



**Subjective Evaluation of the Communications Earplug  
with Flexible Harness (CEP/FH) among CH-47D  
crewmembers**

**By**

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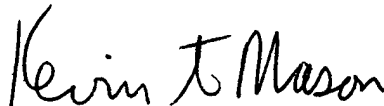
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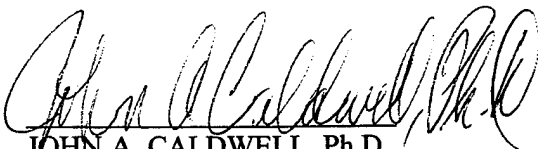
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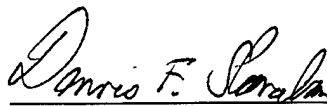
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## Military relevance

The CH-47D (Chinook) cargo helicopter is the largest and the loudest of the U.S. Army rotary-wing aircraft. Noise levels inside the CH-47D may be as high as 115 dBA at some of the crew positions. Communications during operations are critical between crewmembers (pilot and crew chief), particularly when external cargo is carried. Existing communications headsets provide adequate hearing protection in most Army aviation noise environments. However, in many of the CH-47D operational environments, hearing protection is marginal. Most aviation environments need improvements in speech intelligibility, especially in the CH-47D. The Army is evaluating a new hearing protection/communications device that improves speech intelligibility in noise. The Communications Earplug (CEP) is a simple, lightweight, relatively inexpensive device that provides adequate hearing protection to meet DOD standards (DODI 6055.12) and enhances speech intelligibility in noise (Mason and Mozo, 1995).

## Background

Most Army aviators wear the SPH-4 series helmet. Auditory-related functions of the helmet include hearing protection and speech communications (Mozo et al., 1974). Use of double hearing protection (helmet plus personal protection earplugs) is common among crewmembers as a means of providing additional in-flight hearing protection (Mozo, Murphy, and Ribera, 1995; Ribera, Mozo, and Murphy, 1996). However, double protection adversely affects a crewmember's ability to hear and understand speech. The problem is that the helmet earphone output must overcome the attenuation of the earplug to provide speech signals to the ear that are loud enough to be understood. An additional problem arises when one of the aviators in the cockpit has normal hearing and the other has some degree of hearing loss, or if one wears double hearing protection and the other does not. A "normal" hearing aviator, or one who does not wear double protection, tends to adjust the radio volume control to a much lower level than an aviator with a hearing loss or one who is wearing double hearing protection. This can result in conflict over volume control settings, degrade speech intelligibility, and compromise optimum communications, all of which are potential safety issues.

The CH-47D, with its two large transmissions, turbine engines, and auxiliary power unit (APU) produces hazardous noise levels during normal operations. Aviators (officers) and crew chiefs (enlisted) must maintain a high level of effective communication when transporting external loads, such as vehicles or cannons. In these situations, crew chiefs partially exit the floor hatch in flight and manually release or attach a cargo hook to the load. In this precarious position, crew chiefs give exact directions to the aviators through the inter-communications system (ICS) on where to position the aircraft vertically and horizontally. The accuracy of these instructions usually is to within 1 foot. Sometimes the aircraft is hovering over water, or an embankment, or in a confined area. An error in communication can mean disaster. Speech intelligibility in these situations is critical.

Crewmembers encounter other auditory-related problems such as postflight tinnitus, muffled hearing, or reduced noise attenuation when wearing ancillary equipment such as eyeglasses or CB protective mask (Ribera et al., 1996). Because of these and other communications-related issues facing the rotary-wing community, the U.S. Army Aeromedical Research Laboratory (USAARL), Fort Rucker, Alabama, developed the CEP.

The CEP is composed of a miniature earphone transducer adapted with a screw-on tip compatible to either the triple flange earplug or a Comply™ foam earplug (Figure 1). A 2.5 mm diameter hole from tip to handle of the earplug provides a path for sound to enter the occluded portion of the external auditory meatus. The complete system is lightweight, and is easy to clean and maintain.

The CEP provides hearing protection for rotary-wing personnel while enhancing speech intelligibility in high noise environments (Mason and Mozo, 1995). When the CEP is worn in combination with the aviator helmet, noise attenuation is increased for all frequencies. Figure 2 shows the real-ear attenuation data from 20 aviators wearing the SPH-4B with and without the CEP. Based on these data, the CEP, worn in conjunction with the SPH-4B helmet, should yield an enhanced speech-to-noise ratio as well as greater noise attenuation when compared with the aviator's standard issue helmet. Such a combination results in fewer incidents of hearing loss due to exposure to aircraft noise.

Results of initial field testing of an early prototype revealed that the CEP was comfortable and acceptable in the operational environment (Mozo, Murphy, and Ribera, 1995). However, the external coiled cable was cumbersome. This led to the development of a flexible head harness platform for the CEP (Figure 3), made of Simplex cotton, the same material used in aviator skull caps. Table 1 outlines the key characteristics for the harness.

In an attempt to develop a self-contained communications device, a noise canceling microphone eventually was added to the harness. A microphone was integrated into the harness to permit aviators/crewmembers to don the CEP with flexible harness (CEP/FH) before entering the aircraft. Once connected to the aircraft's communications system, crewmembers could establish voice contact with each other, while going through start-up procedures, before donning the helmet. The microphone was commercially available and was adapted to the aircraft communications system. A thick laminate microphone footplate was sewn into the harness fabric so as to fit directly over the right temple and provide stability. It was hypothesized that additional stability would be provided by the helmet, once in place.

The CEP/FH design incorporated anthropometric measurements made on 20 aviators and crewmembers. Measurements were "head circumference," "bitracion/coronal" (over the top of the head, from the superior portion of the ipsilateral tragus to the top of the contralateral tragus), and "transverse-to-wall" (distance from the anterior superior attachment of the helix to theinion).

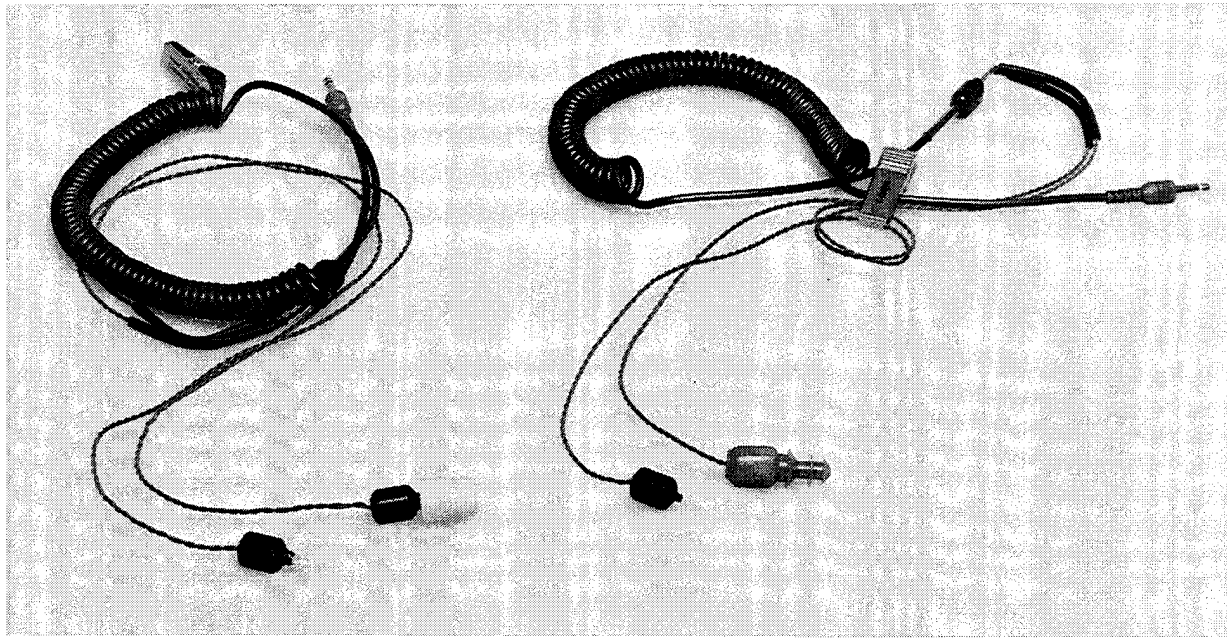


Figure 1. Communications earplug (CEP) prototype. CEP is compatible with plastic triple-flange or Comply™ foam eartips.

**Attenuation of communications devices in UH-60 simulated noise  
(N = 20)**

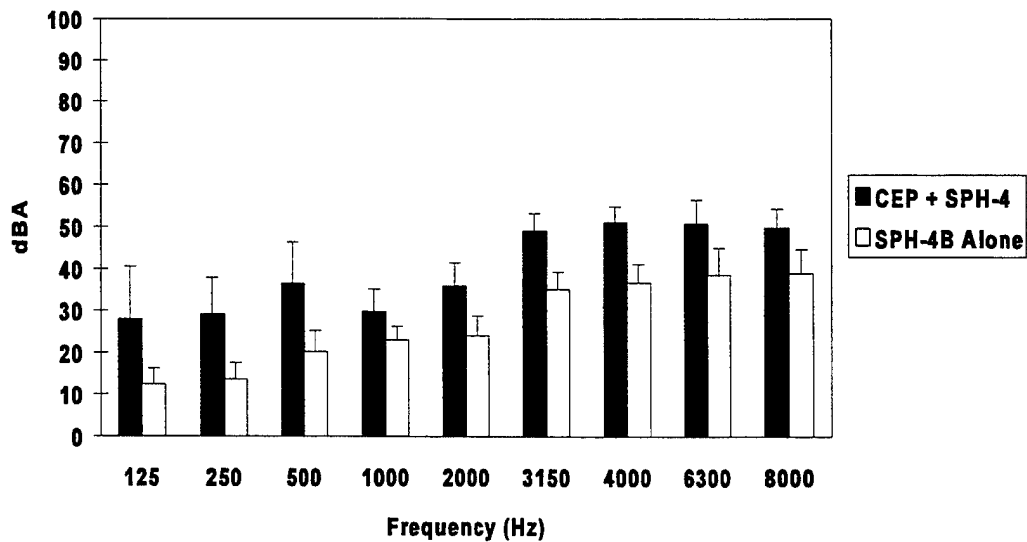


Figure 2. Attenuation in dBA of SPH-4B aviator's helmet alone and with CEP.

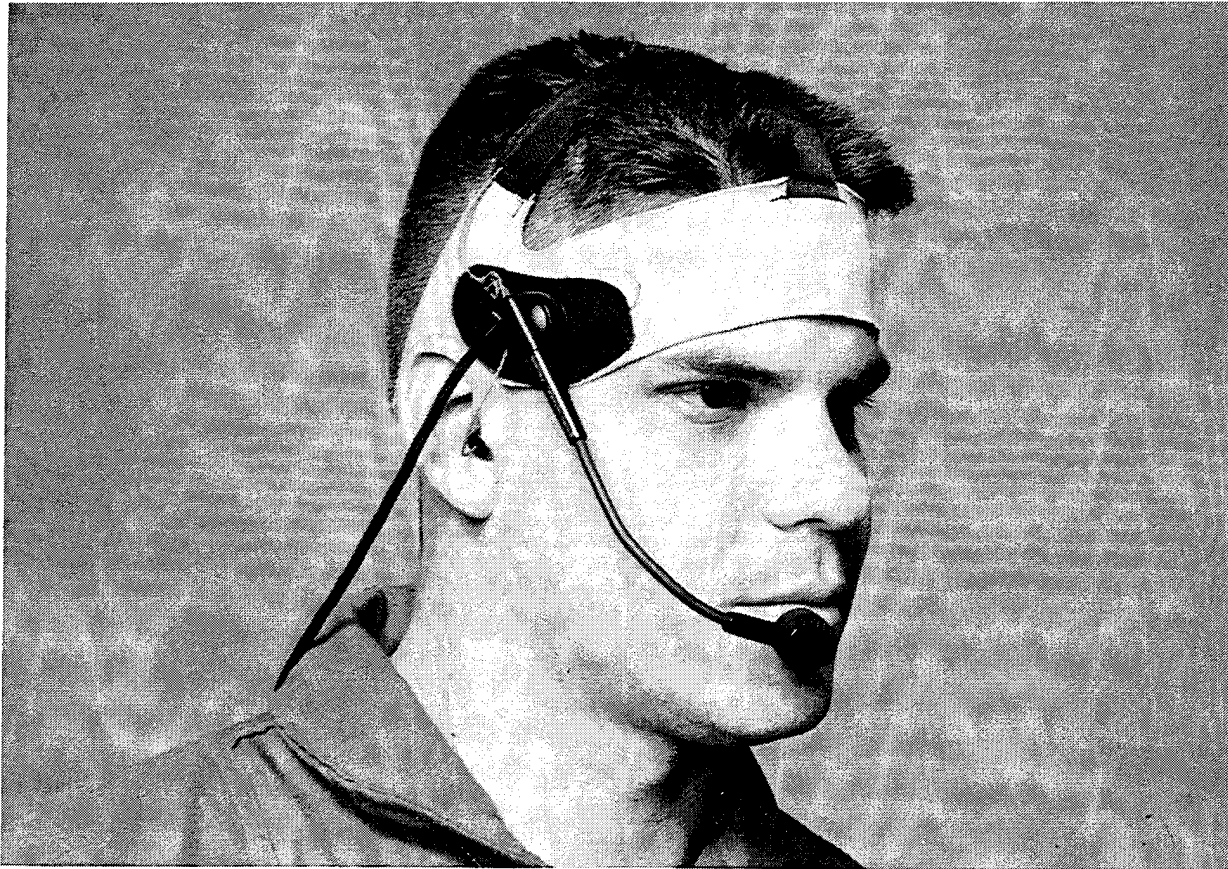


Figure 3. Communications earplug with flexible harness (CEP/FH) prototype including commercial microphone, flexible “goose neck” boom, and temple footplate for added stability.

Table 1.  
Desired design characteristics of CEP/FH.

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Comfortable  
Adjustable  
Compatible with men’s and women’s hair styles  
Able to breathe  
Fire retardant  
Able to hold the CEP in place during flight

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The purpose of this study was to evaluate the function, comfort, and acceptability of the CEP/FH in the operational environment.

### Methods

Subjects (N = 17; 16 male, 1 female) were members from a U.S. Army Reserve CH-47D unit. CEP/FH devices were assembled and individually fitted to each subject. Instructions were given on fitting, adjustments, and operational use in the aircraft communications system. Subjects were instructed to use the CEP/FH whenever flying during their 2-week annual training. Crewmembers responded to a 48-question survey at the completion of active duty training. The first part of the questionnaire dealt with hearing protection, helmet and ancillary equipment, noise in the CH-47D environment, in-flight communications, air traffic controllers, audible warning and navigational signals, and postflight hearing status (Ribera et al., 1996). Questions specifically relating to the CEP/FH were posed in the second half of the questionnaire and will be discussed below.

### Results

Subjects ranged in rank from Sergeant to Major (6 crewchiefs, 11 aviators). 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 or modified SPH-4 Army aviator helmet, while two wore the newer SPH-4B model. Respondents flew a total of 264 (mean 20) hours with the CEP/FH.

Of 17 respondents, 15 (88 percent) reported a noticeable improvement in speech clarity over the ICS system when the CEP/FH was worn (Figure 4). All respondents reported a noticeably reduced level of aircraft noise at the ear; 13 crewmembers (74 percent) qualified their answers indicating the reduction in noise ranged from "great" to "slight" (Figure 5). This perception was consistent with laboratory results (Mason and Mozo, 1995).

Most respondents reported that the tendency was to set the radio and ICS volume control much lower when wearing the CEP/FH than when wearing the SPH-4 alone. Eleven crewmembers (65 percent) found the CEP/FH generally helpful in the operational environment. Problems reported are presented below and are divided into the three major components of the CEP/FH (viz., microphone, harness, and the CEP itself). Recommended solutions to these problems are listed in Table 2.

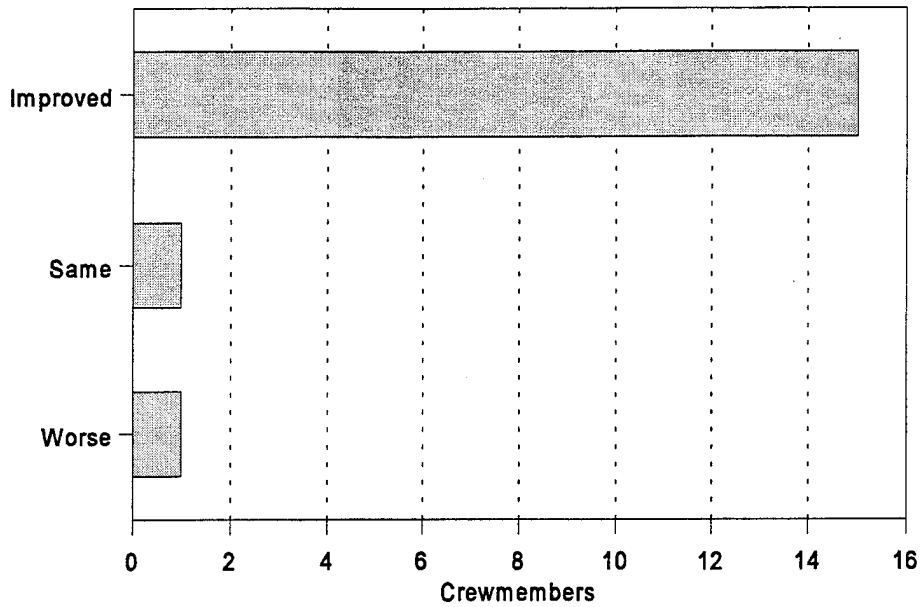


Figure 4. Perceived improvement in speech clarity in noise among CH-47D crewmembers when wearing the CEP/FH.

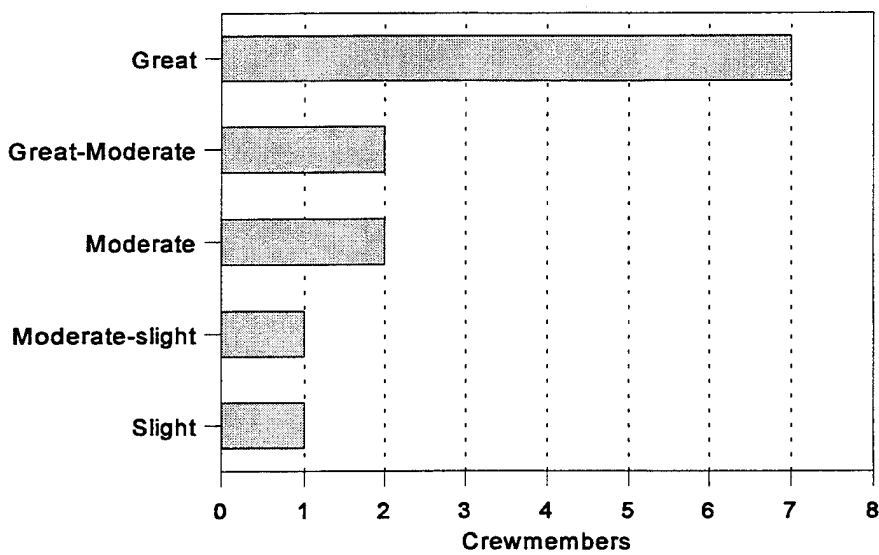


Figure 5. Degree of perceived noise reduction when wearing the CEP/FH.

## Microphone

Of 17 respondents, 8 (47 percent) reported problems with the microphone. Some crewmembers indicated that the microphone moved away from the mouth whenever the crewmember lowered his/her head to look down. This reduced the level and quality of speech signal through the communications system. Additionally, there was no provision for attaching a lip light to the microphone. The lip light is a device popular with many aviators that attaches to the microphone boom and enhances vision in the cockpit at night. Other problems with the microphone were the level and quality of the side tone. The side tone or audio feedback through the headset permits the user to hear his/her own voice. Respondents complained of side tone distortion with the CEP/FH device. One respondent noted a louder perception of aircraft transmission noise while wearing the CEP/FH than in the standard SPH-4. Some subjects reported that other crewmembers sounded fainter during ICS transmissions.

## Harness

Five of the respondents (29 percent) commented on the harness. Most of the comments dealt with the movement of the harness after the helmet was donned, more specifically that the harness was too loose. Once a user began to perspire, the fabric tended to lose its elasticity. In some instances, the harness rolled up on the forehead.

## CEP element

Ten respondents (63 percent) found the CEP device to be uncomfortable. Two crewmembers (12 percent) made comments directly relating to CEP discomfort in the ear canal. Table 2 presents recommendations for improving the CEP/FH as recorded from the posttrial questionnaire.

Table 2.  
Recommended changes to CEP/FH.

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Incorporate CEP into helmet
Improve or eliminate microphone/boom
Improve fit of harness or eliminate altogether
Make of sturdier construction
Place patch cord on left side
Provide external volume controls for each ear

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## Discussion

Several questions emerged from the results of this study:

1. *Why did CH-47D crewmembers wearing the CEP/FH set the radio volume lower than when wearing the SPH-4 alone?*

First, lower volume control settings may have been due to increased sensitivity of the CEP/FH circuitry when compared with the aviator helmet. Second, the speech signal driver (speaker) in the CEP was located closer to the eardrum than the standard SPH-4/B earphone. As a result, speech was perceived as being louder than in the standard SPH-4 helmet, a by-product of the improved speech-to-noise ratio. Finally, the foam tip for the CEP provided hearing protection in addition to that provided by the helmet earcup and seal.

2. *What are the potential benefits for CH-47D crewmembers with the reduced noise levels that result from wearing the CEP?*

First, there is an increase or improvement in the speech-to-noise ratio that results in enhanced clarity of voice communications. This is due to the location of the speaker in the outer ear and the attenuation characteristics of the foam earplug. Second, the incidence of hearing loss and related symptoms (tinnitus and muffled hearing) due to noise external to the helmet and aircraft system noise should be reduced. Again, this is due in part to the attenuation of the earplug coupled with that of the helmet's ear cushion and the lower volume control settings.

All six crew chiefs preferred the CEP over the SPH-4 alone for clarity of voice communications during flight operations. This is a significant finding when one considers the level of noise can reach 115 dBA in the aft ramp area. Anecdotal information suggests that during normal flight operations, when working in the aft ramp area, crew chiefs encounter considerable difficulty hearing voice communications from the aviators. Our impression is that this is a fairly wide-spread complaint throughout the CH-47D community and could constitute a potential safety hazard.

3. *Why were there so many negative responses relative to the CEP/FH in terms of comfort?*

There were three basic components to the CEP/FH, any one of which may have affected the overall comfort rating of the device. This is an issue of ergonomics or human factors. Responses addressed issues about the fit of the harness, the instability and side tone quality of the microphone, and the comfort of the CEP itself. A more concise interpretation of results would require redesigning and readministering the questionnaire to factor out the differences by component.

4. *Why did so many (10) respondents report discomfort when wearing the CEP?*

Interestingly, 12 (71 percent) of the surveyed crewmembers had not worn double hearing protection prior to this study. A foreign object or device in the ear canal may be considered uncomfortable to someone who routinely wears a circumaural helmet ear cushion. Conversely, a crewmember who wears foam earplugs on a regular basis may notice little or no difference when wearing the CEP foam eartip. In a separate study, 70 percent of surveyed crewmembers in an active duty Army UH-1 unit routinely wore EAR™ in conjunction with the SPH-4 helmet (Mozo, Murphy, and Ribera, 1995). When asked to comment on the comfort of the CEP with foam ear tips, 10 of 20 UH-1 respondents reported no discomfort, while the remainder indicated the discomfort level was "mild." The reported discomfort in the CH-47D unit may be a reflection of the novelty of the sensation in the ear canal rather than an indicator of intolerable discomfort. These findings suggest that rating CEP comfort could have been a judgment affected by prior experience with other insert protectors.

5. *Why did the CEP/FH microphone move excessively during normal operations?*

The anterior superior temporal bone did not provide a uniformly flat surface for the microphone footplate. In addition, the stretch of the Simplex™ fabric failed to produce the necessary tension to immobilize the footplate. An alternative approach would have been to attach the microphone footplate directly to the helmet using Velcro™. This was attempted on one or two helmets toward the end of the study and decreased the amount of microphone movement.

6. *Why was microphone movement a problem?*

A noise canceling microphone works optimally when it approximates the sound source (mouth). There is an optimum distance between the mouth and the microphone. When the optimum distance is exceeded, even a fraction of an inch, signal level changes may occur compromising intelligibility.

7. *Why was the harness too loose?*

This was the result of the stretch characteristics of the fabric, an error in the initial fitting strategy, or a combination of both. There was an adjustable Velcro™ sizing tab on the back side of the harness. Wearers who complained of fitting difficulties may not have tightened the harness sufficiently prior to securing the tab.

As a result of the recommendations for improvement presented in Table 2, the harness and microphone were eliminated from the CEP design. A helmet-mounted version of the CEP

(HM-CEP) has been developed. The HM-CEP uses a Lemo™ coaxial connector (Figure 6). A simple modification is made by drilling a ¼-inch hole through the helmet earcup, threading the CEP cable through the hole and securing the cable with a rubber grommet. The CEP leads are soldered to the existing helmet earphone. This does not disable the existing communications system (earcup and earphone), and does permit its use in the event of a failure in the CEP. There are several locations on the helmet that will accommodate the connector (Figure 7). The HM-CEP can be connected to the helmet with gloves on and, if necessary, with only one hand (Figure 8). The HM-CEP cable can be worn over the head, under the chin, or behind the neck. Field testing of the HM-CEP prototype is being evaluated by a CH-47D unit and a UH-1 unit. Initial feedback comments have been positive. The HM-CEP is easier to don, lighter, less cumbersome than the CEP/FH, yet characteristic of the basic CEP, it enhances speech intelligibility and reduces levels of noise reaching the ear.

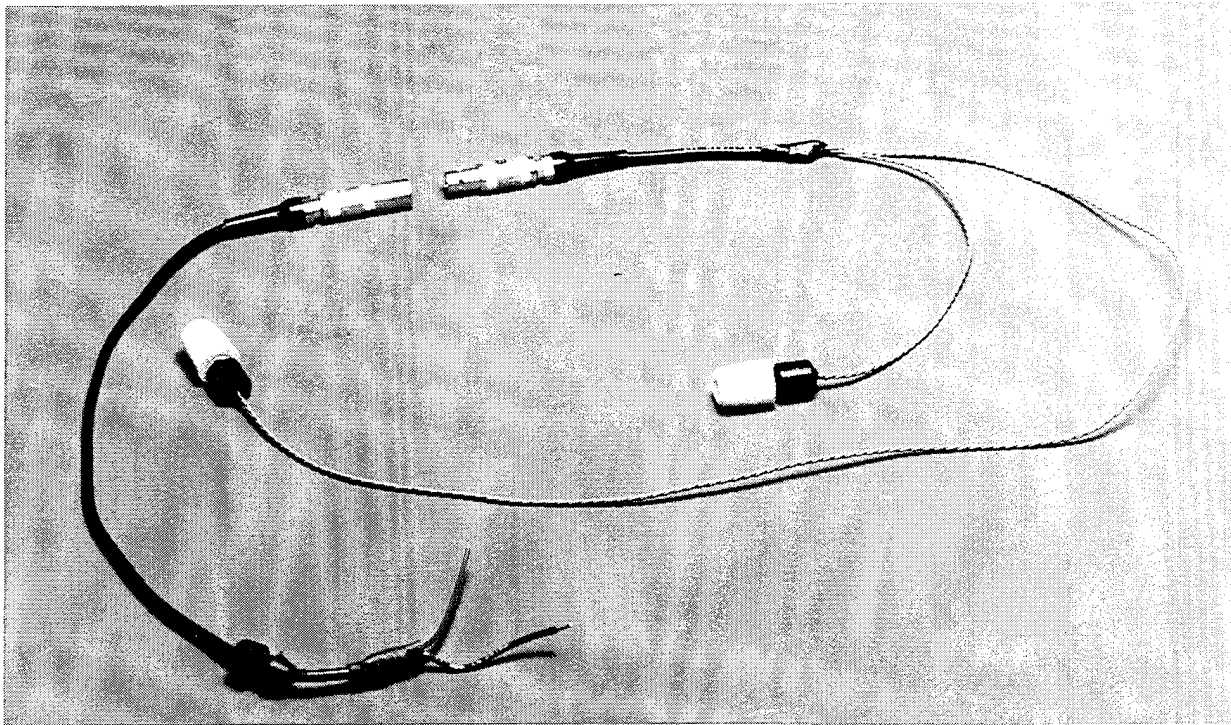


Figure 6. Helmet-Mounted Communications Earplug (HM-CEP) prototype. Left to right: Earphone leads, grommet to secure wire into earcup shell, Lemo™ connectors, cable, CEP transducer, and Comply™ earplugs.

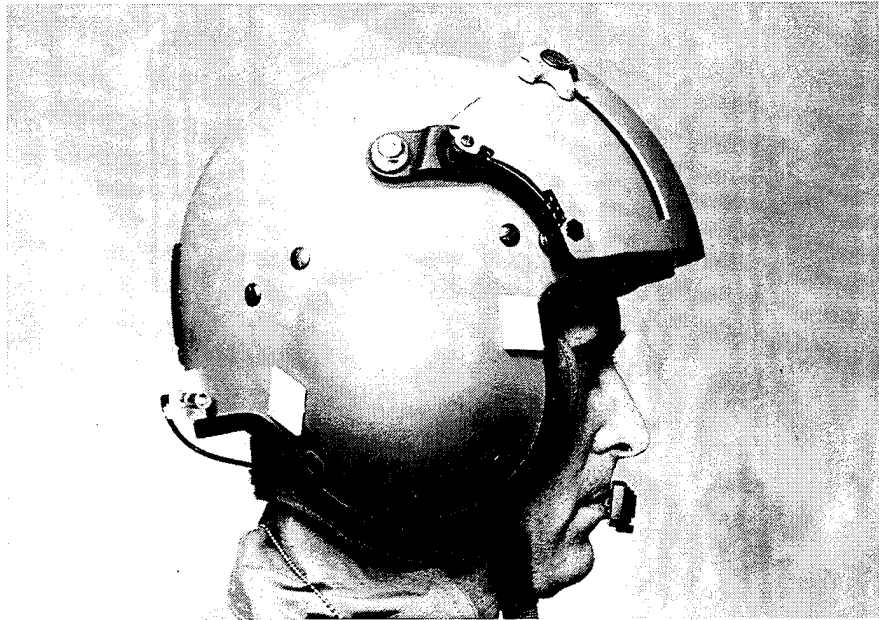


Figure 7. Lateral view of SPH-4B aviator's helmet with rear-mounted connector. White squares indicate possible alternative locations for mounting CEP.

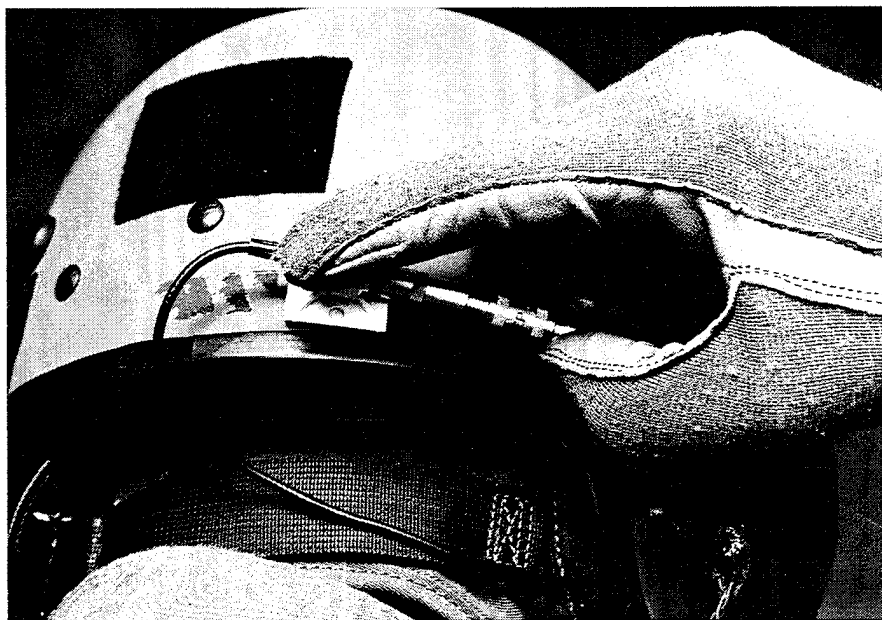


Figure 8. Connection of CEP to SPH-4B can be accomplished quickly and easily even when flight gloves are worn.

## Conclusions

Table 3 presents a comparison of the CEP and the SPH-4 alone. These findings are based on data from this study and other evaluations of the CEP (Mason and Mozo, 1995; Mozo, Murphy, and Ribera, 1995; and Ribera et al., 1996). While problem areas were identified in the CEP/FH system, the CEP itself possesses characteristics that are beneficial to voice communications in the rotary-wing noise environment, such as reduced noise levels at the ear, improved speech intelligibility and clarity, lower radio volume control settings, comfort, and simplicity. Further studies on the operational effectiveness of the CEP are ongoing and needed. In the quest for the optimum hearing protection/communications device for rotary-wing crewmembers, CEP now is a viable option.

**Table 3.**  
Comparison of CEP and SPH-4 alone.

Issue	CEP	SPH-4 w/o earplug
Attenuation (hearing protection)	Adequate	Adequate?
Ancillary equipment	Attenuation not compromised	Attenuation reduced
Speech Intelligibility	Increased	Adequate?
Perceived background noise	Lower than SPH-4	Louder than w/CEP
Setting for volume control	Lower than SPH-4	Higher than w/CEP
Weight (2 earphones)	1.06 oz.(includes connectors, cables, and eartips)	1.4 oz.
Comfort	Adequate	Adequate
Impact protection	Unaffected	Adequate
Compatibility with aircraft comms system	Unaffected	Adequate

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