMMARY

Understanding the noise attenuation performance of a flight helmet is important not only to protect the pilot from excessive noise exposure but also to improve communication capabilities. SPEAR Labs designed a new passive earcup called the Stealth Cup as well as an air bladder system called the Fully-Articulating Air Bladder System (FAABS). This system could potentially replace the use of shims which are currently used to create a seal between the earcup and the head of the pilot and improve helmet stability.

Noise attenuation performance measurements were collected at the Air Force Research Laboratory's (AFRL) Battlespace Acoustics Branch at Wright Patterson Air Force Base in July of 2010 on flight helmets worn in combination with the newly designed Stealth Cup and the FAABS. Passive insertion loss was measured using American National Standards Institute (ANSI) S12.42-1995(R2004) Microphone-in-Real-Ear (MIRE) and Acoustic Test Fixture Methods for the Measurement of Insertion Loss of Circumaural Hearing Protection Devices¹, while passive noise attenuation was measured using ANSI S12.6-1997(R2002) Methods for Measuring the Real-Ear Attenuation (REAT) of Hearing Protectors, Method A.² Passive insertion loss measurements were collected first to compare the Stealth Cup to currently used earcups. Four earcups, including the Stealth Cup, were tested in combination with the HGU-55/P helmet and FAABS. The Stealth Cup was also tested in combination with two other flight helmets, the HGU-68/P and HGU-84/P. All measurements were completed using a MBU-20/P mask with visor in the down position. Passive noise attenuation was then measured on the Stealth Cup worn in combination with 3 flight helmets with and without FAABS.

The Stealth Cup provided similar, if not better, protection across all frequencies from 125 to 8000 Hz when compared to the currently worn earcups in the HGU-55/P. The Stealth Cup was also a better performer when comparing the passive insertion loss of the HGU-68/P and HGU-84/P flight helmets with the currently used earcups (measurements collected previously at AFRL in 2008 and 2009 respectively). No noise attenuation differences were found between the use of FAABS and the currently used shims to seal the earcup around the ear in flight helmets.

1.0 INTRODUCTION

The noise attenuation performance of a flight helmet is important to know in order to estimate the pilot noise exposure, while increased attenuation can improve communications by blocking out excessive cockpit noise. The Stealth Cup is a wedge-shaped earcup designed to ensure optimum fit and attenuation performance (Figure 1a). The earcup was designed to balance air volume and material used to enhance attenuation over the currently worn earcups, collectively referred to as "legacy" earcups. The Stealth Cup uses a standard issue earphone element for communication transmission. FAABS (Figure 1b) was created with the goal of improving the earcup seal and helmet stability by using an equalizing bladder that is independent of the actual ear seal. The system was intended to increase comfort and helmet fit by giving the pilot the ability to adjust the

inflation of the bladder. Active duty pilots have expressed the desire to be able to release some of the pressure on their head created by the helmet during a mission for a brief period, which has the potential to positively impact the pilot's comfort and mental state. The objective of this study was to evaluate the noise attenuation performance of the Stealth Cup and the FAABS in conjunction with flight helmets and compare the attenuation performance of these configurations to the legacy earcups and shims currently in use.



Figure 1. a. Stealth Cup b. Fully-Articulating Air Bladder System (FAABS)

2.0 METHODS

2.1 Subjects

Ten paid volunteer subjects (6 male, 4 female) participated in the noise attenuation performance measurements. All subjects had hearing threshold levels less than or equal to 15 dB hearing level (HL) from 125 to 8000 Hz. The ten subjects ranged in age from 19 to 26 with a mean age of 23 years.

2.2 Test Matrix

Passive insertion loss measurements, using the MIRE method, were collected on the HGU-55/P helmet and FAABS worn in combination with four earcups: the newly designed Stealth Cup, the standard HGU-55/P earcup called the H-154/AIC, the standard HGU-84/P earcup called the Oregon Aero (OA) Softseal Oval Cup, and the HGU-68/P standard earcup (Figure 2). Passive insertion loss measurements using the MIRE method were also collected with the HGU-55/P, HGU-68/P, and HGU-84/P flight helmets (Figure 2), with the Stealth Cup (Figure 3a) and regular shims (Figure 3b). Measurements for all flight helmets were completed using a MBU-20/P mask with visor in the down position. Passive noise attenuation using the REAT method was then measured on all flight helmets and the Stealth Cup with and without FAABS.



Figure 2. Flight Helmets (left to right HGU-55/P, HGU-84/P, and HGU-68/P) and Passive Earcups (left to right Stealth Cup, H-154/AIC, OA Softseal Oval, and the HGU-68/P Standard earcup)



Figure 3. a. FAABS b. Shim

2.3 MIRE – Passive Insertion Loss

The AFRL MIRE facility was used to measure the passive insertion loss of hearing protectors (Figure 4). Insertion loss was defined as the algebraic difference in dB between the sound pressure levels (SPL) measured at a reference point with and without the hearing protection device in place. The facility and measurements were operated in accordance with ANSI S12.42-1995(R2004).¹ Miniature microphones (Knowles model BT-1759) were used to simultaneously measure the SPL at the entrance of both ear canals. 105 dB overall SPL was generated and two objective measurements were collected to complete one trial: open ear and occluded ear. Three such measurements were collected per subject according to the standard. For each subject, the mean of these three measurements was computed for both the open and occluded ear conditions. Average insertion loss for the ten subjects was then calculated for each configuration.



Figure 4. Male subject sitting in test facility at AFRL for MIRE measurement

2.4 REAT – Passive Noise Attenuation

The AFRL REAT facility was used to measure the passive attenuation performance of hearing protectors. The facility was built for the measurement, analysis, and documentation of the sound attenuation properties of passive hearing protection devices. The chamber, its instrumentation, and measurement procedures were in accordance with ANSI S12.6-1997(R2002).² The procedures described in ANSI S12.6 consist of measuring the open ear (without the hearing protector, Figure 5) and occluded ear (with the hearing protector) hearing thresholds of human subjects using a von Békésy tracking task. These psychoacoustic thresholds were measured two times for the open condition and two times for the occluded condition. The real-ear attenuation at threshold for each subject was computed at each frequency, 125 to 8000 Hz, by averaging the two trials (the difference between open and occluded ear hearing thresholds). The mean and standard deviation at each frequency was then calculated across all the subjects.



Figure 5. Female subject in REAT facility, open ear condition

3.0 RESULTS

Passive insertion loss measurements using ANSI S12.42 methods and passive noise attenuation measurements using ANSI S12.6 methods were collected on the HGU-55/P, the HGU-68/P, and the HGU-84/P flight helmets. The attenuation of the Stealth Cup in configuration with the flight helmets was collected and compared to the legacy earcups: H-154/AIC, OA Softseal Oval, and the HGU-68/P Standard Cup (Figures 6-9). The attenuation of the FAABS in conjunction with the HGU-55/P was collected and compared to the use of regular shims (Figure 10).

3.1 MIRE – Passive Insertion Loss

Passive insertion loss data were collected in the MIRE facility at AFRL to compare the performance of four different earcups in the HGU-55/P with FAABS. Mean insertion loss data from 125-8000 Hz are shown graphically in Figure 6. The SPEAR Labs Stealth Cup provided more protection in the lower frequencies, 125-1000 Hz, and similar protection in the upper frequencies when compared to the legacy earcups.

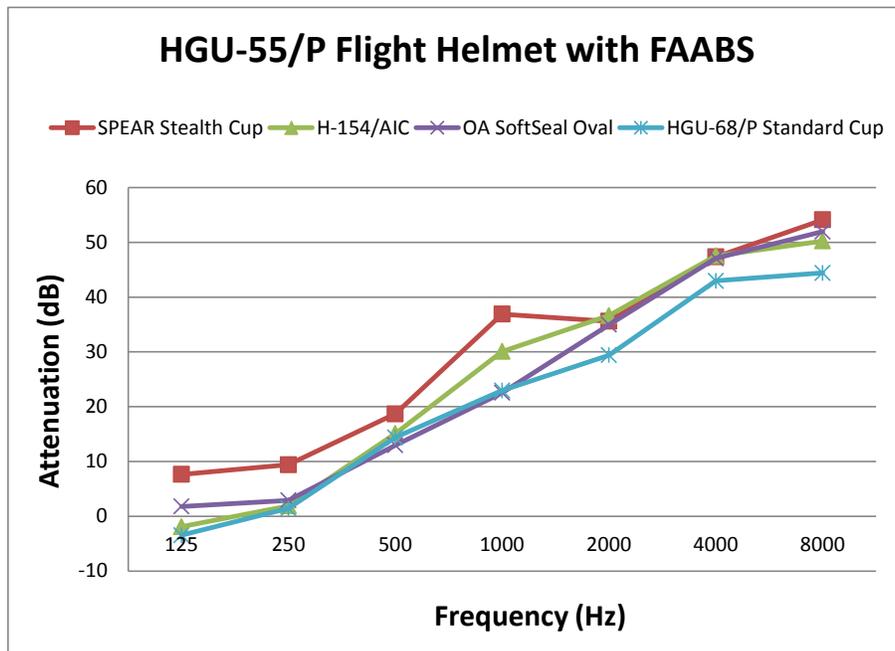


Figure 6. Mean passive insertion loss comparison of the HGU-55/P and FAABS with four different earcups

Passive insertion loss data were then collected in the MIRE facility at AFRL on the HGU-55/P, HGU-68/P, and HGU-84/P with the Stealth Earcup and regular shims. Mean data from 125-8000 Hz are shown in Figure 7 to compare the HGU-55/P with the Stealth Cup and the H-154/AIC. The Stealth Cup provided better or comparable insertion loss results than the legacy earcup from 125 – 1000 Hz and 8000 Hz while the H-154/AIC provided better or comparable insertion loss results than the Stealth Cup at 2000 and 4000 Hz.

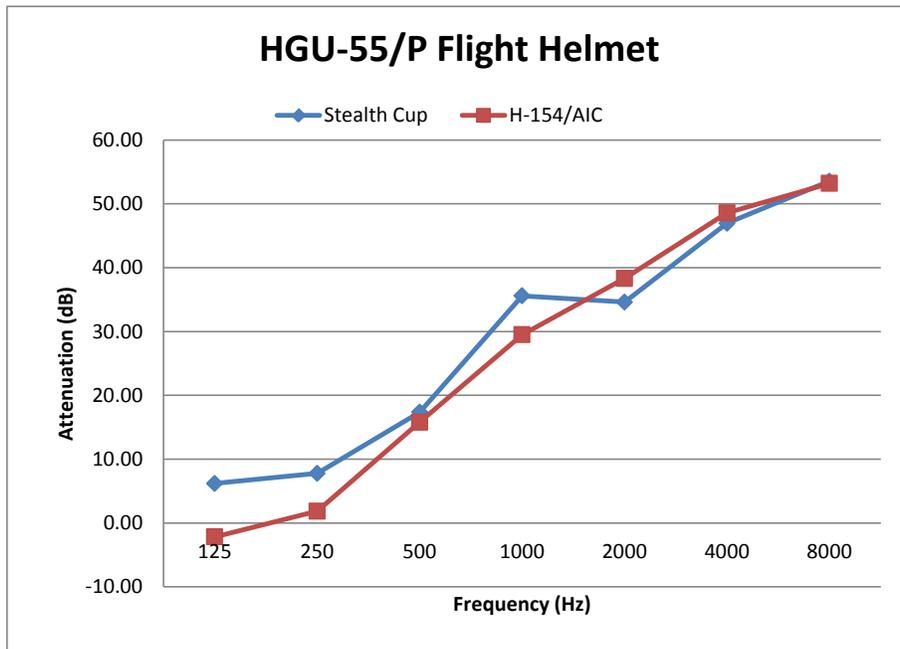


Figure 7. Mean passive insertion loss comparison of the HGU-55/P with the Stealth Cup and the H-154/AIC

Passive insertion loss data were also collected on the HGU-68/P and HGU-84/P with the Stealth Earcup and regular shims. Limited time and resources did not permit additional measurements of these flight helmets with their legacy earcups for a comparison with the same set of subjects. However, these measurements have been collected in our lab during previous studies and are plotted here to compare the insertion loss of each helmet with different earcups. Mean data from 125-8000 Hz are shown in Figures 8-9 for the HGU-68/P and the HGU-84/P respectively. The Stealth Cup performed equally, if not better, across all frequencies when compared to the legacy earcups.

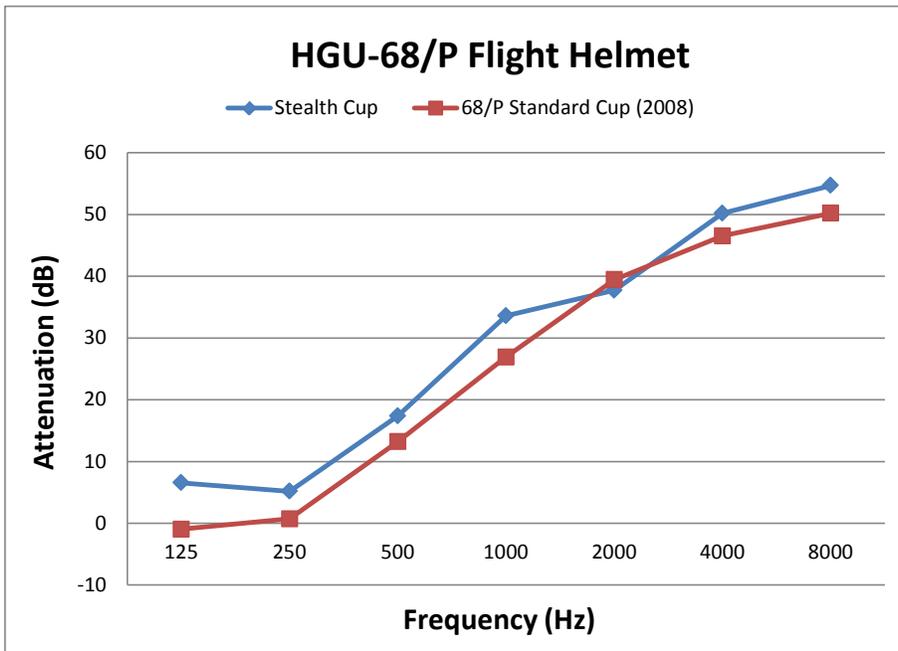


Figure 8. Mean passive insertion loss comparison of the HGU-68/P with the Stealth Cup and the standard earcup

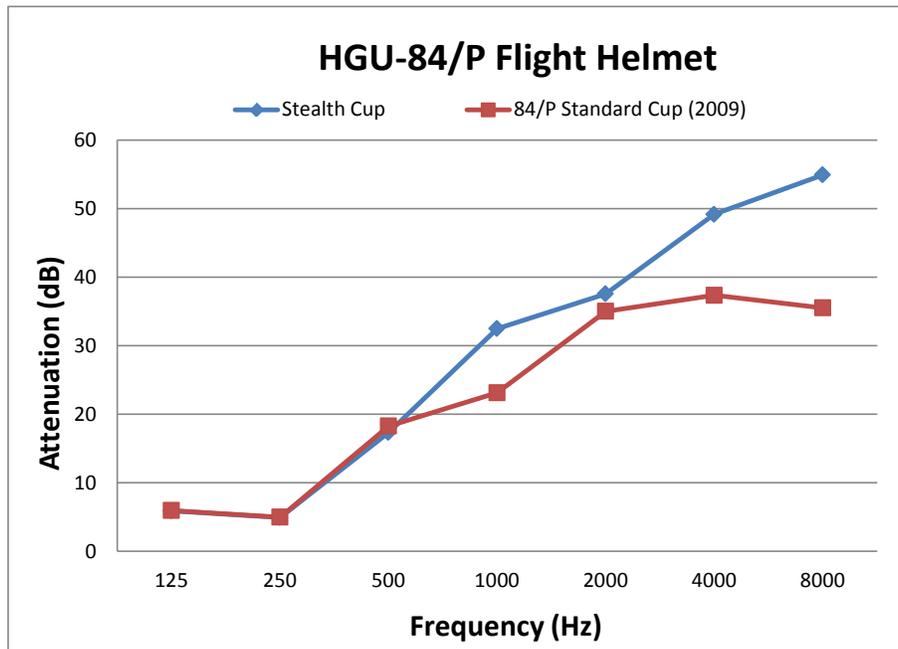


Figure 9. Mean passive insertion loss comparison of the HGU-84/P with the Stealth Cup and the standard earcup

The passive insertion loss of the HGU-55/P was collected in combination with the Stealth Cup with and without FAABS (Figure 10). There is essentially no difference when comparing the use of FAABS and the currently used shims in the HGU-55/P with the Stealth Cup from 125 – 8000 Hz.

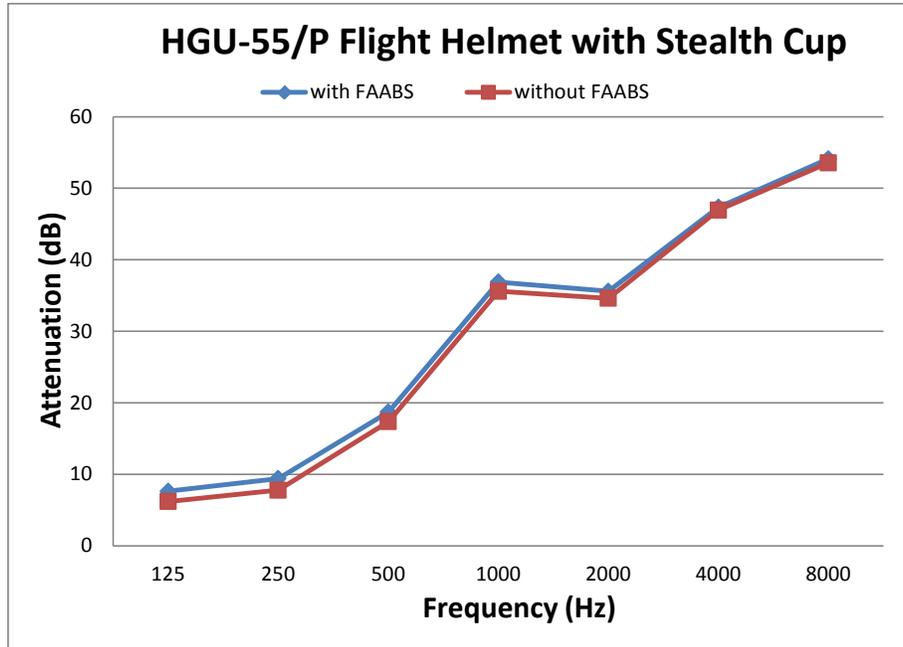


Figure 10. Mean passive insertion loss comparison of the HGU-55/P and the Stealth Cup with and without FAABS

3.2 REAT – Passive Noise Attenuation

Passive noise attenuation data were measured on the Stealth Cup with and without the FAABS in the HGU-55/P, HGU-68/P, and the HGU-84/P flight helmets at AFRL’s REAT facility. Mean and standard deviation results from 125-8000 Hz are shown numerically in Table 1 and the mean results shown graphically in Figures 11-13 for the HGU-55/P, HGU-68/P, and the HGU-84/P respectively. Overall, similar results were found when comparing the noise attenuation of the flight helmets and the Stealth Cup with and without the FAABS.

Table 1. Mean and standard deviation noise attenuation data on the HGU-55/P, HGU-68/P, and HGU-84/P and the Stealth Cup with and without FAABS

Helmet Configuration		Frequency (Hz)						
		125	250	500	1000	2000	4000	8000
HGU-55/P with Stealth Cup	Mean	11	8	12	34	33	42	54
	SD	4	3	4	3	4	4	4
HGU-55/P with Stealth Cup and FAABS	Mean	13	10	15	33	33	42	56
	SD	4	3	5	3	2	4	5
HGU-68/P with Stealth Cup	Mean	10	4	9	30	37	42	56
	SD	4	3	4	3	4	5	3
HGU-68/P with Stealth Cup and FAABS	Mean	12	6	11	28	34	44	53
	SD	4	4	3	5	4	4	4
HGU-84/P with Stealth Cup	Mean	12	4	8	27	35	41	57
	SD	4	2	2	4	3	4	4
HGU-84/P with Stealth Cup and FAABS	Mean	11	7	10	28	37	42	57
	SD	5	4	4	4	3	4	2

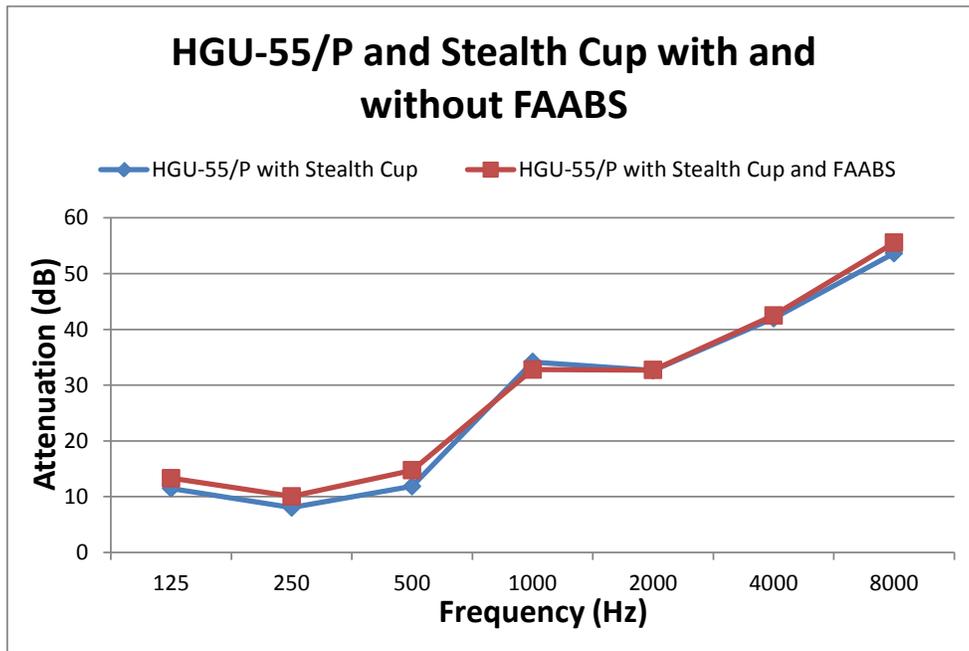


Figure 11. Mean passive noise attenuation comparison of the HGU-55/P and Stealth Cup with and without the FAABS

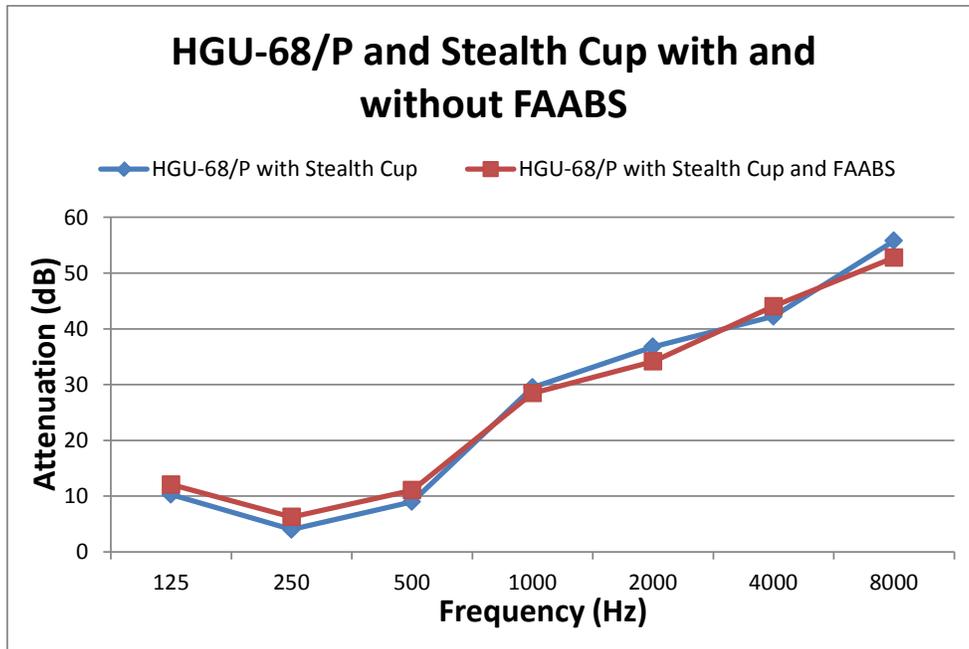


Figure 12. Mean passive noise attenuation comparison of the HGU-68/P and Stealth Cup with and without the FAABS

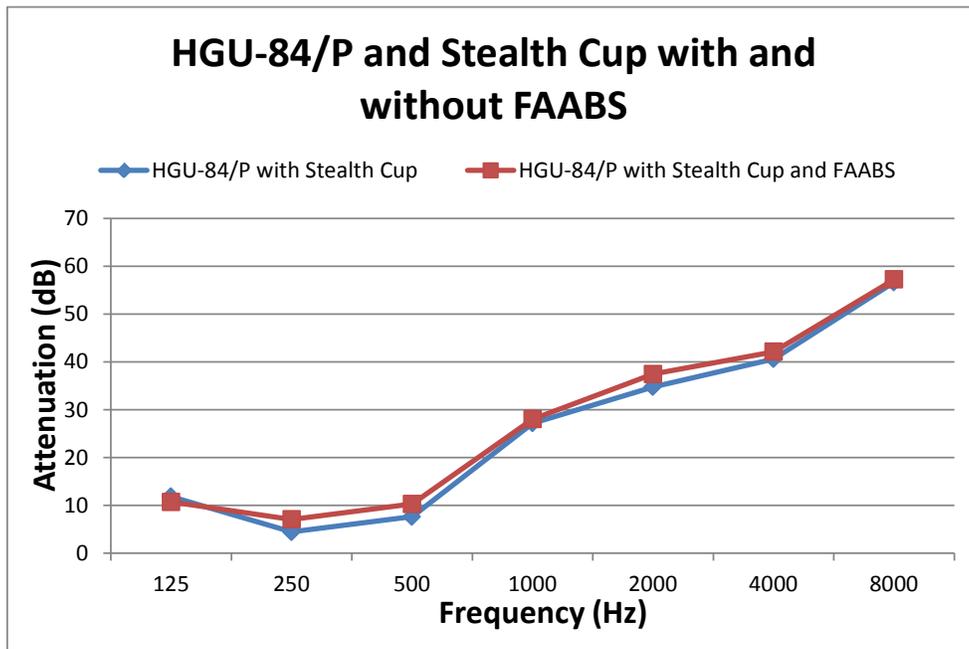


Figure 13. Mean passive noise attenuation comparison of the HGU-84/P and Stealth Cup with and without the FAABS

4.0 DISCUSSION

Both MIRE and REAT methods were used to collect noise attenuation performance data. MIRE methods are objective measurements and were developed for engineering controls and product development/assurance. REAT methods are psychoacoustic measurements and the data can be used in conjunction with the applicable service-specific and/or Department of Defense (DoD) hearing conservation program regulations to estimate the noise level at the ear of the user and, when integrated with the exposure time, to estimate the noise dose.

Regardless of the test methodology, similar noise attenuation results were found when comparing the helmet configurations with and without FAABS (using current shims). Future studies should evaluate the attenuation performance of the system with the bladder “deflated” to determine the level of decreased attenuation performance of the system for the brief time that pilots might relieve the pressure of the helmet in flight. The potential for improving the comfort of the flight helmet using the FAABS should also be examined.

5.0 CONCLUSIONS

Passive insertion loss (MIRE) data and passive noise attenuation (REAT) data were collected on the HGU-55/P, HGU-68/P and the HGU-84/P in conjunction with the Stealth Cup and the FAABS. Overall, the Stealth Cup proved to be an equal, if not better, protector than the earcups that are currently used in the HGU-55/P, HGU-68/P, and the HGU-84/P flight helmets. When comparing the noise attenuation performance of the helmets with FAABS versus shims, similar results were found. The REAT data presented in this report are suitable for use in noise exposure calculations for the DoD and individual service hearing conservation programs.

6.0 REFERENCES

1. ANSI S12.42-1995(R2004) American National Standard for Microphone-in-real-ear and Acoustic Test Fixture Methods for the Measurement of Insertion Loss of Circumaural Hearing Protection Devices.
2. ANSI S12.6-1997(R2002) American National Standard Methods for Measuring the Real-Ear Attenuation of Hearing Protectors.