USAARL-TECH-TR--2020-017

Acoustic Measurement of Unmanned Aircraft Systems (UAS)

Efrem R. Reeves

Notice

Qualified Requesters

Qualified requesters may obtain copies from the Defense Technical Information Center (DTIC), Fort Belvoir, Virginia 22060. Orders will be expedited if placed through the librarian or other person designated to request documents from DTIC.

Change of Address

Organizations receiving reports from the U.S. Army Aeromedical Research Laboratory on automatic mailing lists should confirm correct address when corresponding about laboratory reports.

Disposition

Destroy this document when it is no longer needed. Do not return it to the originator.

Disclaimer

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation. Citation of trade names in this report does not constitute an official Department of the Army endorsement or approval of the use of such commercial items.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
30-04-2020	Technical Report	

4. TITLE AND SUBTITLE

Acoustic Measurement of Unmanned Aircraft Systems (UAS)

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Reeves, Efrem R.

5d. PROJECT NUMBER

22870

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Aeromedical Research Laboratory
Bldg 6901 Farrel Road
Fort Rucker, AL 36362-0577

8. PERFORMING ORGANIZATION REPORT NUMBER

USAARL-TECH-TR--2020-017

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

DISTRIBUTION STATEMENT A. Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This report details the measurement of sound levels around a Shadow and a Gray Eagle unmanned aircraft system (UAS). Sound levels inside of Universal Ground Control Stations (UGCS) were also measured. The results indicate the Shadow UAS operator should be well protected using the David Clark H10 headset. The Gray Eagle operators did not wear hearing protection and it is recommended that they use some sort of hearing protection. The sound levels in the measured UGCSs were relatively low and the RACAL RA5000/1/1026 Raptor headsets that are currently being used will provide more than adequate hearing protection.

15. SUBJECT TERMS

Hearing protection, UAS, Shadow, Gray Eagle, sound level, UGCS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Loraine St. Onge, PhD
UNCLAS	UNCLAS	UNCLAS	SAR	34	19b. TELEPHONE NUMBER *(Include area code)* 334-255-6906

This page is intentionally blank.

Summary

An unmanned aircraft system (UAS) is an unmanned aircraft (UA) with associated support equipment, control station, data links, telemetry, communications, and navigation equipment necessary to operate it (FDOT, 2019). USAARL tested sound levels produced by two different UA systems—the RQ-7Bv2 Shadow and MQ-1C Gray Eagle. The RQ-7 Shadow Tactical Unmanned Aircraft System (TUAS) provides reconnaissance, surveillance, target acquisition, and force protection for the Brigade Combat Team (BCT) in near-real-time during day, night, and limited adverse weather conditions. The MQ-1C Gray Eagle is a medium-altitude, long-endurance (MALE) UAS and is an upgrade to the MQ-1 Predator UAV drone line.

The purpose of this test was to determine the sound level around the Shadow and Gray Eagle UASs and inside the universal ground control station (UGCSs). The study also looked at the effectiveness of headsets currently used with those systems.

Results indicated that sound levels around the Shadow and Gray Eagle require the use of hearing protection per Section 7-13 of DA PAM 40-501 which states that appropriate hearing protection must be worn when working with or around aircraft that produces exposure to steady state noise levels of 85 dB(A) of *any* duration. The Shadow (at the operator position) reaches a maximum sound level of 98dB(A). The Grey Eagle produces sound levels of 87 dB(A) next to the UAS on the right side, and a measurement of 92 dB(A) underneath during short intervals of time. Sound levels inside the UGCS do not reach the threshold to require additional hearing protection per Section 7-13 of DA PAM 40-501.

Results related to the evaluation of the current headsets being used by UAS operators indicate that Shadow UAS operators should be well protected using the current David Clark H10 headset. However, it is recommended that Gray Eagle operators use some sort of hearing protection. The sound levels in both UGCSs were relatively low and the RACAL RA5000/1/1026 Raptor headsets that are currently being used provide more than adequate hearing protection.

This page is intentionally blank.

Acknowledgements

The author would like to thank Mr. Juan Colon-Cruz and Dr. Paul St. Onge for their assistance in organizing the activity and in data collection. He would also like to thank Mr. Lamas, Ms. Fauver, MAJ Simpson and the 2-13th Aviation Regiment at Fort Huachuca. This report would not have been possible without their assistance.

This page is intentionally blank.

Table of Contents

List of Figures

List of Tables

This page is intentionally blank.

Introduction

An unmanned aircraft system (UAS) is an unmanned aircraft (UA) with associated support equipment, control station, data links, telemetry, communications, and navigation equipment necessary to operate it (FDOT, 2019). The focus of this test is to accurately quantify sound levels produced by two different UA systems. The two systems tested are the RQ-7Bv2 Shadow and the MQ-1C Gray Eagle. The RQ-7 Shadow Tactical Unmanned Aircraft System (TUAS) provides reconnaissance, surveillance, target acquisition and force protection for the Brigade Combat Team (BCT) in near-real-time during day, night and limited adverse weather conditions. The MQ-1C Gray Eagle is a medium-altitude, long-endurance (MALE) UAS and is an upgrade to the MQ-1 Predator UAV drone line.

The universal ground control station (UGCS) is the common control station for the U.S. Army's Shadow and Gray Eagle unmanned aircraft systems. Built on a flexible crew station architecture, the UGCS can be configured and housed based on army mission requirements, supporting a wide variety of assets and operations (Textron Systems website, 2019). In order to get a complete picture of the noise exposure of UAS operators sound measurements were conducted inside UGCS as well as around the aircraft.

Figure 1. The RQ-7 Shadow Tactical Unmanned Aircraft System (TUAS).

Figure 2. The General Atomics MQ-1C Gray Eagle unmanned aircraft system (UAS).

Figure 3. Universal ground control stations (UGCS).

Methods

Measurements were conducted around the RQ-7Bv2 Shadow and the MQ-1C Gray Eagle UAS vehicles at Fort Huachuca, AZ in July 2019. Measurements were also conducted inside of the UGCS for both vehicles. The same equipment was used for all measurements.

Unmanned Aerial Systems

Microphone placement was similar for both the Shadow and Gray Eagle UAS sound level measurements. Due to a limited opportunity to collect data, since training exercises could not be altered or interrupted, it was decided to place the microphones at varying distances perpendicular to the aircraft centerline. The height of each microphone diaphragm was 5 feet except for the microphone closest to the Gray Eagle UAS which was 4 feet high. The relative microphone positions for the Gray Eagle can be seen in Figure 4 and the first three microphones can be seen in Figure 5. The first four microphone locations at the Shadow launch site can be seen in Figure 6. The microphone distances from the aircraft centerline are shown in Table 1.

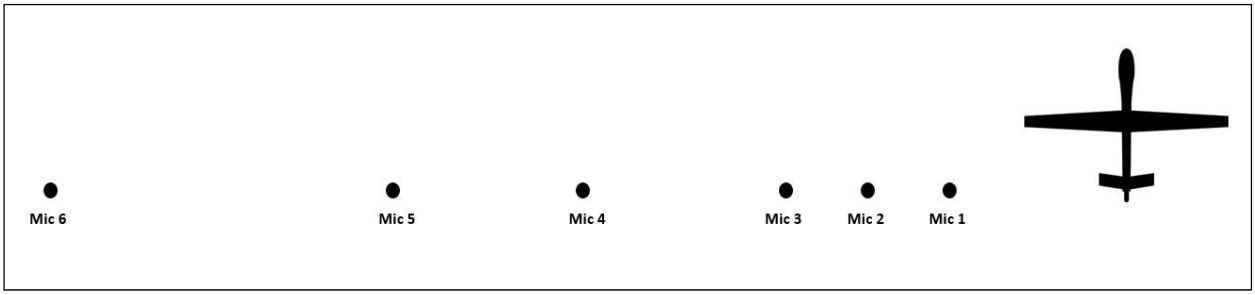

Figure 4. Microphone positions for the Gray Eagle.

Table 1. Microphone distances from the aircraft centerline in feet

Mic	Distance in Feet	
	Grey Eagle	Shadow
Mic 1	30	30
Mic 2	40	45
Mic 3	60	90
Mic 4	90	115
Mic 5	125	150
Mic 6	183	171

Prior to aircraft start up, the data acquisition modules were set up for standalone recording. This mode of operation allowed for the data to be saved as a .WAV file to a microSD card that was plugged into each module. The recording parameters were set to a sampling rate of 131,072 Hz with a frequency span of 51.2 kHz and 24-bit resolution. The data acquisition modules were powered on after all microphones were in place, but the recording was not started until the aircraft were in place and ready to be powered up.

Figure 5. Gray Eagle UAS with first three microphone positions.

Figure 6. Shadow UAS on launcher showing first four microphone positions.

Universal Ground Control Systems

Inside the UGCS the same six microphones and data acquisition modules that were used to measure the UAS sound levels captured the ambient sound level while the UGCS was powered on but not occupied. Figure 7 shows the dimensions and microphone layout for the Shadow UGCS. Microphone 4 and Microphone 6 were placed on the chairs to approximate crew member head positions. Figure 8 shows the front-most microphone positions in the Shadow UGCS.

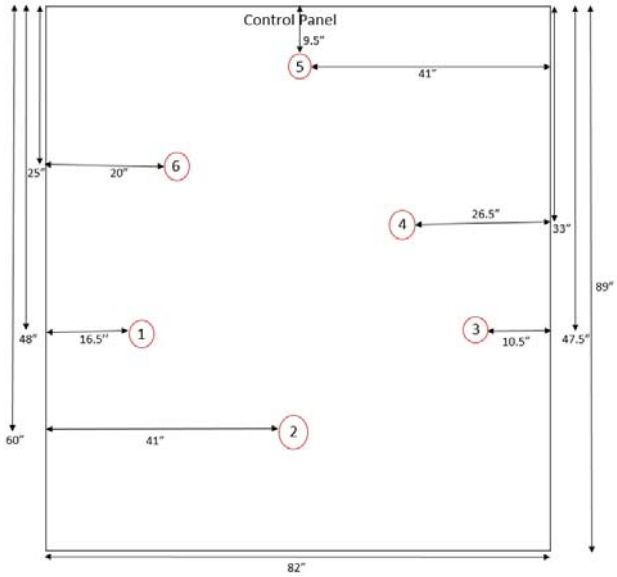

Figure 7. Shadow UGCS dimensions and microphone placement.

Figure 8. Microphone positions four, five, and six in Shadow UGCS.

A similar microphone layout was used in the Gray Eagle UGCS. Figure 9 shows the dimensions and microphone layout for the Gray Eagle UGCS. Microphone 1 and Microphone 2 were placed on the chairs to approximate crew member head positions. Figure 10 shows the first five microphone positions in the Gray Eagle UGCS.

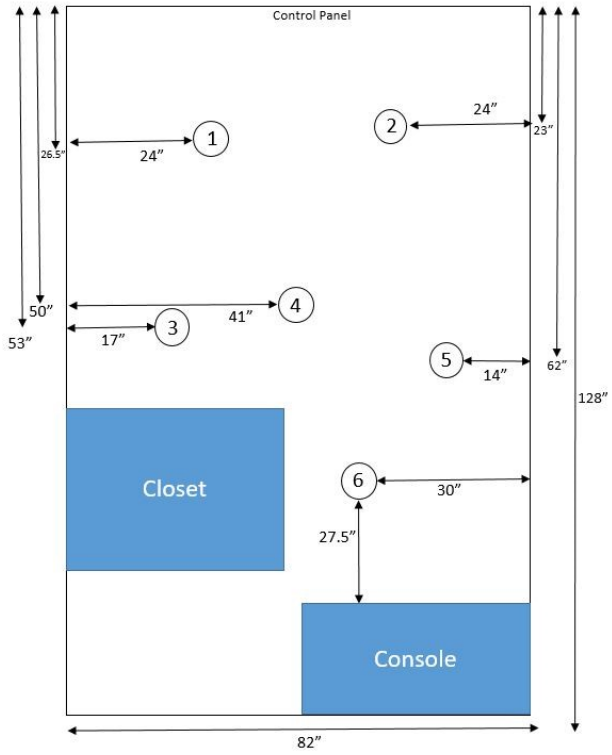

Figure 9. Gray Eagle UGCS dimensions and microphone placement.

Figure 10. Microphone positions one, two, three, four, and five in Gray Eagle UGCS.

Materials

Brüel & Kjær (B&K) Type 4938-A-011 (4938) microphones with Type 2670 preamplifiers (Figure 4) were used to measure sound levels. The 4938s are ¼-inch pressure-field microphones designed for high-level and high-frequency measurements. The microphones have a frequency range of 4 Hz to 70 kHz, and a dynamic measurement range of 42 dB to 172 dB with a maximum peak sound level of 180 dB(P).

Figure 11. Brüel & Kjær Type 4938-A-011 microphones with Type 2670 preamplifiers.

The microphones provided the input signal to a B&K LAN-XI Type 3050 module running Notar Time Data Recorder software in stand-alone mode. The module is a six channel system with a bandwidth of 51.2 kHz (sample rate of 131 kHz). A B&K 2270 hand-held analyzer was also used to supplement the measurement hardware. The 2270 is a multifunctional Class 1 sound measurement system the use of which added flexibility to the measurement activity. Additionally, a B&K Type 3052-A-3/0 LAN-XI data acquisition module, which has three input channels and a frequency range of direct current (DC) to 102.4 kHz, was to be used to collect additional data. Figure 5 shows the B&K Type 3052-A-3/0 LAN-XI and 2270 hand-held analyzer.

Power for the Type 3050 and Type 3052 modules was provided by Battery Module Types 2831-A. The battery module is a rechargeable Lithium (Li)-Ion battery with an output voltage of 14.8 V and a capacity of 6400 mAh. The battery is capable of powering a LAN-XI data acquisition module for over 7 hours (Brüel & Kjær, 2017).

Figure 12. B&K Type 3052-A-3/0 LAN-XI and 2270 hand-held analyzer.

Figure 13. LAN-XI data acquisition systems (circled) at Shadow launch site.

Results

The results below are A-weighted average sound levels (LAeq) measured during the listed condition in decibels [dB(A)].

Shadow

Figure 14. Close up of Shadow on launcher.

Measurements were conducted during the launches of two Shadow UASs. The launches were separated by about 30 minutes. The results are shown in Table 2.

Table 2. Shadow UAS sound levels

dB(A)	Shadow UAS Sound Levels							
	Launch 1				Launch 2			
	Start-up	Low Idle	High (Snaps)	Launch	Start-up	Low Idle	High (Snaps)	Launch
Mic 1	96.8	91.7	110	105	97	91.4	108	107
Mic 2	92.7	87.2	105	101	92.6	87.4	104	103
Mic 3	87.9	81.9	99.3	94.8	86.9	81.8	97.7	97
Mic 4	84.8	79.4	96.5	91.2	84.5	80.1	94.9	94.4
Mic 5	82.2	76.5	93.5	87.6	81.3	77.2	92.1	92.3
Mic 6	81.3	75	92.2	95.9	80.3	76.1	90.7	90.5

Sound levels measured in the Shadow UGCS are shown in Table 3. Each measurement sample was one minute long.

Table 3. A weighted ambient sound levels in Shadow UGCS

dB(A)	Shadow UGCS Sound Levels		
	Sample 1	Sample 2	Sample 3
Mic 1	79.5	79	78.6
Mic 2	77	75.8	76.7
Mic 3	81.3	80.8	79.7
Mic 4	76.2	76.6	76.1
Mic 5	73.1	73	72.4
Mic 6	74.2	72.5	72.8

Gray Eagle

Figure 15. Gray Eagle UAS.

Measurements were conducted prior to launch while the Gray Eagle UAS idled on the tarmac. The results are shown in Table 4. During the 'Low Idle' measurement Microphone 2 and Microphone 5 malfunctioned therefore no result (NR) was measured.

Table 4. Gray Eagle UAS sound levels

dB(A)	Gray Eagle UAS Sound Levels	
	Low Idle	High Idle
Mic 1	78.7	103
Mic 2	NR	100
Mic 3	75.1	98.3
Mic 4	72.7	95.1
Mic 5	NR	89.4
Mic 6	61.6	85

Sound levels measured in the Gray Eagle UGCS are shown in Table 5. Each measurement sample was one minute long. The results of Microphone 2 and Microphone 5 are highlighted to indicate potential microphone malfunctions.

Table 5. A-weighted ambient sound levels in Gray Eagle UGCS

dB(A)	Gray Eagle UGCS Sound Levels		
	Sample 1	Sample 2	Sample 3
Mic 1	76.2	74.8	77
Mic 2	93.1	88.7	83.8
Mic 3	77.1	77	77.8
Mic 4	78.6	76.9	77.4
Mic 5	81.5	75.8	76.1
Mic 6	74.4	73.6	74.8

This page intentionally left blank.

Discussion

In order to assess the noise exposure of the Shadow UAS operator a microphone was placed near his position, which was about 100 ft away from the launcher, as shown in Figure 16. The operator was wearing a David Clark H10 Headset which has a listed Noise Reduction Rating (NRR) of 23 dB. Unfortunately, due to a hardware malfunction no data was collected at the operator position. However, looking at the results in Table 2 for mic 3 and mic 4, which were 90 feet and 115 feet away from the launcher respectively, it can be determined that the sound levels at the operator position would reach a maximum of approximately 98 dB(A). The NRR provided by the headset should offer adequate protection for the operator, especially due to the short exposure time of the maximum sound levels which occur during snaps (engine alternating between high and low idle) and at launch.

Figure 16. Shadow operator with microphone nearby.

The Gray Eagle Operator did not wear hearing protection. For the majority of time that the Gray Eagle UAS was on the tarmac it was at low idle and the operator was standing back at least 60 feet from the aircraft. However, there was an occasion shortly after start-up that the operator had to be next to and even under the aircraft. Measurements taken at these positions with the hand-held analyzer resulted in a measurement of 87 dB(A) next to the UAS on the right side, and a measurement of 92 dB(A) underneath. The operator was not exposed to these levels for more than a few minutes but it is still recommended that some type of hearing protection be worn. Further, Section 7-13 of DA PAM 40-501 states that appropriate hearing protection must be worn

when working with or around aircraft that produces exposure to steady state noise levels of 85 dB(A) of any duration.

The headsets worn in the UGCSs were the RACAL RA5000/1/1026 Raptor which have an NRR of 18 dB. The UGCS sound levels are shown in Table 3 and Table 5 and according to DA PAM 40-501 hearing protection would not be required since levels do not exceed 85 dB(A).

Conclusions

The purpose of this test was to determine the sound level around the Shadow and Gray Eagle UASs and inside the UGCSs. The results indicate the Shadow UAS operator should be well protected using the David Clark H10 headset. However, it is recommended that the Gray Eagle operators use some sort of hearing protection. The sound levels in both UGCSs were relatively low and the RACAL RA5000/1/1026 Raptor headsets that are currently being used will provide more than adequate hearing protection.

This page intentionally left blank.

References

American National Standards Institute. (2012). *Methods for the measurement of noise emissions from high performance military jet aircraft* (ANSI S12.75-2012). Melville, NY: Acoustical Society of America (ASA).

Brüel & Kjær. (2017). Product Data Sheet, LAN-XI Data Acquisition Hardware. Retrieved from https://www.bksv.com/doc/bp2215.pdf

Department of the Army. (2015, January 8). Army Hearing Program (DA Pamphlet 40–501). Washington, DC: Department of the Army. Retrieved from https://armypubs.army.mil/epubs/DR_pubs/DR_a/pdf/web/p40_501.pdf

Florida Department of Transportation (n.d.). *Unmanned Aircraft Systems (UAS)*. Retrieved from https://www.fdot.gov/aviation/uas.shtm

Harris, C. M. (1998). Handbook of Acoustical Measurements and Noise Control. Acoustical Society of America, Woodbury, NY.

Textron Systems. (n.d.). Universal Ground Control Station. Retrieved from https://www.textronsystems.com/products/universal-ground-control-station

This page intentionally left blank.

Appendix A. Acronyms and Abbreviations

BCT	Brigade Combat Team
dB(A)	decibels
kHz	kilohertz
LAeq	A-weighted equivalent
Li	Lithium
mAh	milliampere hour
MALE	Medium Altitude, Long Endurance
NR	no result
NRR	Noise Reduction Rating
TUAS	Tactics Unmanned Aircraft System
UA	unmanned aircraft
UAS	Unmanned Aircraft System
UAV	unmanned aerial vehicle
UGCS	universal ground control station
USAARL	U.S. Army Aeromedical Research Laboratory
V	volt
WPG	Warfighter Protection Group

U.S. Army Aeromedical Research Laboratory
Fort Rucker, Alabama

All of USAARL's science and technical information documents are available for download from the Defense Technical Information Center.

https://discover.dtic.mil/results/?q=USAARL

Army Futures Command
U.S. Army Medical Research and Development Command