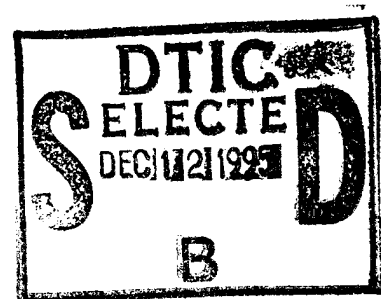




## Communication and Noise Hazard Survey of CH-47D Crewmembers

By

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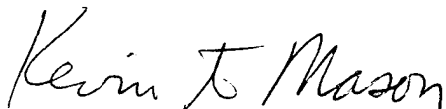
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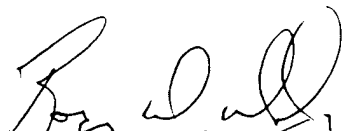
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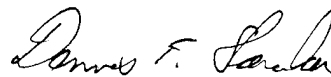


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### Military relevance

U.S. Army rotary-wing aviators (pilots) and enlisted crewmembers (crewchiefs) are exposed routinely to high levels of steady-state noise. The CH-47D helicopter is the largest and the loudest of the Army's rotary-wing aircraft. To put this in perspective, the Department of Defense requires hearing protection be worn when an employee is exposed to noise levels of 85 dBA or more.<sup>1</sup> The CH-47D, with noise levels of 115 dBA, produces sound pressures a thousand-fold greater than this standard. The purpose of this study was to survey crewmembers working in the CH-47D environment to determine what baseline conditions, if any, impact on their ability to effectively communicate during routine flight operations.

### Background

The CH-47D configuration is unique with two large fore and aft transmissions and two corresponding sets of rotor blades as shown in Figure 1. The auxiliary power unit (APU) is another noise source in proximity to the aft transmission. As a result crewmembers, whether fore (aviators) or aft (crewchiefs), are exposed to significant noise levels during normal operations.

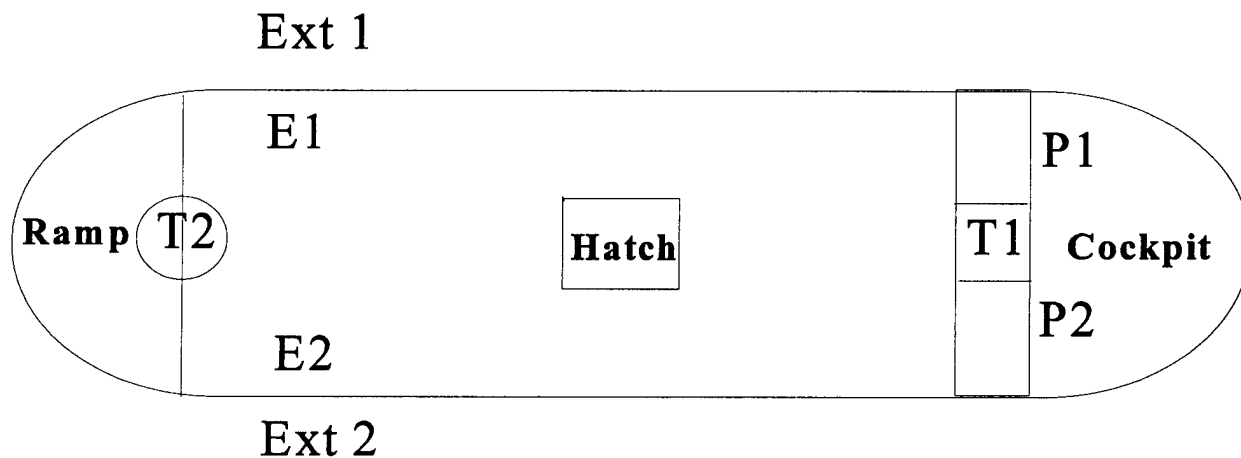


Figure 1. Top-view schematic of the CH-47D aircraft showing sound measurement and noise source locations: Pilot stations in the cockpit (P1, P2), crewchief stations (Hatch, Ramp), transmission and rotor systems (T1, T2), engine systems (E1, E2), and sound measurement stations external to the aircraft (Ext 1, Ext 2).

The noise in the cargo area of the CH-47D varies depending on whether the floor hatch and aft ramp doors are open or closed. To transport a load outside the aircraft, such as a vehicle, or cannon etc., crewchiefs must open the floor hatch. Being secured only by a "monkey harness," they partially exit the hatch in flight and manually attach or release the hook to the cargo. They communicate exact directions to the aviators on where to position the aircraft vertically and

horizontally, often with an accuracy of within one foot. Speech intelligibility in this situation is critical.

During start up and shut down operations, the crewchief exits the aircraft to perform certain maintenance and safety checks near the aft ramp and on both sides of the aircraft near the engines. This is done while maintaining contact with the pilot in command (PIC) and the copilot via the intercom system(ICS). Movement of the crewchief in and out of the aircraft is limited by the 50-75 foot ICS cable.

This study was preparatory to research that will examine new hearing protection technologies for air and ground combat crewmembers. Currently, the U.S. Army Aeromedical Research Laboratory, Fort Rucker, Alabama, is developing and evaluating a communications earplug (CEP). The CEP is a promising device that provides hearing protection for rotary-wing crewmembers while enhancing speech intelligibility.<sup>2</sup>

### Methods

Respondents (N = 17; 16 male, 1 female) were members of a U.S. Army Reserve CH-47D unit. A survey was distributed to the subjects during their annual summer camp. In-flight noise levels were measured on two consecutive days in two CH-47D aircraft using a Rion™ sound level meter, model NL11, at locations noted in Figure 1. These are positions where CH-47D crewmembers work during normal operations. Air speeds during measurements ranged from 80 to 160 knots.

### Results

Volunteer respondents ranged in rank from Sergeant to Major (11 officer aviators, 6 enlisted crewchiefs). The mean age was 35.8 (range 26-51), mean flying experience in years was 10.1 (range 2-26), and mean lifetime flight hours was 1786 (range 200-8500). Fifteen respondents wore the standard SPH-4 Army aviator helmet, while the remainder wore the newer SPH-4B model.

#### Personal hearing history

Seven (41%) of the subjects (2 crewchiefs, 5 aviators) reported a history of hearing loss, most being documented as sensorineural hearing disorders. Three (43%) of those crewmembers with a hearing loss attributed it to a combination of job-related and recreational noise, while three other respondents reported losses solely due to flying-related noise.

Three subjects (18%) had aeromedical waivers for hearing loss. Following an audiometric evaluation, aeromedical waivers are granted to crewmembers with hearing deficits that exceed U.S.

Army Class 2 flying duty medical standards. Waivers permit continued flying duties with hearing deficits, and in some cases with hearing aid devices. Rarely, crewmembers with advanced hearing loss are removed from flying duties.

Hearing protection

Five of 17 crewmembers (29%) reported that they used double hearing protection, defined as wearing personal hearing protection (EAR™ yellow foam earplugs) with their helmet earcups. Table 1 compares double hearing protection use between crewchiefs and aviators. The proportion of aviators wearing double hearing protection was 24% compared to 6% of the crewchiefs. However, aviators were not statistically more likely to use double hearing protection (Fisher's exact, one-tail,  $p = 0.395$ ) than their enlisted counterparts, given the small sample size.<sup>3</sup>

Table 1.  
Comparison of hearing protection practice among CH-47D aircrew members.

	Double hearing protection	Helmet only	N
Aviator	4	7	11
Crewchief	1	5	6
Total	5	12	17

One respondent reported discomfort with the EAR™ plug as a personal hearing protector. Of the seven crewmembers with a hearing loss, only one reported wearing double hearing protection. This raises an issue of why crewmembers, aware that noise levels in the CH-47D are higher than in other Army helicopters, choose to wear the standard helmet with hearing protector earcup only. By comparison, in a separate survey of 20 UH-1 aviators and crewchiefs, 70% used double hearing protection.<sup>4</sup>

Helmet and ancillary equipment

Nine (53%) crewmembers reported frequent discomfort with their helmets. This number was unexpectedly high. The reasons given for helmet discomfort ranged from hot spots on the scalp to itching. The onset of discomfort was estimated at less than 2 hours of flight time.



Five (29%) of those surveyed routinely wore eyeglasses while flying. Of those, three (60%) had a hearing loss and four (80%) complained of tinnitus or muffled hearing after flying.

Thirteen (76%) of the crewmembers reported prior experience wearing a chemical and biological protective mask in flight. Eight (62%) described problems such as muffled voice and earcup seal compromise while wearing the mask.

Noise in the CH-47D environment

Table 2 presents the in-flight sound level data obtained using an A-weighted scaling. Noise levels reached 115 dBA in the CH-47D ramp area. Crewchiefs spend a considerable amount of time near the ramp, particularly during start up and shut down operations. Aviators are exposed to high noise levels in the cockpit (107 dBA). In contrast, the in-flight noise level in the cockpit of a UH-60 (Blackhawk) at 120 knots is 102-103 dBA, more than a two-fold reduction in noise compared with the CH-47D cockpit.

Table 2.  
Sound level measurements of CH-47.\*

Sound measurement location	Sound level dBA
Ramp area (E1, E2, and T2)	111-115
Cockpit/jump seat (P1, P2 and T1)	107
Cargo area (floor hatch closed)	105
Outside during start up (Ext 1 and Ext 2)	103-105
Cargo area (hatch open)	102-104

\* See Figure 1 for locations.

Respondents rank ordered the loudest area(s) of the CH-47D as shown in Table 3. Crewchiefs, whose duty station is routinely near the ramp, tended to find the aft section under the transmission and auxiliary power unit (APU) to be the loudest work environment. Aviators, whose duty position is in the cockpit, found the jump seat directly under the forward transmission to be the loudest area. These subjective findings agreed with the physical data provided in Table 2. Crewmembers rank ordered the loudest operational condition for the CH-47D. Table 4 shows take-off was identified as the loudest condition.

### In-flight communications

There was a universal concern among surveyed aviators regarding the setting of the radio volume controls on the console in the cockpit. Six of the 11 (55%) aviators reported disagreement with their copilots on the setting of the volume control for the aircraft radios. Two respondents considered this extremely annoying. Table 5 presents the open-ended responses from crewmembers on their procedure or technique for setting of the volume control during operations. There is not a consensus of opinion on how to optimize the setting.

When respondents were asked how frequently they experienced in-flight communication difficulties, 8 (47%) answered "occasionally" as shown in Figure 2. Six out of 17 (35%) reported communication problems were occurring more than half of the time. Aviators are required to monitor several communications channels simultaneously to include radio, intercom, warning, and navigational signals. Figure 3 presents the mean values of crewmember responses when asked to rank the most demanding condition during flight operations with respect to communications. The higher the value, the greater the criticality of the condition. "Multiple trans." refers to a condition where more than one radio channel is active with incoming traffic. "ICS" refers to the intercom system (i.e., within the aircraft). "ILS" refers to the instrument landing system, which is used when visibility is low and aviators must rely on instrumentation to determine altitude, speed, heading etc. "Fire guard" duty refers to the position of the crewchief outside the aircraft during engine start and refueling with engines running. In this situation, the crewchief communicates with the pilot via the ICS. "Other" refers to hoist operations, sling loads, and operations in confined areas. "Landing", "Take-off", and "Night" are self-explanatory.

Table 3.  
Perceived loudest areas for the CH-47D.

- |  |
|--|
| <ol style="list-style-type: none"><li>1.<ol style="list-style-type: none"><li>a. Forward transmission</li><li>b. Aft transmission</li><li>c. Aft ramp area</li></ol></li><li>2. Auxiliary Power Unit (APU)</li><li>3. Cargo/passenger area</li></ol> |
|--|

Table 4.  
Loudest CH-47D operating conditions.

- |   |
|---|
| <ol style="list-style-type: none"> <li>1. Take off</li> <li>2. Forward cruise (wind effect on the fuselage)</li> <li>3. Engine run-up</li> <li>4. Landing, sling operation, APU operation</li> <li>5. Hoist operation or shut down</li> </ol> |
|---|

Table 5.  
Volume control preferences in CH-47D.

- |  |
|--|
| <ol style="list-style-type: none"> <li>1. Personal preference (3 respondents)</li> <li>2. Loud enough to hear without discomfort (3)</li> <li>3. Maximum setting all the time (3)</li> <li>4. Depends on condition of radio (2)</li> <li>5. Adjust just above the background noise</li> <li>6. Based on personal experience</li> <li>7. Depends on the situation</li> <li>8. ½ way between minimum and maximum</li> <li>9. Happy medium between two aviators</li> <li>10. Set the volume to maximum when the copilot is looking the other way [sic]</li> </ol> |
|--|

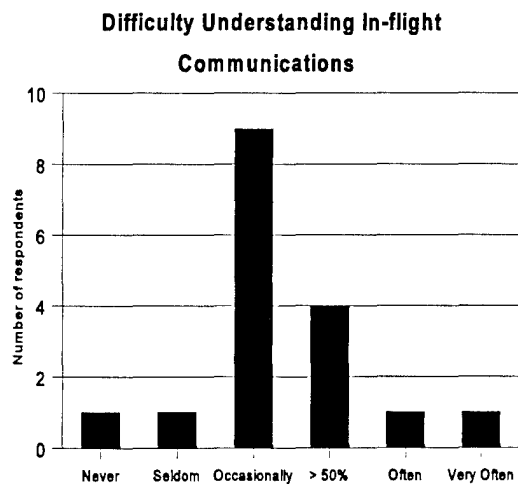


Figure 2. Frequency of in-flight communication problems.

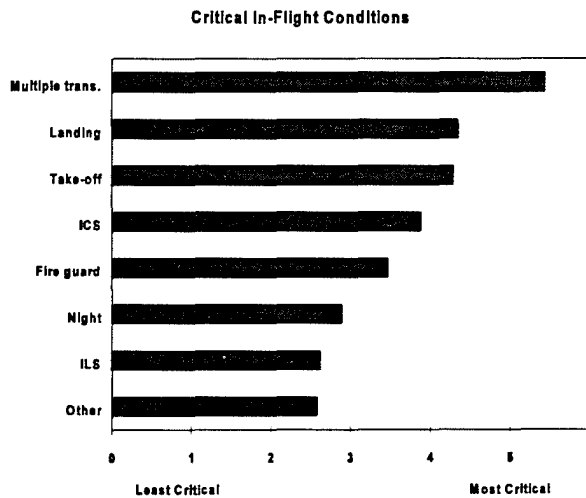


Figure 3. Criticality of communications during phases of flight.

### Air traffic controllers

When asked to evaluate speech intelligibility from control tower transmissions, 63% of the crewmembers surveyed felt that air traffic controller (ATC) voices, whether male or female, were comparable. Of the three who responded that female voices were more difficult to understand than male voices, two had hearing losses. This perception is understandable as most noise-induced sensorineural hearing losses occur initially in the higher frequencies. Women's voices have a higher fundamental frequency than men's voices, and are more difficult to understand when a listener has a high frequency hearing loss. Twelve of 14 respondents (86%) felt speech intelligibility was better when the air traffic controllers were native or near native in their ability to speak American English, than when nonnative speakers were transmitting over the radio.

### Audible warning and navigational signals

Five (29%) respondents reported problems in hearing audible in-flight signals such as navigational signals (pure-tone beeps of various patterns) and warning signals (e.g., low rotor RPM). CH-47D crewmembers considered other important auditory signals were the APU (auxiliary power unit), engine shut down, and operation of the air-cooling fan. When asked how often difficulty in hearing these signals occurred, responses ranged from "seldom" to "occasionally".

### Post-flight

Four (24%) crewmembers (2 aviators, 2 crewchiefs) complained of chronic tinnitus (ringing in the ears) after flying. Three (18%) other respondents (2 aviators, 1 crewchief) complained of muffled hearing after flight. Of the seven who complained of either tinnitus or muffled hearing, four (57%) reported having a permanent hearing loss. A subsequent check of medical records verified the hearing losses. Several of the respondents who complained of tinnitus or muffled hearing, indicated that they had been trying for months to improve the fit of their helmets, and were still in the fitting process.

### Discussion

First, there was a considerable number of hearing losses reported by the crewmembers surveyed. Most of the hearing losses were categorized as mild, high frequency, usually above 2,000 Hz and sensorineural. The mild degree of hearing loss was evidenced by the small number of hearing waivers in effect. Second, more than two-thirds of the CH-47D crewmembers surveyed chose to forego double hearing protection to enhance communications in the operational environment. Respondents expressed concerns about hearing key or critical sounds necessary for operation of the aircraft. They suggested that in the operational noise environment of the CH-47D, double hearing protection was a disadvantage. Crewchiefs were quite vocal about not being able to

hear "diagnostic sounds" in the aircraft when wearing double hearing protection. This bias is understandable given the levels of noise in which the crewchiefs operate, particularly when in the vicinity of the ramp.

Herein lies a paradox. Hearing protectors are designed to attenuate hazardous levels of sound. Consequently, their attenuation may occur in the frequency band of those "diagnostic" sounds which the crewmembers need to monitor. The problem is compounded when crewmembers have a preexisting hearing loss which lies within the target frequency band of the "diagnostic" sound(s). A hearing loss coupled with the use of double protection could attenuate the sound to the degree that the crewmember would have to rely on cues other than hearing in order to function effectively.

Third, the majority of crewchiefs in this study preferred turning the VC on their ICS box up to maximum in order to hear communications from the cockpit. This was particularly true when crewchiefs were in the ramp area during operations. Therefore, in addition to the ambient noise of transmissions, turbines, and the APU, the ears of crewchiefs were exposed to the loudest speech signal possible in the aircraft communications system. It is highly probable that this bombardment upon the auditory system will eventually result in hearing loss(es).

Fourth, the wearing of eyeglasses with an aviator's helmet may affect the preservation of crewmembers' hearing. Eyeglass temples, such as the Army-issue bayonet style, compromise the integrity of the ear cup seal and reduce its attenuation characteristics.<sup>5</sup> The number of aviators wearing eyeglasses is increasing, especially in the reserve components.<sup>6</sup> Older crewmembers are more likely to need glasses than younger ones. The average age of members in a reserve unit is higher than that found in a typical active duty unit.<sup>7,8</sup> Age differences and prevalence of wearing glasses may confound comparison of this study to other hearing conservation surveys of aviator cohorts.

Eighty percent of crewmembers who wore eyeglasses in flight experienced tinnitus or muffled hearing. Tinnitus and/or muffled hearing are evidence of temporary threshold shift or serve as predictors of noise-induced hearing loss. Of those who wore eyeglasses in flight, 60% reported having a hearing loss, while only 40% wore double protection. The decision not to wear double hearing protection puts the majority of crewmembers, particularly crewchiefs, at risk for eventual permanent hearing damage. Future development of personal hearing protection/equipment should reduce the noise levels reaching crewmembers' ears, enhance speech intelligibility and compatibility with eyeglasses, protective masks, or other ancillary equipment, without sacrificing attenuation. Research on this issue is forthcoming from our laboratory.

Fifth, the SPH-4 helmet, when properly fitted, should provide adequate protection to the CH-47D crewmember to meet the Department of Defense Instruction 6055.12 exposure criteria of 85 dBA. If this premise is true, why would seven of 17 crewmembers be experiencing tinnitus and/or muffled hearing after flight? Why would over half of the respondents be experiencing helmet discomfort? Despite efforts of the crewmembers and support personnel, many helmets at this unit

may not be adjusted adequately. Inspection of respondents' helmets revealed that some, but not all, had been upgraded with thermoplastic liner (TPL) that is designed to improve helmet fit.

Sixth, over half the aviators surveyed complained of problems in setting the radio and ICS VC. The issue of setting the radio and ICS VC is not only one of listening comfort, but also is germane to issues of safety and crew coordination. In the CH-47D, there are three radios plus an ICS box for each aviator. The radios and ICSs have separate volume controls. However, the radios are monitored through the ICS. Aviators first set the level of each radio, then set the ICS to their preferred listening level. This leads to disagreements between aviators on the volume setting.

For example, if a pilot in command (PIC) wears double hearing protection and the copilot does not, a problem arises regarding how to adjust the VC. Double hearing protection reduces the levels of noise as well as speech getting through to the crewmember's ears. To compensate for the reduced level of the speech signal transmitted over the radio, the natural reaction for an aviator is to increase the VC setting. This is a problem for the copilot who does not have the benefit of double hearing protection and must listen to the radio at an uncomfortably loud setting. The copilot is exposed to loud levels of acoustic energy under the helmet earcup in addition to the loud aircraft noises. This increases the risk for noise-induced hearing loss.

To compensate for the increased loudness, the copilot lowers the volume of his/her ICS. In this condition, radio communications become tolerable. However, when other crewmembers eventually communicate over the ICS, the copilot must readjust the VC up to hear intra-aircraft traffic. Constantly readjusting the VC during flight while attending to other aviation responsibilities is a safety concern for the aviator. Improvements are needed in the communications systems used by Army rotary-wing crewmembers.

Seventh, less than one-third of the respondents expressed difficulty monitoring in-flight navigational/warning signals. A safety issue arises when crewmembers begin to incur a hearing loss. For example, if the hearing loss falls within the spectrum of sound where the navigational/warning signal is generated, and if the crew are flying ILS (instruments only), important in-flight information could be missed.

Several questions arise as a result of this survey: 1) Does the SPH-4 series helmet provide adequate hearing protection for CH-47D crewmembers, particularly the crewchiefs? 2) If so, why are crewmembers experiencing tinnitus and muffled hearing after flight? 3) What effect does the wearing of eyeglasses have on the attenuation characteristics of the SPH-4 helmet? 4) If the earcup seal is compromised, could this lead to earlier hearing loss for crewmembers? 5) Why should the majority of CH-47D aviators and crewchiefs in this study prefer to only wear the aviator helmet when additional protection (e.g. EAR<sup>TM</sup> earplugs or similar personal hearing protection) would reduce the probability of hearing loss? 6) Why are so many of the crewmembers experiencing discomfort with their helmets? 7) What can be done to reduce the communication difficulties encountered by aviators and crewchiefs in the CH-47D, particularly regarding setting of the volume control?

## Conclusion

This was a preliminary look at a small population of CH-47D crewmembers. Some trends surfaced that raise safety- and communications-related concerns. CH-47D crewmembers are exposed to noise levels that are at least twice those of other Army rotary-wing aviators. Most crewmembers attempted to compensate for the noise environment by wearing single protection (helmet earcups only), and by maximizing the radio volume control setting. These operational practices and preferences, coupled with less-than-optimum helmet adjustment, were likely contributing factors that resulted in 40% of the crewmembers sustaining hearing losses. Other possible factors were the wearing in flight of eyeglasses or protective masks. One-third of the crewmembers in this study reported in-flight communications problems. These and other findings underscore the need for substantial improvements in the development of communications systems for CH-47D crewmembers. Paramount among these improvements should be increased attenuation of hazardous noise levels and enhanced speech intelligibility.

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