The Danger Zone for Noise Hazards Around the Black Hawk Helicopter

Heath G. Jones; Nathaniel T. Greene; Michael R. Chen; Cierrah M. Azcona; Brandon J. Archer; Efrem R. Reeves

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BACKGROUND: During ground operations, rotary-wing aircraft engines and subsystems produce noise hazards that place airfield personnel at risk for hearing damage. The noise exposure levels outside the aircraft during various operating conditions, and the distances from aircraft at which they drop to safe levels, are not readily available. The current study measured noise levels at various positions around the UH-60 Black Hawk helicopter for three operating conditions typically used when the aircraft is on the ground.

METHODS: Microphones were positioned systematically around the helicopter and A-weighted sound pressure levels (SPLs) were computed from the recordings. In addition, the 85-dBA SPL contour around the aircraft was mapped. The resulting A-weighted SPLs and contour mapping were used to determine the noise hazard area around the helicopter.

RESULTS: Measurements reported here show noise levels of 105 dB or greater in all operating conditions. The fueling location at the left rear of the aircraft near the auxiliary power unit (APU) is the area of greatest risk for noise-induced hearing loss (NIHL). Additionally, sound field contours indicate noise hazard areas (>85 dBA SPL) can extend beyond 100 ft from the helicopter.

CONCLUSIONS: This report details the areas of greatest risk for auditory injury around the UH-60 Black Hawk helicopter. Our findings suggest the area of hazardous noise levels around the aircraft can extend to neighboring aircraft, particularly on the side of the aircraft where the APU is located. Hearing protection should be worn whenever the aircraft is operating, even if working at a distance.

KEYWORDS: noise hazard, helicopter, Black Hawk, rotary-wing aircraft.

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Rotary-wing aircraft engines and subsystems are major sources of high-level noise that disrupts the ability to hear and degrades speech communication between individuals on the airfield (i.e., pilots, aircraft technicians, mechanics, and on/off boarding passengers). There are currently three primary rotary-wing airframes actively used by the U.S. Army: 1) UH-60 Black Hawk; 2) AH-64 Apache; and 3) CH-47 Chinook. For ground personnel working on or around these helicopters, noise-induced hearing loss (NIHL) remains an ever present occupational health hazard. Repeated exposure to noise levels in excess of 85 dBA has been shown to cause permanent NIHL in aviators.[1,2,7] In addition, the Army Hearing Program currently indicates that exposure to any steady-state noise level of 85 dBA or greater (regardless of duration of exposure) is considered hazardous and requires the use of hearing protection.[4,5] Despite the substantial noise levels produced outside of a helicopter, the hearing risks experienced by ground personnel have not received the same amount of consideration as those for pilots and aircrew. For example, regulations require that both pilots and aircrew wear double hearing protection; however, ground personnel are only required to wear single hearing protection in accordance with the Army Hearing Program.

Previous studies have reported that rotary-wing aircraft produce steady-state noise levels that exceed 85 dBA inside the cabin.[8,9] However, the noise level exposures of ground crew and maintenance personnel outside the aircraft during various

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operating conditions, and the distance from aircraft at which noise levels drop to safe levels are not readily available. In particular, the auxiliary power unit (APU) is a subsystem used to provide power to the aircraft during engine start-up procedures and is anecdotally reported to be uncomfortably loud. However, it is difficult to find information about the actual noise levels produced by the APU and how far they extend from the aircraft. As such, the noise level management and protections set in place for ground personnel are only being considered when these individuals are working on a helicopter with the APU running, but not when working on a helicopter (with the APU off) and next to an aircraft with the APU running.

All of the helicopters employed by the U.S. Army use an APU during start-up procedures and during maintenance that requires the aircraft to have power. Findings from the current study will serve as the basis for further research detailing the noise hazards associated with each airframe, and the communication demands of the individuals working in these complex and hazardous noise environments. As it is not possible to control the source of the noise from the engine and/or aircraft, one means for protecting personnel from the dangers of excessive noise is by identifying the areas of increased risk and improving existing preventative measures for reducing NIHL within these areas. Consequently, if preventative measures are not implemented, there are substantial incumbent training costs to the military for replacing personnel downgraded as a result of hearing loss.[11] Here we begin exploring the risk of hearing injury to ground crew and maintenance personnel by reporting the levels and spatial patterns of noise produced by the UH-60A Black Hawk helicopter on the airfield.

METHODS

The current study used the UH-60A (Alpha model) Black Hawk helicopter operated by the Flight Systems Branch at the U.S. Army Aeromedical Research Laboratory. Measurements were made around the aircraft during three operating conditions: APU Only, APU + Engine, and Engine Only (details in **Table I**). Microphones were positioned at 10-ft intervals along 45° radials centered on a point midway between the main wheels (**Fig. 1**). In addition, the 85-dBA sound pressure level (SPL) contour around the aircraft was mapped using a handheld sound level meter; however, only measurements for the first operating condition (APU Only, see Table I) were obtained due to pilot and aircraft crew instructions to reduce the researchers' movement around the aircraft while the rotor blades were turning. This was done for the protection of the researcher team, as air and ground crewmembers generally do not have the same movement restrictions imposed on them. Typically, one crewmember stands at the front of the aircraft near the left pilot's window and most crew operations take place within the diameter of the rotors. Once the rotors are at 100% rpm, the area around the aircraft is then cleared for takeoff, and the crewmembers climb in the aircraft and take seats at their crew stations.

Table I. Testing Conditions.

CONDITION #	CONDITION NAME	OPERATING CONDITION
1	APU Only	Engines off, APU operating, rotors not turning
2	APU + Engine	All engines operating with rotors turning at flight-idle and the APU operating
3	Engine Only	All engines operating with rotors turning at flight-maximum and the APU off

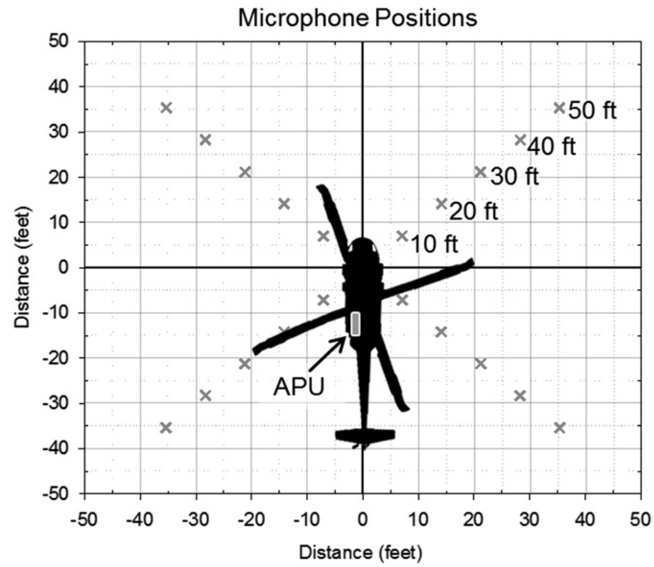

Fig. 1. Testing setup around the UH-60 Black Hawk helicopter. Microphones were placed at 45° angles 10 ft from the center point between the wheels. The location of the auxiliary power unit (APU) is indicated by the small gray box on the left side of the aircraft. Measurements were made at increasing distances of 10 ft (locations indicated by an 'x').

Microphone Recordings and Analysis

Four 1/4″ microphones (Model #4938, Bruel & Kjaer, Nærum, Denmark) with dynamic range spanning 30–172 dB were connected to two Bruel & Kjaer high-frequency LAN-XI Type 3052 modules, which is a three-channel system with a bandwidth of 102.4 kHz (sample rate of 262 kHz). Microphones were placed vertically on stands approximately 4 ft above the ground and were weighed down with sandbags to prevent them from being blown over by the rotor-downwash that occurs when the rotors are turning. For the third condition (Engine Only), only the 10-ft distance was measured due to concerns regarding microphone stand stability. Each recording lasted 2 min in length in accordance with MIL-STD-1474E and were analyzed in Bruel & Kjaer PULSE Reflex software to produce A-weighted SPLs. The resulting A-weighted SPLs were used to assess the noise hazard for typical ground crew exposure.

85-dBA Contour Measurement and Hazardous Noise Mapping

A type I sound level meter (Model #2270, Bruel & Kjaer) was used to obtain the locations of the 85-dBA contour around the aircraft. During the 'APU Only' condition (when the rotor

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blades were not turning), positions around the aircraft that were measured at 85 dBA SPL were marked. Distances and angles were measured from the center of the aircraft (defined here as the center point between the two front wheels) to each marked location. From this contour, a noise level contour map was generated via 2-D linear interpolation of data from the microphone recordings and assuming an increase of 6 dB as the distance to the aircraft was decreased by half for areas where measurements were not made. It should be noted that the noise hazard mapping is an approximation based on this assumption simply to illustrate the areas of increased risk.

RESULTS

The microphone recordings indicate that all locations within 30 ft of the aircraft exceed 85 dBA. Of particular concern, the location where the petroleum specialist stands to refuel the aircraft is directly under the APU exhaust (**Fig. 2**, rear left). Our measurements indicate this is the area of greatest risk for hearing damage and levels are consistently at or above the requirement for double hearing protection (i.e., combining over-the-ear muffs with ear inserted protection) as specified by the Army Hearing Program.[4,5] When the engines are operating at maximum power, noise levels exceed 110 dBA for all locations within 10 ft of the aircraft. Although it is rare to have personnel other than the aircrew around the aircraft when engines are at maximum power, there are instances when passengers are on/off-boarding during these conditions. For such instances, passengers who are not wearing hearing protection would be exposed to a significant amount of noise, which in this case exceeds the maximum allowable exposure duration in no more than 1.5 min.[6]

Distances around the aircraft at which the SPL was 85 dBA were mapped for the 'APU Only' condition. As indicated by the gray box on the helicopter image in Fig. 1, the APU (and the APU exhaust) is located on the left side of the aircraft. **Fig. 3** details the unique sound field around the aircraft and illustrates the acoustic shadowing of the aircraft. This placement results in an asymmetric sound field around the aircraft, where the 85-dBA contour extends ~40 ft to the right and ~130 ft to the left of the aircraft. Additionally, a substantial front-back asymmetry is observed, where the 85-dBA contour was closest directly in front of the aircraft's nose (0°), and furthest directly to the aircraft's left (−90°) and to the back-left (~ −170°). While it is not surprising that sound levels are greater on the side of the aircraft where the APU is located, it is remarkable how far the 85-dBA contour extends on this side.

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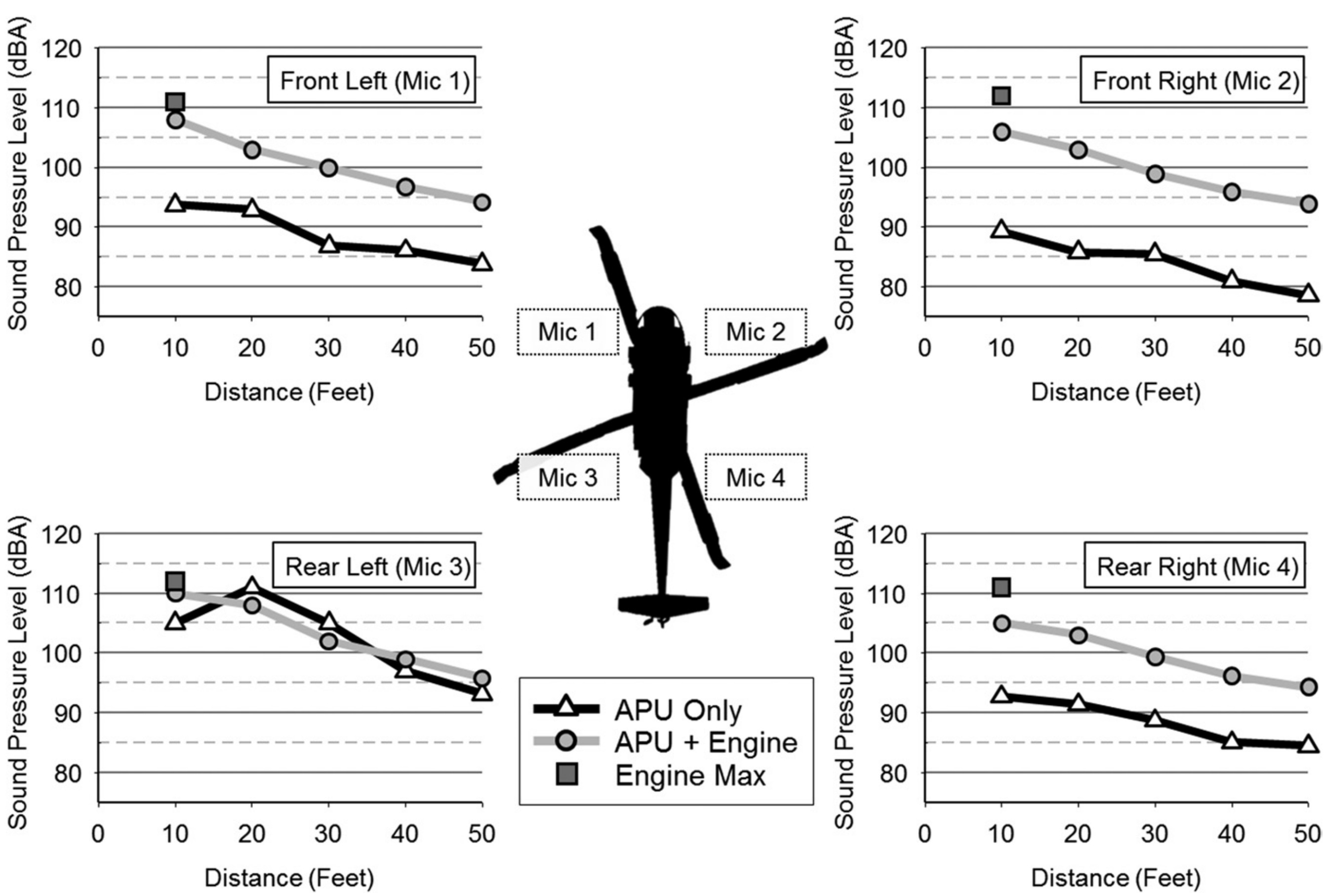

Fig. 2. Microphone recordings. Sound pressure levels (in dBA) recorded from microphones around the UH-60 Black Hawk helicopter at various distances. Data points for each condition are represented by the symbols indicated in the legend at the bottom center of the figure.

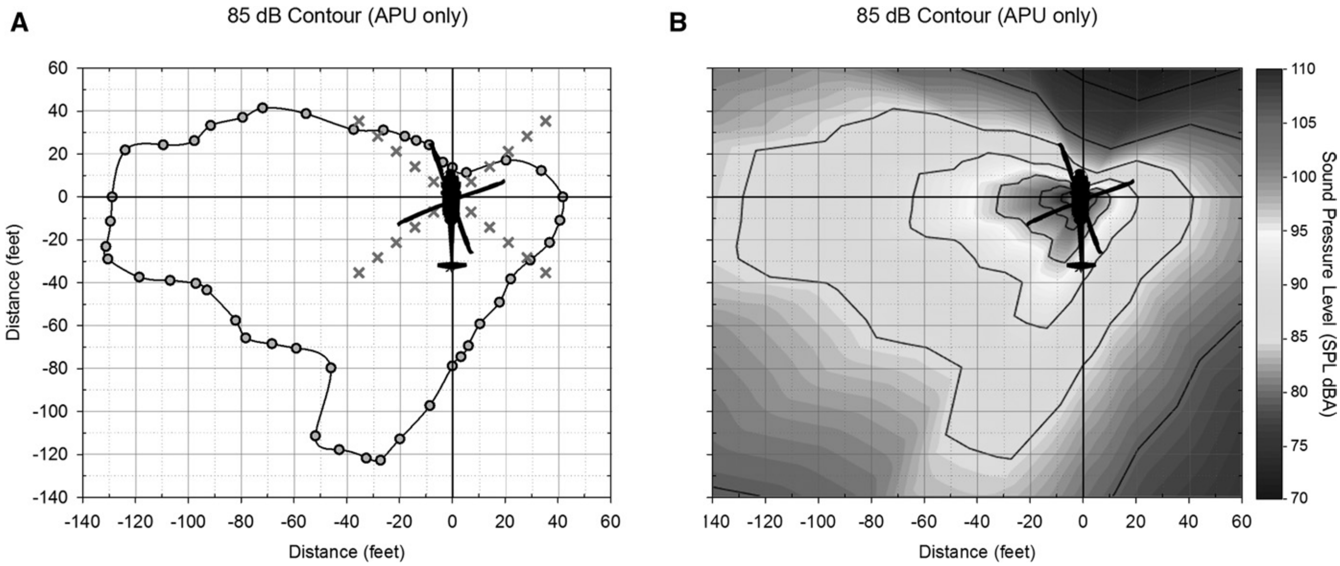

Fig. 3. Hazardous noise mapping for the APU only condition. A) Measurements using a sound level meter were made at distances around the aircraft to map out the 85-dBA contour. The x's are microphone locations and each gray point represents a measurement location. B) A noise-level contour map was generated using a 2-D linear interpolation of the microphone recordings (Fig. 1, x's) and assuming an increase of 6 dB as the distance to the aircraft is decreased by half.

DISCUSSION

Personnel working around rotary-wing aircraft perform their duties in the midst of many challenges. One of the biggest challenges is dealing with the excessive noise generated by the aircraft, as steady-state noise levels exceed 85 dBA (see Fig. 2 and 3B). Such conditions make it difficult to hear and effectively degrade verbal communication abilities, while placing these individuals at greater risk of NIHL.[3] Despite requirements to wear hearing protection,[4,5] it is common for airfield personnel (i.e., pilots, aircrew, ground crew, maintenance, etc.) to only wear hearing protection devices (HPDs) if the aircraft they are working with is operating. Many do not wear hearing protection when adjacent aircraft are operating, despite the observed hazard. The main reason behind this is that information detailing the areas and distances around the aircraft at which sound levels exceed 85 dBA is not readily known. In order to address this, the current study measured the noise levels and assessed the sound field generated by the UH-60A Black Hawk during typical engine operating conditions.

Pilots and aircrew can be downgraded from flying duties (i.e., taken off flight status) if it is discovered that they have hearing loss.[10] In light of the more stringent hearing requirements and safety mechanisms for protecting pilots and aircrew, there is far less attention dedicated to protecting ground crews and maintenance personnel. This is surprising because the inability to hear and communicate effectively interferes with operational performance and can also compromise safety. In fact, the sound levels computed from the microphone recordings reported here detail the hazardous extent to which the acoustic environment is degraded. Sound levels for locations within 10 ft surrounding the aircraft were recorded at 105 dBA or greater for all conditions in which the engines were powered (Fig. 2). At these levels ($>$103 dBA SPL), our data suggest that anyone this close to the aircraft should be required to wear double hearing protection according to the Army Hearing Program.[4] It has been previously reported that Navy aircraft carrier flight deck personnel were at an increased risk of hearing impairment due to inappropriate personal protection (i.e., most did not wear double hearing protection) and markedly elevated noise exposures.[12] Similar issues with HPD compliance more than likely exist for Army airfield personnel.

Currently, there are few times when there is a direct communication link between the pilot or crew chief and the ground crew. Ground crews often use hand signals to communicate, which are not effective if the other person is not looking, on the other side of the aircraft, or simply not visible. Anecdotally, HPDs are removed to facilitate communication on the airfield (i.e., the person giving instructions lifts up the ear cup of the person receiving instructions and shouts the instructions); however, removing HPDs to communicate exposes personnel to extremely hazardous noise doses and does not always guarantee that instructions are successfully communicated. Although there are commercially available products currently on the market that combine hearing protection with communication abilities, it is still important to know where and how far from an aircraft these devices should be worn when the engines and/or the APU are operational. Here we mapped the high-intensity noise environment around one of the Army's more commonly used airframes. The aim is to increase awareness about the areas of greatest risk when working around these aircraft and provide information about where exactly personnel should not be removing their HPDs.

Our findings suggest the area of hazardous noise levels around the aircraft can extend to neighboring aircraft, particularly on the side of the aircraft where the APU is located. In fact, when the APU is on, noise levels at the rear left (Fig. 2, Mic 3) of the aircraft can reach approximately 95 dB SPL even at 50 ft

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away. This means distances further away from where aircraft personnel would typically be operating are still in a noise area that is 10 dB above the Army Hearing Program hearing protection requirement.[4,5] Our 85-dBA contour measurements indicate that hazardous noise levels for the UH-60 Black Hawk extend to 135 ft to the left of the aircraft and 120 ft behind the aircraft. This means that anyone working within these distances of an aircraft that has an operating APU should be wearing hearing protection. Such findings suggest a modification to hearing conservation practices regarding where personnel working around rotary-wing aircraft are safe, and where they should be required to wear hearing protection.

In conclusion, the current study provides evidence that the fueling location at the left rear of the aircraft near the auxiliary power unit is the area of greatest risk for noise-induced hearing loss. Sound pressure levels at the fueling location can exceed 105 dB SPL in all three engine conditions, and exceed 85 dB for almost all locations and engine conditions tested. Hearing protection should be worn whenever the aircraft is operating, even if working at a distance. These findings detail airfield noise hazards for a rotary-wing airframe and invite studies of the communication demands between air and ground crews.

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