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JOINT SERVICE AIRCREW MASK - STRATEGIC AIRCRAFT (JSAM-SA): SPEECH INTELLIGIBILITY PERFORMANCE ASSESSMENT

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Speech intelligibility performance measurements were conducted in accordance with ANSI/ASA S3.2 to determine the effect the JSAM-SA had on communications when worn in combination with flight headsets and earplugs. The average speech intelligibility performance for subjects wearing foam earplugs in combination with the JSAM-SA and each selected headset was <80% in a 95 A-weighted decibel (dBA) ambient noise environment. However, the average speech intelligibility performance for subjects wearing communication earplugs in combination with the JSAM-SA and each selected headset was ≥80% in a 105 dBA ambient noise environment. It is recommended that communication earplugs be included in the hearing protection and communication system when JSAM-SA is required in flight.

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EXECUTIVE SUMMARY

The noise environment on or around an aircraft can be hazardous to hearing and degrade speech intelligibility performance. Hearing protection and communication systems are required to protect aircrew from potentially hazardous noise exposures and provide effective speech communication. Chemical-biological (CB) protective equipment are also required to protect aircrew in an actual or perceived CB warfare environment. The objective of this study was to measure speech intelligibility performance, in accordance with the American National Standards Institute/Acoustical Society of America (ANSI/ASA) S3.2 Method for Measuring the Intelligibility of Speech Over Communication Systems[1], to determine the effect the Joint Service Aircrew Mask (JSAM)-Strategic Aircraft (SA) had on communications when worn in combination with flight headsets and earplugs. The headsets selected for this study were Bose A20, David Clark H10-76, and Gentex Adaptive Mission Platform (AMP). The earplugs selected for this study were EAR Classic Foam Earplugs, Passive Attenuating Communication Earplugs (PACE) communication earplugs with Comply™ Canal Tips, and Gentex Near-Field Magnetic Induction (NFMI) earplugs with Comply™ Canal Tips. Measurements were conducted at the Air Force Research Laboratory (AFRL) VOice Communication Research and Evaluation System (VOCRES) at Wright-Patterson Air Force Base (WPAFB) in January 2021. The average speech intelligibility performance for subjects wearing foam earplugs in combination with the JSAM-SA and each selected headset was <80% in a 95 A-weighted decibel (dBA) ambient noise environment. However, the average speech intelligibility performance for subjects wearing communication earplugs in combination with the JSAM-SA and each selected headset was ≥80% in a 105 dBA ambient noise environment.

1.0 INTRODUCTION

JSAM-SA (M-69), also known as the Modified M-53 and XM-69, was designed to provide Pressure Breathing for Altitude (PBA) and CB protection to Non-Pressure Breathing for Gravity (non-PBG) to aircrew of non-ejection, fixed wing aircraft. Aircrew don the JSAM-SA, Figure 1, based on current threat and operational requirements. The JSAM-SA is available in small, medium, and large sizes.

Figure 1. JSAM-SA (M-69) Mask and Protective Hood

Communication headsets have been donned by aircrew to combat noise and to provide satisfactory voice communications. The Department of Defense (DoD) Handbook for Airworthiness Certification Criteria[2] (Military Handbook [MIL-HDBK]-516C) provides guidance for acceptable speech intelligibility performance. Section 9.2.8 states "an 80% (91% for Army) score on the Modified Rhyme Test (MRT) conducted in accordance with ANSI/ASA S3.2 is considered adequate for all operational military aircraft communication paths essential to safety of flight." It also says that the measurements should be conducted in the worst case noise environments where communications are required.

2.0 BACKGROUND

JSAM is a joint program across the Air Force, Army, and Navy/Marine Corps. JSAM-SA is dedicated to aircrew of strategic aircraft that include variants of the C-130, C-17, E-3, C-12, and many more. It is well known that donning the JSAM-SA, or any CB protective equipment, with a hearing protection and communication device will degrade performance. The JSAM-SA performance specification document established a requirement that the M69 should not degrade noise attenuation more than 3 dB at any one-third octave band.[3] Acoustic measurements collected in the past have documented the degradation of the noise attenuation performance when wearing CB protection under a communication headset or helmet.[4-7] This known degradation has the potential to degrade the ability of aircrew to communicate. The objective of this study was to measure speech intelligibility performance, in accordance with ANSI/ASA S3.2 to determine the effect the JSAM-SA has on communications when worn in combination with flight headsets and earplugs.

3.0 METHODS

Speech intelligibility measurements were collected in accordance with ANSI/ASA S3.2 Method for Measuring the Intelligibility of Speech Over Communication Systems. Measurements were conducted with human research subjects at the AFRL VOCRES facility at WPAFB in January 2021. Performance measurements were conducted to assess the effect of JSAM-SA worn in combination with aircrew headsets and earplugs.

3.1 Equipment

Three headsets were selected for this study: Bose A20, David Clark H10-76, and Gentex AMP. A foam earplug was selected for this study, EAR Classic Foam Earplugs, as well as two communication earplugs: PACE with Comply™ Canal Tips and Gentex NFMI, wire-free communication earplugs (WCEP) with Comply™ Canal Tips.

The Bose A20 is a circumaural headset that features acoustic noise cancelling technology with microphones both inside and outside each earcup. The headset provides access to external communication via the aircraft communication system. Bose A20 comes standard with an adjustable, padded headframe and ear cushions. Figure 2 shows the Bose A20 with the JSAM-SA.

Figure 2. JSAM-SA with Bose A20

The David Clark H10-76 is a passive, circumaural headset that provides access to external communication via the aircraft communication system. David Clark H10-76 comes standard with an expanded, double-foam head pad and gel ear seals. Figure 3 shows the David Clark H10-76 with the JSAM-SA.

Figure 3. JSAM-SA with David Clark H10-76

The Gentex AMP is a closed, circumaural headset that features active, hear-thru capabilities and provides access to external communication via the aircraft communication system. The hear-thru capabilities and external communications are independent of each other, allowing the aircrew greater flexibility with communication options and hearing protection. The Gentex AMP comes standard with an adjustable, padded headframe, gel ear cushions, and foam earcup inserts. The Gentex AMP features two hearing protection and communication configurations: Single Hearing Protection (SHP) and Dual Hearing Protection (DHP) mode. In SHP mode, the aircrew don the headset only and receives all audio transmissions via earcup mounted speakers. In DHP mode, the aircrew don a pair of NFMI earplugs under the earcups and all audio is routed, wirelessly, from the headset to the earplugs. The DHP mode was designed to offer the aircrew double hearing protection, the headset in combination with earplugs, without compromising the audio signals from the hear-thru feature and/or external communications. Comply™ Canal Tips were used for all measurements with the NFMI earplugs and were available in four sizes: slim, short, standard, and large. Figure 4 shows the Gentex AMP with the JSAM-SA.

Figure 4. JSAM-SA with Gentex AMP

3.2 Subjects

All acoustic performance measurements were collected with paid, volunteer human subjects. There were five male and five female subjects, ranging in age from 20-36 years, with English as their native language. All subjects were given a screening audiogram via the Hughson-Westlake method, and were required to have hearing thresholds within the normal hearing range: 25 decibel (dB) Hearing Level or better from 125 to 8000 hertz (Hz). A JSAM-SA subject matter expert sized each subject individually and trained them how to properly don and doff the system. On measurement days, each subject fit his/her own system while being observed by the test administrator. The subject assigned sizes are listed in Table 1.

Table 1. Subjects' Sizing Matrix

Subject ID	Sex	JSAM-SA Size	JSAM-SA #	Comply™ Canal Tips Size
1800	F	S	XM 69-286	Large
1803	F	XS	XM 69-268	Standard
1629	M	M	XM 69-348	Large
1602	F	S	XM 69-288	Large
1737	M	M	XM 69-352	Large
1765	M	M	XM 69-350	Large
1805	F	S	XM 69-291	Standard
1806	M	M	XM 69-326	Standard
1798	M	M	XM 69-327	Large
1804	F	S	XM 69-289	Large

3.3 Speech Intelligibility

Speech intelligibility measurements were conducted in accordance with ANSI/ASA S3.2 in AFRL's VOCRES facility. 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 noise at levels up to 125 dBA emulating acoustic environments in operational situations.

Subject workstations are positioned in the facility (Figure 5), 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 5. AFRL's VOCRES Facility used to Measure Speech Intelligibility Performance.

The MRT was selected for the test material and the stimuli were presented by live talker. The MRT consists of 50, six-word lists of monosyllabic English words, rhyming, differed only in initial or final consant (e.g., toil/boil and came/cane). The goal was to quantify the ability of trained listeners to correctly identify target words transmitted by a trained talker using the various hearing protection and communication device configurations. Cueing of target words for the talker and recording of listener responses were both accomplished via a custom matrix laboratory (MATLAB) application. A tablet with a graphical user interface was utilized for subject response.

ANSI/ASA S3.2 requires a minimum of five talkers and five listeners. For this measurement, the subjects were paired together. The five pairs acted as both talkers and listeners. During the measurements, the talker was presented with the stimulus on the tablet and then communicated the phrase to the listener via the JSAM-SA through the AIC-25 aircraft communication system. Listeners selected a word they thought they heard from a list of six possible 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 6.

Number 1, you will mark **WENT** please.
Number 2, you will mark **HOLD** please.
Number 3, you will mark **PAT** please.
.
.
.

1.

Went	Sent	Bent
Dent	Tent	Rent

2.

Sold	Cold	Told
Fold	Hold	Gold

3.

Pan	Pad	Pat
Path	Pack	Pass

Figure 6. Examples of the Talker Prompt (left) and Listener Response Matrix (right).

Speech intelligibility measurements were collected in pink noise at 95 and 105 dBA. The subjects' scores were adjusted for guessing, per subject, as described in ANSI S3.2 and the equation below. An overall average was then calculated for all subjects in each condition.

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

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

4.0 RESULTS

For speech intelligibility in high-noise environments (95 and 105 dBA), MIL-HDBK-516C recommends an acceptable speech intelligibility score of 80% or greater. If the subjects were able to achieve acceptable speech intelligibility scores for a particular noise level, performance at all lower levels were considered acceptable and no further measurements were made. If the subjects were unable to achieve acceptable speech intelligibility scores for a particular noise level, performance at all higher levels were assumed to be unacceptable and no further measurements were made. The average score and standard deviation were calculated across all subjects and reported in Table 2. Subjects achieved acceptable speech intelligibility scores ≥ 80% at 105 dBA when communication earplugs were worn in combination with JSAM-SA and the flight headsets, Figure 8. Subjects were unable to achieve acceptable speech intelligibility scores at 95 dBA when foam earplugs were worn in combination with JSAM-SA and the flight headsets, Figure 7.

Table 2. Average and Standard Deviation per JSAM-SA Configuration.

JSAM	Headset	Earplug	Noise Level (dB)	Average Score (%)	Standard Deviation
JSAM-SA	Bose A20	EAR Classic Foam	95	34	12
JSAM-SA	Bose A20	PACE	105	93	4
JSAM-SA	David Clark H10-76	EAR Classic Foam	95	31	14
JSAM-SA	David Clark H10-76	PACE	105	93	6
JSAM-SA	Gentex AMP	EAR Classic Foam	95	64	12
JSAM-SA	Gentex AMP	NFMI, WCEP	105	91	7

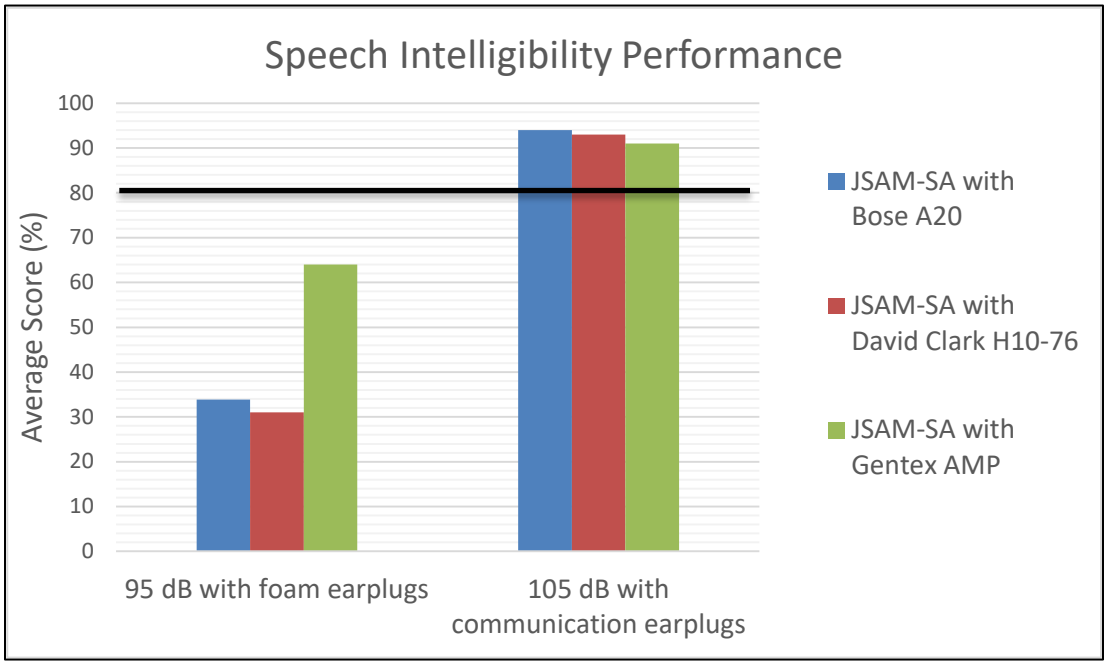

Figure 7. Average Speech Intelligibility Score.

5.0 DISCUSSION

The negative effect JSAM has on the level of protection provided by a hearing protection and communication device is well documented.[4-7] An additional layer of hearing protection is typically added to the system to reduce the risk to hearing loss and other hearing related disorders. JSAM studies have been conducted to measure the noise attenuation and speech intelligibility performance when combined with a flight helmet or headset and foam or communication earplugs. Foam earplugs were designed to block all sounds including the communication signal while communication earplugs increase the level of protection and allow the communication signal to be delivered directly to the ear. In 2015, speech intelligibility performance with the F-35 flight helmet, JSAM-Joint Strike Fighter (JSF), and foam earplugs was unacceptable with an average score of 8% in a 115 dBA noise environment.[8] In 2017, speech intelligibility performance was deemed unacceptable for the JSAM-Tactical Aircraft (TA), multiple flight helmets (HGU-55A/P and HGU-68/P), and foam earplugs in a 95 dBA noise environment. However, acceptable speech intelligibility performance was found with the JSAM-TA, the same flight helmets, and communication earplugs in a 115 dBA noise environment.[9-10] In 2016, acceptable speech intelligibility performance was also found with the JSAM-Rotary Wing (RW), the same flight helmets, and communication earplugs in a 115 dBA noise environment.[11] For this study, the speech intelligibility performance was degraded with the use of foam earplugs (<80%) and acceptable with the use of communication earplugs (≥80%).

6.0 CONCLUSION

Speech intelligibility performance measurements were conducted in accordance with ANSI/ASA S3.2 to determine the effect the Joint Service Aircrew Mask (JSAM)-Strategic Aircraft (SA) had on communications when worn in combination with flight headsets and earplugs. The average speech intelligibility performance for subjects wearing foam earplugs in combination with the JSAM-SA and each selected headset was <80% in a 95 A-weighted decibel (dBA) ambient noise environment. However, the average speech intelligibility performance for subjects wearing communication earplugs in combination with the JSAM-SA and each selected headset was ≥80% in a 105 dBA ambient noise environment. It is recommended that communication earplugs be included in the hearing protection and communication system when JSAM-SA is required in flight.

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8.0 LIST OF ACRONYMS

AFRL	Air Force Research Laboratory
AMP	Adaptive Mission Platform
ANSI/ASA	American National Standards Institute/Acoustical Society of America
CB	Chemical-biological
(dB)	Decibel
dBA	A-Weighted Decibel Level
DHP	Dual Hearing Protection
DoD	Department of the Air Force
Hz	Hertz
JSF	Joint Strike Fighter
JSAM	Joint Service Aircrew Mask
MATLAB	Matrix Laboratory
MIL-HDBK	Military Handbook
MRT	Modified Rhyme Task
NFMI	Near-Field Magnetic Induction
non-PBG	non-Pressure Breathing for Gravity
PACE	Passive Attenuating Communication Earplug
PBA	Pressure Breathing for Altitude
RW	Rotary Wing
SA	Strategic Aircraft
SHP	Single Hearing Protection
SPL	Sound Pressure Level
TA	Tactical Aircraft
VOCRES	Voice Communication Research and Evaluation System
WCEP	Wire-free Communication Earplugs
WPAFB	Wright Patterson Air Force Base