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Joint Service Aircrew Mask (JSAM) – Tactical Aircraft (TA) A/P22P-14A Respirator Assembly (V)5: Speech Intelligibility Performance with Double Hearing Protection, HGU-84/P Flight Helmet

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14. ABSTRACT

Speech intelligibility measurements were conducted in accordance with American National Standards Institute (ANSI) S3.2-2009 Method for Measuring the Intelligibility of Speech over Communication Systems on the Joint Service Aircrew Mask–Tactical Aircraft (JSAM-TA) A/P22P-14A Respirator Assembly (V)5 with the HGU-84/P flight helmet in combination with Communications Earplug (CEP) and 3M EAR Classic™ foam earplugs. The objective of these measurements was to determine if the JSAM-TA performance requirements were met when double hearing protection was used. The JSAM-TA Respirator Assembly (V)5, when worn with the HGU-84/P and both CEP and EAR Classic™, met the speech intelligibility requirement (≥ 80%) for low-noise environments, when using a torso-mounted Intercommunications Unit (ICU) (V)5, with scores of 93.0% and 88.5%, respectively. In high-noise environments, when hardwired via torso-mounted Communications Control Unit (CCU), speech intelligibility requirements were met for CEP with a score for 96.3% at 115 decibels (dB) and for EAR Classic™ with a score of 88.9% at 105 dB.

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EXECUTIVE SUMMARY

The noise environment in the cockpit of military aircraft can be hazardous to hearing and degrade speech communication performance. Hearing protection and communication devices are required for pilots to sustain mission effectiveness and reduce the risk of hearing loss and hearing related disabilities. Flight helmets, when coupled with an oxygen mask, protect the pilot from potentially hazardous noise exposure and provide effective speech communication while providing impact protection and oxygen to the pilot. Chemical/biological/radiological (CBR) protective equipment may also be required to protect aircrew in an actual or potential CBR warfare environment. Wearing CBR protective equipment under a flight helmet could potentially degrade the noise attenuation performance of the helmet and earcups and therefore degrade speech communication capability. The use of double hearing protection, an earplug worn under the earcups in the helmet, in the form of a communication earplug or passive earplug, has been employed to combat this potential problem and to provide additional attenuation and/or communication capability.

Speech intelligibility measurements were collected in accordance with American National Standards Institute (ANSI) S3.2 Method for Measuring the Intelligibility of Speech over Communication Systems[1] for the Joint Service Aircrew Mask-Tactical Aircraft (JSAM-TA) A/P22P-14A Respirator Assembly (V)5 with the HGU-84/P flight helmet with Communications Earplug (CEP) and 3M EAR Classic™ foam earplugs. Measurements were conducted at the Air Force Research Laboratory's (AFRL) bioacoustics facilities at Wright-Patterson Air Force Base from December 2016 to January 2017. Speech intelligibility results were used to determine if the JSAM-TA Joint Program Office (JPO) requirements were met for ground and in-flight operations. In low-noise environments, when using a torso-mounted Intercommunications Unit (ICU) (V)5, the speech intelligibility performance of the JSAM-TA Respirator Assembly (V)5 and the HGU-84/P, with both CEP and EAR Classic™ foam earplugs, met the JSAM-TA requirement for speech intelligibility with scores of 93.0% and 88.5%, respectively. In high-noise environments, when hardwired via torso-mounted Communications Control Unit (CCU), speech intelligibility requirements were met for CEP with a score for 96.3% at 115 decibels, A-weighted (dBA) and for EAR Classic™ with a score of 88.9% at 105 dBA.

1.0 INTRODUCTION

The noise environment in the cockpit of military aircraft can be hazardous to hearing and degrade speech communication performance. Hearing protection and communication devices are required for pilots to sustain mission effectiveness and reduce the risk of hearing loss and hearing related disabilities. Flight helmets, when coupled with an oxygen mask, protect the pilot from potentially hazardous noise exposure and provide effective speech communication while providing impact protection and oxygen to the pilot. CBR protective equipment may also be required to protect aircrew in an actual or potential CBR warfare environment. Wearing CBR protective equipment under a flight helmet could potentially degrade the noise attenuation performance of the helmet and earcups and therefore degrade speech communication capability. The use of double hearing protection, an earplug worn under the earcups in the helmet, in the form of a communication earplug or passive earplug, has been employed to combat this potential problem and to provide additional attenuation and/or communication capability.

The Gentex HGU-84/P Dual Visor Helmet Assembly was developed for the U.S. Navy and U.S. Marine Corps. The helmet was designed to provide improved comfort, stability, retention, communication, and protection for military aircrew personnel. The HGU-84/P flight helmets used in this study were equipped with OregonAero SoftSeal 3/4" thick earcups, OregonAero ZetaLiner®, single lens safety visor, helmet mounted microphone D6001618, standard helmet assembly bayonets, and a chin strap. The OregonAero SoftSeal 3/4" earcups are an approved replacement to the standard issue leather earcups delivered with the HGU-84/P helmet. The OregonAero ZetaLiner® is designed to be worn between the users head and the Energy Absorbing Liner inside of the helmet. The ZetaLiner® is designed to carry perspiration away from the users head, help reduce skin temperature, limit pressure points, and provide a stable fit. The ZetaLiner® is approved for use with the HGU-84/P helmet in five lengths (12, 13, 14, 15, and 16") and four thicknesses (1/4, 3/8, 1/2, and 5/8"). Speech intelligibility measurements were conducted for the HGU-84/P in CBR configuration only. The HGU-84/P with JSAM-TA Respirator Assembly (V)5 is shown in Figure 1.

Figure 1. HGU-84/P with JSAM-TA Respirator Assembly (V)5 hood

The designated material solution for the JSAM-TA is the A/P22P-14A respirator (currently in use) with incorporated Engineering Change Proposals (ECPs). The ECPs include: four conductor cable pass-through to integrate with CEP, four separate pockets to hold torso assembly and removal of over-vest, 8 inch lower manifold hoses, and anti-stretch retention cords added to the lower manifold hoses. The official nomenclature will be designated at a later time. From this point on, the A/P22P-14A respirator with incorporated ECPs will be referred to as the JSAM-TA Respirator Assembly (V)5. Due to the engineering changes, additional evaluations are required to ensure airworthiness.

The JSAM-TA Respirator Assembly (V)5 (Figure 2) is a chemical, biological, and radiological respirator assembly manufactured by Cam Lock. The respirator assembly consists of a hood and torso assembly. The respirator also includes a rubber hood cowl that incorporates a tear-away component, Advanced Dynamic Oxygen Mask (ADOM), a rubber neck seal, closeable hood outlet valve, and a demist hose. The ADOM oronasal mask includes an articulating visor, inhalation/exhalation valves, microphone assembly part number CL7769, drink facility, inlet hoses, helmet universal bayonets, and a pass-through with plug to attach communication earplugs. The hood assembly is worn under the flight helmet using bayonet receivers to assist in maintaining an oronasal seal. The torso assembly is comprised of various components, including an oxygen hose, demist hose, lower breathing hoses, hose manifolds, pusher fan, pusher fan battery, C2A1 CBR Canister filter for ambient air, C2A1 CBR Canister filter for aircraft oxygen, and ICU (V)5. The respirator was provided in small and large sizes with XL, XS, and XXS sizes available through special order, providing the ability to fit a large range of aircrew.

Figure 2. JSAM-TA Respirator Assembly (V)5 hood (left) and close-up of CEP cable pass-through (right)

The JSAM-TA Respirator Assembly (V)5 provides individual aircrew head/eye, respiratory, and percutaneous protection against CBR warfare agents, radiological particles, and continuous protection against CBR agent permeation. The JSAM-TA Respirator Assembly (V)5 also provides protection against selected toxic industrial chemicals and toxic industrial materials. When integrated with aircraft-mounted and aircrew-mounted breathing equipment, the system provides combined hypoxia and CBR protection. The respirator can also be integrated with other aircraft subsystems, including but not limited to, Aircrew Life Support Systems, portable aircrew systems, restraint systems, sighting systems, and communications systems.

Communication earplugs, like Communications & Hearing Protection, Inc.'s CEP (left panel in Figure 3), and passive earplugs, like the 3M EAR Classic™ (right panel in Figure 3), have been integrated for use with flight helmets in order to improve the noise attenuation and/or speech intelligibility performance of the combined systems. The CEP configuration used for the HGU-84/P measurements was a passive, non-vented hearing protection/communication system, with non-custom foam eartips that support mono audio communication via audio cabling part number CEP508-C15. Comply™ Canal Tips were used for all CEP configurations and were available in four sizes: slim, short, standard, and large. 3M EAR Classic™ earplugs are passive foam earplugs available in two sizes: Classic and Small.

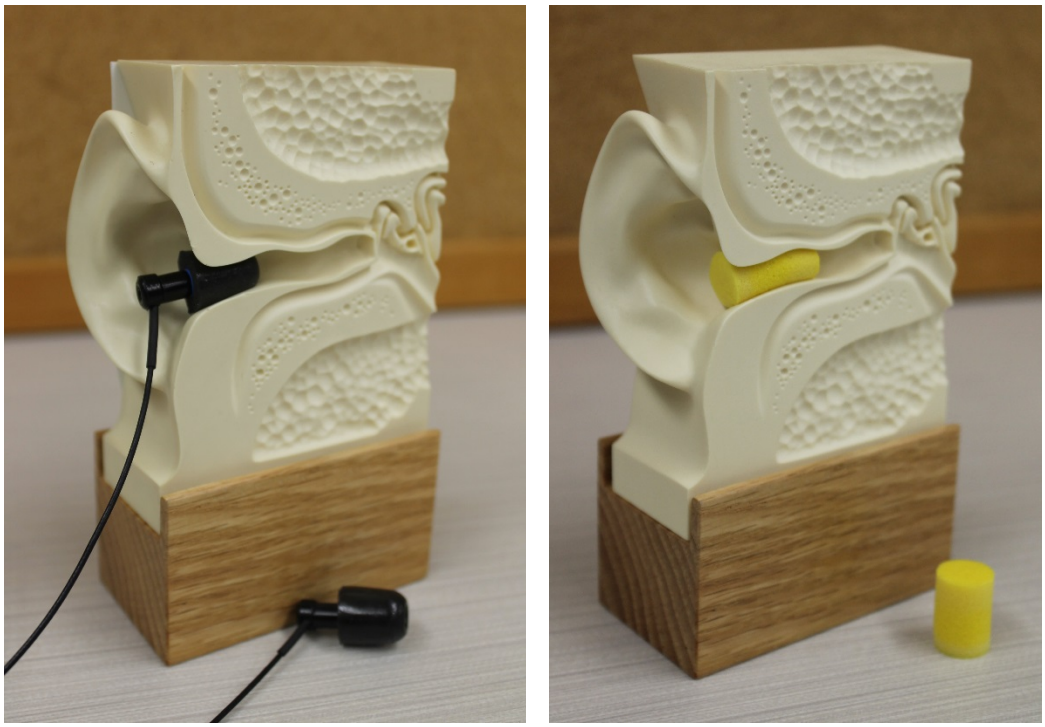

Figure 3. CEP (left) and 3M EAR Classic™ foam earplugs (right)

The objective of this study was to measure the speech intelligibility performance of the JSAM-TA Respirator Assembly (V)5 when donned with the HGU-84/P flight helmet and CEP or 3M EAR Classic™ earplugs to determine if the CBR respirator met the JSAM-TA JPO performance requirements, as defined in the Purchase Description (PD)[2], as shown below. To note, noise attenuation measurements were not conducted for the HGU-84/P and are addressed in the Discussion.

> *Hearing Protection / Noise Attenuation*
> *The JSAM-TA, when integrated with existing head-mounted personal/life support equipment, shall result in no more than a 3 dBA degradation of the measured one-third octave band hearing protection compared to the non-CBR protection configuration.*
>
> *Speech intelligibility (Low-Noise) - 65 dB Background Pink Noise*
> *Ground speech communication should be audible in an environment with 65 dB background pink noise between CBR protected aircrew and unprotected ground personnel at a distance of 1 meter.*
>
> *Speech intelligibility (High-Noise) - 71-115 dB Background Pink Noise*
> *Speech communication should be audible in an environment 71-115 dB Sound Pressure Level (SPL) background pink noise. The speech intelligibility tests shall result in a Modified Rhyme Test (MRT) score as listed below.*
>
> *Speech intelligibility testing shall be measured per ANSI S3.2 for each background pink noise level using a minimum of ten talkers and of ten listeners. The test shall be conducted wearing the JSAM-TA using appropriate communication*

amplification. Test must include the configurations listed in MRT Configurations table below.

MRT Score

Pink Noise Overall Sound Pressure Level (dB SPL)	*Modified Rhyme Test Score (% Correct)*
75	*95*
95	*90*
105	*85*
115	*80*

MRT Configurations

Helmet	*JSAM*	*Earplug*	*Pink Noise Level (dB)*
HGU-84P	*Listener Only*	*CEP*	*65*
HGU-84P	*Listener Only*	*EAR Classic™*	*65*
HGU-68P	*Listener Only*	*CEP*	*65*
HGU-68P	*Listener Only*	*EAR Classic™*	*65*
HGU-55A/P	*Listener Only*	*CEP*	*65*
HGU-55A/P	*Listener Only*	*EAR Classic™*	*65*
HGU-84P	*Talker & Listener*	*CEP*	*115*
HGU-84P	*Talker & Listener*	*CEP*	*105*
HGU-84P	*Talker & Listener*	*EAR Classic™*	*115*
HGU-84P	*Talker & Listener*	*EAR Classic™*	*105*
HGU-68P	*Talker & Listener*	*CEP*	*115*
HGU-68P	*Talker & Listener*	*CEP*	*105*
HGU-68P	*Talker & Listener*	*EAR Classic™*	*115*
HGU-68P	*Talker & Listener*	*EAR Classic™*	*105*
HGU-55A/P	*Talker & Listener*	*CEP*	*115*
HGU-55A/P	*Talker & Listener*	*CEP*	*105*
HGU-55A/P	*Talker & Listener*	*EAR Classic™*	*115*
HGU-55A/P	*Talker & Listener*	*EAR Classic™*	*105*

2.0 METHODS

Speech intelligibility performance measurements were collected with human subjects. There were six male and four female subjects, ranging in age from 19 to 36 years. All subjects were given a technician-administered screening audiogram via the Hughson-Westlake method, and were required to have hearing thresholds within the normal hearing range: 25 dB Hearing Level or better from 125 to 8000 hertz (Hz). The subjects had English as their native language and were trained to participate in the task as both a talker and a listener.

Anthropometric head measurements were collected by a JSAM-TA Subject Matter Expert (SME) for each subject in order to determine the appropriate size for the HGU-84/P flight helmet and JSAM-TA Respirator Assembly (V)5. Sizing adjustments and all helmet and respirator fittings were conducted by the JSAM-TA SME. Each subject fit his/her own earplugs according to the manufacturer's instructions and the sizing and fit were verified by the test administrator. The size of each component of the ensemble employed for each subject is shown in Table 1. Several subjects were sized into larger helmets after the first

series of measurements to accommodate for comfort or fit. All adjustments are noted in parentheses.

Table 1. Subject HGU-84/P, JSAM-TA Respirator Assembly (V)5, CEP, and EAR Classic™ sizing matrix for speech intelligibility

Subject ID#	Gender	HGU-84/P Helmet	Helmet Liner (inches)	Earcup Spacers (centered behind both earcups unless noted otherwise)	JSAM-TA	Comply™ Canal Tip	3M Classic™
15	M	Medium (Large)	12x1/4 (14x3/8)	1/4" shim half pad (no shims)	Small	Standard	Classic
1584	M	Large (X-Large)	14x3/8 (15x3/8)	1/4" shim (no shims)	Small	Large	Classic
1602	F	Medium	12x3/8 (13x1/4)	1/4" shim (no shims)	Small	Large	Classic
1625	M	Large	14x1/2 (14x1/4)	1/4" shim (no shims)	Small	Large	Classic
1629	M	Large (X-Large)	14x3/8 (15x1/2)		Large	Large	Classic
1633	M	Medium (X-Large)	12x3/8 (15x3/8)		Large	Standard	Small
1651	F	Large (X-Large)	14x3/8 (15x3/8)	1/4" shim (1/4" shim, bottom)	Small	Slim	Small
1673	F	Medium (Large)	12x3/8 (14x1/2)		Small	Slim	Small
1674	M	Large	14x3/8 (14x1/4)		Large	Large	Classic
1686	F	Large	14x3/8 (14x1/4)	1/4" shim (no shims)	Small	Slim	Small

The AFRL VOice Communication Research and Evaluation System (VOCRES) facility was used for the speech intelligibility portion of the study. VOCRES was designed to evaluate voice communication effectiveness in operationally-realistic acoustic environments. The facility consists of a programmable, high-power sound system housed in a large reverberant chamber, capable of generating shaped pink noise at levels ranging from 55 to 125 dBA SPL emulating acoustic environments in operational situations. Subject workstations are positioned in the facility (Figure 4), each equipped with a touch-screen display and communication system capable of replicating end-to-end military communication chains (i.e., intercoms, oxygen systems, headsets, microphones, and helmets). In this way, full communication systems, as well as individual system components, may be evaluated under operational conditions to determine the impact these systems might have on speech intelligibility.

Figure 4. AFRL's VOCRES facility used to measure speech intelligibility performance

The MRT was selected for the test material and stimuli were presented by a live talker. The MRT consists of 50, six-word lists of monosyllabic English words. The goal was to quantify the ability of trained listeners to correctly identify target words transmitted by a trained talker using the combination of the helmet, respirator, and earplugs. Cueing of target words for the talker and recording of listener responses were both accomplished via a custom MATLAB 7.0 application. A laptop computer with a graphical user interface was utilized for subject response. The talker and listeners had individual computers at their respective work stations.

Measurements were collected in noise for two different configuration modes: low-noise, or ground configuration mode, and high-noise, or flight configuration mode. Measurements were collected for the helmet and respirator with CEP and EAR Classic™ for both configuration modes. The speech intelligibility measurement configuration matrix is listed in Table 2. The talker and listener were in the same noise environment for all configurations.

Table 2. Speech intelligibility measurement configuration matrix for JSAM-TA Respirator Assembly (V)5 with HGU-84/P and CEP or EAR Classic™

Configuration #	Configuration Mode	JSAM-TA	Earplug Type		Pink Noise Level (dBA)
			CEP	3M Classic™	
1	Ground	Listener Only	x		65
2	Ground	Listener Only		x	65
3	Flight	Talker & Listener	X		95
4	Flight	Talker & Listener	X		105
5	Flight	Talker & Listener	X		115
6	Flight	Talker & Listener		X	95
7	Flight	Talker & Listener		X	105
8	Flight	Talker & Listener		X	115

Low-noise environment measurements were conducted to mimic the operational environment pilots, flight crew, and ground crew may experience on the ground, typically before or after flight. The measurements were conducted with the listener in the JSAM-TA Respirator Assembly (V)5 with the HGU-84/P and either CEP or EAR Classic™ and the talker in the corresponding earplug for passive attenuation only. The subjects were seated at adjacent VOCRES workstations, facing each other, spaced one meter apart, with communication conducted via ICU (V)5 (Figure 5). The Gentex ICU (V)5 is designed to enable clear communication from the pilot to ground crew when a pilot is wearing a JSAM CBR ensemble for ground operations (Figure 6). The talker transmitted his/her voice over-the-air to the listener's torso mounted ICU (V)5. From the ICU (V)5, the signal was presented to the listener via either CEP or HGU-84/P earcups, depending on the device configuration. Additionally, the listeners were encouraged to use visual cues, like lip-reading, to assist with the task. Measurements were conducted with the JSAM-TA blower on to provide demist air to the subjects and simulate ground operations. All measurements in the low-noise environment were collected at 65 dBA.

Figure 5. Subjects sitting one meter apart during a low-noise, over-the-air speech intelligibility measurement

Figure 6. ICU (V)5 (10 volts) used for low-noise speech intelligibility measurements

High-noise environment measurements were conducted to mimic operational environments during flight. Subjects were seated at VOCRES workstations, facing forward, with audio hardwired through a torso mounted CCU (Figure 7). Much like the ICU (V)5, the Gentex CCU is designed to enable clear communication from the pilot to rigger/ground crew when a pilot is wearing a JSAM CBR ensemble (Figure 8). The talker's voice was transmitted from the microphone mounted inside the JSAM-TA Respirator

Assembly (V)5, through the CCU (switched to Hardwire Mode), to the listener via CEP or HGU-84/P earcups, depending on the device configuration. Measurements were conducted with the JSAM-TA blower off. Supplemental breathing air was provided by connecting the JSAM-TA oxygen hose to the facility's supplied air system to simulate flight operations. Measurements in the high-noise environment were collected at 95, 105 and 115 dBA.

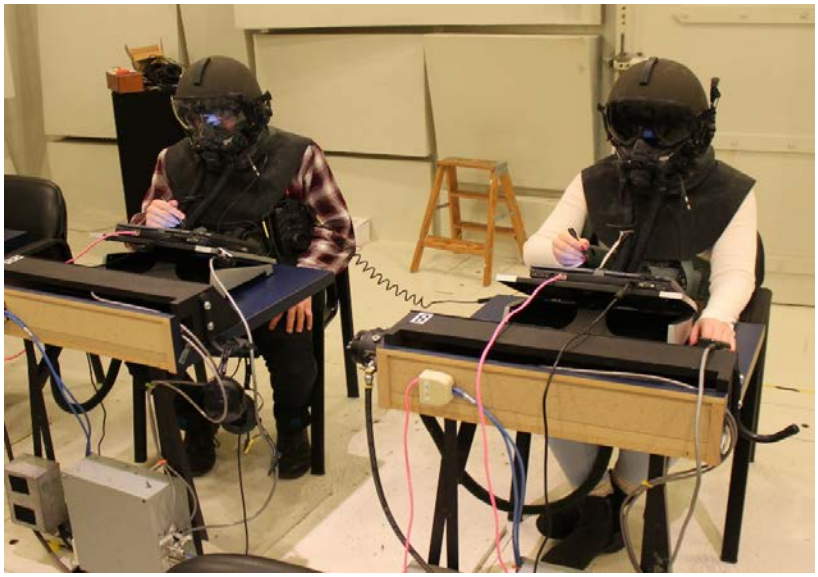

Figure 7. Subjects communicating via CCU for a high-noise, hardwired speech intelligibility measurement

Figure 8. CCU used for high-noise speech intelligibility measurements

A CCU was used in place of the facility's intercommunication system, Aircraft Intercom (AIC)-25, as a result of incompatibility between the AIC-25 and the JSAM-TA Respirator Assembly (V)5's microphone. The microphone assembly part number CL7769 inside the respirator requires 10 volts of external power, which is not supplied by the AIC-25. In a 2015 study conducted at AFRL, both the CCU and AIC-25 were used for speech intelligibility measurements for the JSAM-Joint Strike Fighter respirator with CEP. At 115 dBA, performance across the CCU and AIC-25 varied by < 1 dB¸ with mean speech intelligibility scores of 89.3% and 88.6%, respectively[3]. Due to time limitations, it was at the discretion of the lab and JPO to proceed with the CCU for all high-noise environment speech intelligibility measurements with the HGU-84/P.

Measurements were conducted in accordance with ANSI S3.2 Method for Measuring the Intelligibility of Speech over Communication Systems[1] with the exception of the number of subjects. Lengthy donning and doffing times and a limited number of helmets and respirators reduced the number of subjects to one talker and one listener at a time.

Ten subjects were divided into five pairs, with each subject in the pair acting as a talker for three MRT lists and as a listener for three MRT lists in a single session, per configuration. During the experimental task, the talker was presented with the stimulus on the computer screen ("You will mark MRT word please"). The talker then communicated the phrase to the listener via ICU (V)5 or CCU, depending on configuration. Listeners selected the word heard by using a pen to click on the correct word from a list of six words on the tablet screen. Responses were recorded and an average score was calculated. An example of the MRT format for the talker and listener workstations is provided in Figure 9.

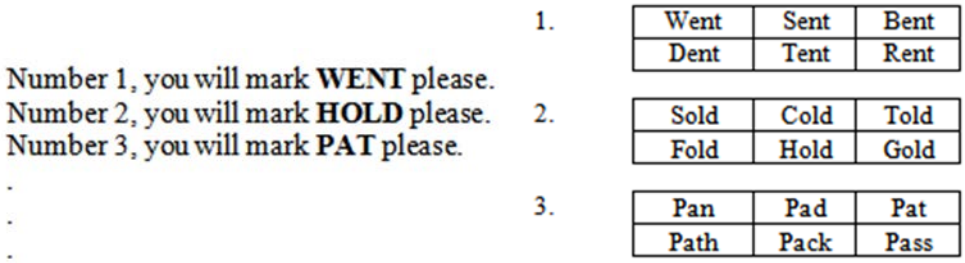

Figure 9. Examples of the talker prompt (left) and listener ensemble (right)

3.0 RESULTS

Results were combined for all subjects per configuration. The subjects' scores were adjusted for guessing as described in ANSI S3.2 and the equation below. An overall average was then calculated for all subjects per configuration, Table 3.

$$Score = 2(R - \frac{W}{n-1})$$

Where:

Score	=	Percent Correct (Adjusted For Guessing)
R	=	Number Correct
W	=	Number Incorrect
n	=	6 (number of choices available to listener)

Table 3. Speech intelligibility performance of JSAM-TA Respirator Assembly (V)5 with HGU-84/P and CEP or EAR Classic™

Configuration #	Configuration Mode	JSAM-TA	Earplug Type		Pink Noise Level (dBA)	Score (%)
			CEP	3M Classic™		
1	Ground	Listener Only	x		65	93.0
2	Ground	Listener Only		x	65	88.5
5	Flight	Talker & Listener	X		115	96.3
6	Flight	Talker & Listener		X	95	91.0
7	Flight	Talker & Listener		X	105	88.9
8	Flight	Talker & Listener		X	115	73.1

In the low-noise environment, speech intelligibility for the JSAM-TA Respirator Assembly (V)5 with the HGU-84/P flight helmet and CEP configuration was 93.0%. Speech intelligibility in the same respirator/helmet configuration with the EAR Classic™ earplug was 88.5%. The JSAM-TA PD did not give any direct guidance for speech intelligibility performance thresholds in low-noise environments so the threshold set by the Department of Defense (DoD) MIL-STD-1474E was used the determine JSAM-TA JPO compliance in low-noise: $\geq 80\%$[4]. The speech intelligibility scores for JSAM-TA Respirator Assembly (V)5 with HGU-84/P exceeded the JSAM-TA JPO performance requirements for both earplug configurations in low-noise environments.

For the high-noise environment, the JSAM-TA performance requirement listed four measurement levels: 75, 95, 105, and 115 dBA. If the subjects were able to achieve scores $\geq$ the threshold set by the requirement for a particular dB level, performance at all lower SPLs was considered acceptable and measurements for that configuration would be complete. A few test trials were completed with each configuration at test levels 95, 105, and 115 dBA to determine the appropriate SPL level to begin the measurement. In the high-noise environment, speech intelligibility performance of the JSAM-TA Respirator Assembly (V)5 with the HGU-84/P flight helmet and CEP was measured at 96.3% at 115 dBA, with no further measurements required. High-noise measurements were conducted

with the same respirator/helmet configuration with EAR Classic™ at 95, 105, and 115 dBA, with speech intelligibility scores of 91.0, 88.9, and 73.1%, respectively. JSAM-TA JPO performance requirements were exceeded for all measurement levels with EAR Classic™ except 115 dBA.

4.0 DISCUSSION

The use of CBR protection under a flight helmet has the potential to degrade the noise attenuation performance of the helmet and potentially degrade speech intelligibility performance. Early versions of JSAM performance requirements highlighted the JSAM attenuation requirement as a comparison between the original, helmet only configuration and the helmet with JSAM. Attenuation measurements conducted at AFRL for the JSAM-Strategic Aircraft, JSAM-Rotary Wing, and even an earlier version of the JSAM-TA revealed that this requirement could not be met with single hearing protection[5-7]. In these measurements, the addition of the JSAM respirator created a break in the acoustic seal between the helmet or headset and the subject's head, which resulted in a degradation in attenuation performance (greater than 10 dB at multiple octave frequency bands)[5,7]. The JSAM performance requirements were revised to include the use of double hearing protection to meet JSAM attenuation requirements[2]. Comply™ and 3M both claim users of their foam eartips/earplugs can achieve a Noise Reduction Rating (NRR) greater than 29 dB[8-9]. This high level of attenuation from the earplugs, coupled with the additional attenuation from the helmet earcups, provided enough overall attenuation to negate the effects of the broken acoustic seal created by the addition of JSAM.

Speech intelligibility measurements with the JSAM-TA Respirator Assembly (V)5 and HGU-84/P were part of a larger study conducted for the JSAM-TA JPO to assess both noise attenuation and speech intelligibility for the JSAM-TA Respirator Assembly (V)3 with two flight helmets, the HGU-55A/P Joint Helmet Mounted Cueing System (JHMCS) and HGU-68/P, and the JSAM-TA Respirator Assembly (V)5 with the HGU-84/P. In noise attenuation measurements conducted at AFRL from September-December 2016, the HGU-55A/P JHMCS and HGU-68/P were able to meet the JPO attenuation requirement, as defined in the JSAM-TA JPO PD.

The JSAM-TA JPO made the decision not to conduct noise attenuation measurements with the HGU-84/P based on helmet system similarities and the results of the noise attenuation measurements for the HGU-55A/P JHMCS and HGU-68/P with the JSAM-TA Respirator Assembly (V)3; only speech intelligibility measurements were conducted. Both versions of the JSAM-TA Respirator Assembly measured in this study ((V)3 and (V)5) used the same rubber hood cowl and all three helmets used similar components in their helmet assemblies: helmet liner, earcups, visor, bayonets, and chin strap. Oregon Aero SoftSeal® 3/4" earcups were used for all configuration measurements with both the HGU-68/P and HGU-84/P. For the configurations measured with the HGU-55A/P JHMCS and HGU-68/P, the addition of the JSAM-TA Respirator Assembly (V)3 improved sound attenuation performance at 500, 1000, 4000, and 8000 Hz across all configurations. All attenuation

losses were above the 3 dB degradation limit set by the JPO performance requirements. The attenuation data to support this decision are provided in Table 4.

Table 4. Attenuation gain or loss in dB for HGU-55A/P JHMCS and HGU-68/P with CEP and EAR Classic™, with and without JSAM-TA Respirator Assembly (V)3

		Frequency (Hz)						
Configuration		**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
HGU-55A/P JHMCS with CEP: (CBR Attenuation) - (non-CBR Attenuation)	Attenuation Gain or (Loss)	2.7	1.8	3.7	3.0	(1.4)	1.9	1.8
HGU-55A/P JHMCS with 3M EAR Classic™: (CBR Attenuation) - (non-CBR Attenuation)	Attenuation Gain or (Loss)	(0.5)	(2.1)	0.3	0.6	1.1	1.4	2.3
HGU-68/P with CEP: (CBR Attenuation) - (non-CBR Attenuation)	Attenuation Gain or (Loss)	0.2	2.6	4.7	4.6	(0.5)	0.9	2.7
HGU-68/P with 3M EAR Classic™: (CBR Attenuation) - (non-CBR Attenuation)	Attenuation Gain or (Loss)	2.0	1.8	3.4	4.3	(0.5)	1.3	3.5

In legacy systems, passive earplugs (foam) were added to the helmet configuration to reduce the level of noise at the ear; unfortunately, for some users, the added attenuation made it difficult to understand speech. Communication earplugs were developed to improve both speech intelligibility and noise attenuation. These devices ranged from custom molded earpieces to generic fit eartip systems with varying shapes and materials. The benefits of communication earplugs, like CEP, are reflected in the speech intelligibility data collected in this study; all configurations with CEP outscored the respective EAR Classic™ configurations, and the greatest benefit was seen in the highest condition at 115 dBA, with subjects scoring >95%. With EAR Classic™, the subjects were able to meet the JPO requirement at all measurement levels except 115 dBA. The EAR Classic™ attenuated not only the noise, but also the stimuli from the earcups, therefore the noise outside the helmet earcup was likely louder than the stimuli generated under the cup, i.e. small signal to noise ratio, resulting in speech intelligibility scores below the requirement.

The addition of an earplug to flight helmet configurations is operationally relevant even when a JSAM respirator is not employed. For example, in AFRL conducted attenuation measurements, the noise reduction rating (mean minus 1 standard deviation) was 11 dB for

the HGU-84/P, helmet alone[6]. If a pilot achieved a similar amount of attenuation from this helmet and was exposed to 105 dB of noise inside the cockpit, he/she would only be permitted to fly for approximately one hour before exceeding DoD noise exposure limits[10]. Additionally, AFRL was unable to conduct speech intelligibility measurements at 115 dB for the HGU-55/P with JSAM-TA (modified A/P22P-14A (V)3) in a study conducted in 2015 due to a similar attenuation level and risk of overexposure to the subjects[7]. This data supports the notion that double hearing protection, not helmet alone, should be the baseline configuration when the HGU-55/P and most other legacy flight helmets, like the HGU-84/P are worn. Also, based on the speech intelligibility data collected in this and other previously mentioned studies, that earplug should be a communications earplug.

5.0 CONCLUSION

Speech intelligibility measurements were conducted at AFRL in accordance with ANSI S3.2 from December 2016- January 2017. Measurements were collected on the JSAM-TA Respirator Assembly (V)5 with the HGU-84/P flight helmet in combination with CEP and EAR Classic™ foam earplugs to determine if JSAM-TA JPO performance requirements were met when double hearing protection was used. In low-noise environments, when using a torso-mounted ICU (V)5, the speech intelligibility performance of the JSAM-TA Respirator Assembly (V)5 and the HGU-84/P, with both CEP and EAR Classic™ foam earplugs, met the JSAM-TA requirement for speech intelligibility with scores of 93.0% and 88.5%, respectively. In high-noise environments, when hardwired via torso-mounted CCU, speech intelligibility requirements were met for CEP with a score for 96.3% at 115 dBA and for EAR Classic™ with a score of 88.9% at 105 dBA.

6.0 REFERENCES

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7.0 LIST OF ACRONYMS

(ADOM)	Advanced Dynamic Oxygen Mask
(AFRL)	Air Force Research Laboratory
(AIC)	Aircraft Intercom
(ANSI)	American National Standards Institute
(CBR)	Chemical Biological Radiological
(CCU)	Communications Control Unit
(CEP)	Communications Earplug
(dB)	Decibel
(dBA)	A-Weighted Decibel Level
(DoD)	Department of Defense
(ECPs)	Engineering Change Proposals
(Hz)	Hertz
(ICU)	Intercommunications Unit
(JPO)	Joint Program Office
(JSAM-TA)	Joint Service Aircrew Mask- Tactical Aircraft
(MRT)	Modified Rhyme Task
(NRR)	Noise Reduction Rating
(PD)	Purchase Description
(SME)	Subject Matter Expert
(SPL)	Sound Pressure Level
(VOCRES)	Voice Communication Research and Evaluation System