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UNBROKEN: UH-1N AIRCREW CONTINUE OPS DESPITE WEAK HEARING PROTECTION

by

Zachary J. Minner, Capt

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Instructor: Dr. Marcia Ledlow

Maxwell Air Force Base, Alabama

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ABSTRACT

Since its inception in 1947, the United States Air Force has faced a nearly infinite list of problems which needed to be solved. Through the dedicated work of generations of Airmen, it has managed to find solutions to many of these issues and has maintained its position as the world's greatest Air Force. However, that doesn't mean that the US Air Force is perfect, and there are still many issues that need attention.

One of which, is the level of hearing protection provided to UH-1N helicopter aircrew. Despite having the best interests of its Airmen at heart, the Air Force has failed to equip these helicopter crews with proper personal protective equipment (PPE). Helicopter aircrews are subjected to dangerously high levels of noise during standard operations and despite advances in helmet and earplug technologies, leadership in the UH-1N community is still using older versions. This older equipment does not provide the same level of protection, and leaves crews susceptible to issues with hearing loss after long term exposure to the hazardous noise levels.

This issue not only affects the health and welfare of the UH-1N community now, but it also has long term negative effects for the Air Force. The refusal of the Huey community to spend the small amount of money that it would cost to update PPE now, will cost the Air Force and the American tax payer, money in the long run as those crew members receive disability payments in compensation for their hearing loss. In fact, the Department of Veterans Affairs reports that upwards of $7 billion have been spent on the treatment of hearing loss since 1977, some portion of which goes to retired Huey aircrew.

INTRODUCTION

United States Air Force aircraft have undergone massive changes in design and function as engineers and leaders have sought perfection in form and function. Some of these changes have been made to increase the performance of the aircraft so they may outperform or outmaneuver, so they can carry more cargo, fly more efficiently, or go undetected behind enemy lines. Other changes have been made to increase the margin of safety for operations, whether that means creating more robust systems, or increasing personal protective equipment for the crew members who operate them. Across the aviation industry, in both the civilian and military sectors, ergonomics and other human factors studies have revolutionized how humans interact with machines in a safe and sustainable manner. From seat design, to instrumentation placement, to personal protective equipment, these changes have sought to optimize the human element and protect the operator from any long term degradation in health. In many cases these efforts have resulted in more comfortable/supportive equipment and easier to manipulate controls. However, these changes have not been implemented uniformly across the Air Force and some communities are being left behind.

UH-1N aircrew at seven out of eight bases of operation are still not funded or authorized to use various hearing protection technologies which are available in other aviation communities. Helmets with more dense ear cup materials designed to reduce ambient noise, active noise cancelling headphones, and molded earplugs with communication systems embedded are just a few of the options available to help protect aircrew. However, leadership in the UH-1N community have seemed to ignore these advances and continue to provide crews with outdated technologies. This may not seem like a huge deal, but in fact, the Veterans Administration

reports spending more than $7 billion on the treatment of hearing loss between 1977 and 2007.[1] That is seven billion dollars in just 30 years spent treating an issue which is almost completely preventable. Seven billion American taxpayer's dollars which could have been spent elsewhere improving lives or helping treat other issues. Additionally, for more than 25 years, noise-related hearing loss has been listed as one of the overall most prevalent occupational health concerns.[2] The Bureau of Labor Statistics has reported close to 125,000 workers suffering from significant, permanent hearing loss since 2004 and more than 21,000 cases in 2009 alone.[3] In fact, approximately 30 million people are exposed to hazardous noise levels every year.[4] Obviously, helicopter aircrews make up just a small part of that overall number, but non-UH-1N communities have taken the appropriate actions to help prevent these issues from continuing. However, with so many options and variations, and with each aircraft experiencing different noise hazards, it is impossible to simply copy the equipment used by other communities. To know what exact combination is best for the UH-1N, careful evaluation and analysis of the possible options must be made, and then based on the results, an optimal solution can be selected.

BACKGROUND

Development for the UH-1N Iroquois (Huey) began in 1955 when the Army expressed an interest in a utility helicopter with a turboshaft engine.[5] The first three aircraft in the design series received an XH-40 designation, but the Army later switched to a more standard two-letter designation of HU-1, which stood for Helicopter Utility and coined the name "Huey" which would stick with the aircraft throughout many modifications.[6] Later in 1962, the aircraft received the new UH-1 designation under the DoD standardized system and continued adaptation through successive models.[7] The aircraft was first deployed in Vietnam in various roles

including armed support, personnel transport, and light airlift. The aircraft continued its service in many variations, which allowed for night operations, rescue/MedEvac, command and control, air assault, and even gunship operations.[8] Now, despite a relative draw down on helicopter usage in the Air Force, the UH-1N version of the Huey is still used for various missions at eight active duty bases. Three of these bases, Minot AFB, North Dakota, Malmstrom AFB, Montana, and FE Warren AFB, Wyoming, perform missile field security operations. Two, Andrews AFB, Maryland and Yakota AFB, Japan, are primarily postured for distinguished visitor transport. Another two, Ft. Rucker, Alabama and Kirtland AFB, New Mexico, are involved in student training. The final one at Fairchild AFB, Washington, is focused on search and rescue operations and supports the Survival, Evasion, Resistance, and Escape (SERE) School. These key missions support strategic nuclear deterrence, multiple classified national OPLANs, save lives, and train more pilots to continue that tradition into the future. However, the crews who fly this versatile and influential aircraft are oftentimes poorly equipped and underfunded.

Since this research focuses on hearing loss in helicopter aircrew and the potential preventative measures which could be implemented, a basic understanding of noise and decibels is required. Decibels are the unit of measure of sound pressure levels and are named after Alexander Graham Bell.[9] A-weighted sound levels (dBA) closely match the perception of loudness, as experienced by the human ear.[10] Decibels are measured on a logarithmic scale, which means that a small change in the decibel value actually equates to a large change in the amount of noise a person hears.[11] In fact, OSHA uses a 5 dBA "exchange rate" which means that as the noise level increases by 5 dBA, the amount of time a person can be exposed to that noise level to receive the same level of harm is cut in half.[12] So, a noise reduction of just a few decibels can actually make a huge difference in an individual's hearing safety. To lend some

perspective to this logarithmic scale of sound, a soft whisper heard at two meters is somewhere between 30 and 40 dBA, a vacuum cleaner at three meters is approximately 75 dBA, a jackhammer heard from 15 meters is about 95 dBA, and for most people, the threshold of pain clocks in at about 140 dBA.[13] With Huey measuring just above jackhammer levels, aircrews are clearly in an "at risk" position.

DESCRIPTION OF PROBLEM

Due to a lack of personal protective equipment, UH-1N crewmembers suffer from consistent, predictable, and preventable health concerns both during and after their military careers. Specifically, progressive hearing loss is a prevalent issue throughout the community due to a lack of personal protective gear. While some of this hearing loss may be unavoidable, or specific to an individual, mostly it could be easily avoided through the use of proper protective gear or physical precautions. For example, tools like molded communication earplugs (CEPs) or helmet "hush kits" could greatly reduce the inner ear damage that leads to hearing loss. In fact, UH-1N aircrews are currently the only Air Force helicopter crews not using molded earplugs.

Figure 1 UH-1N in Flight, USAF photo

Additionally, none of the AF helicopter platforms are using helmets equipped with high density foam "hush kits" designed to block hazardous noises. This lack of modernization leaves crews exposed to hazardous noise levels, which over the course of an Air Force career, can cause hearing loss, negatively impacting the member, putting the individual at risk of losing flight status, and in the long run, costing the Air Force money. This problem is being minimized for various reasons, including aircrew covering up hearing issues due to pride or fear of losing flight status, limited funding causing leadership to prioritize PPE out of the spending plan, or outdated regulations not allowing for use of new equipment as it becomes available. However, as this paper will show, this is a very real problem which affects a large portion of all Huey aircrew members. The protective measures are actually very reasonable in price and are easily implemented, to save the Air Force and tax payer money over the long term. It is absolutely justifiable and necessary, from both a practical and psychological standpoint, for the Air Force to implement precautions to help protect Vertical Lift crews from damaging cockpit noise.

ANALYSIS OF PROBLEM

Over the years, there have been many studies linking helicopter operation to hearing loss later in life. In fact, an Army study found that many helicopter pilots experience sustained noise levels in excess of 100 decibels (dBA).[14] Since a dangerous sound is defined as anything that is 85 dBA or higher, this is an extremely worrisome issue.[15] Remember, this 100 dBA level falls 5 dBA above the noise created by a jackhammer from 15 meters. In fact, the 100 dBA level falls well above the 90 dBA OSHA limit for workers during an 8 hour day.[16] Using the 5 dBA "exchange rate" this ten dBA increase would limit safe exposure time to less than two hours.

Now some might argue that even with these dangerous noise levels, it is hard to prove that there is a causal relationship, rather than a merely a correlation. These pilots could be experiencing normal hearing loss as a result of the aging process, rather than the exposure to helicopter noise. Well, the same Army study, which included the UH-1 and the HH-60, found that hearing loss in aviators is, "mainly a function of helicopter noise exposure, as measured by total flight hours."[17] Also, the American Academy of Audiology (AAA) reports that by age 60, the median material hearing impairment is only 17 dBA for males, and 12 dBA for females.[18] According to the AAA, "aging alone should not prevent the average person from enjoying normal hearing throughout all or most of his or her working career."[19]

With all of this data pointing to this issue as a serious problem, it is easy to wonder why the Air Force has not taken the necessary steps to protect Huey aircrew. One reason might be that the issue is being underreported because aircrew members are afraid they would be grounded, or that the hearing loss might otherwise negatively impact flight status. A Department of Defense (DoD) survey of 10,000 actually found that although 85 percent of the crewmembers were suffering from neck, back and leg pain, many aircrew had a tendency to hide symptoms or, "play through the pain" for fear of being grounded.[20] This survey also found, that 62 percent of the crewmembers suffering from these issues, were avoiding medical treatment for the same reason.[21] If these survey results are true for something like neck and back pain, which affect everyday activities, the same could certainly be true for progressive hearing loss or other insidious hearing issues. Additionally, the reported number of suffering aircrew could be further reduced because some pilots will even seek civilian medical treatments to health issues out of a fear that reporting the injuries might jeopardize their careers.[22] With all of these factors combined, it is no wonder that there has not been a greater outcry among Air Force leadership, or

the general public. But, this does not decrease the severity of the issue. The human element is the most important aspect of all military operations, and the Air Force needs to take all practical precautions to protect the men and women who serve.

CRITERIA FOR SOLUTION

The forms of hearing protection being used by UH-1N crews are a step in the right direction, but the hearing loss problem still persists. So, a new form of PPE needs to be implemented to protect these aircrew members from dangerous noise levels and prevent hearing loss. But, when looking for a solution to this problem, the Air Force must first decide what specific criteria possible solutions should meet. Only then, can a fair and reasonable decision be made as to which combination of available products should be used. In this situation, there are basically two separate layers of protection with multiple options each. First, there is the helmet itself, which can be fitted with standard foam ear cups, Hush Kit ear cups, or active noise cancelling ear cups. This is similar to commercially available over-the-ear headphones which come in variations of foam materials or with active noise cancelling. Second, is the earplug layer which can consist of foam earplugs, CEPs with foam tips, or CEPs with molded tips. These two layers of protection are autonomous in that they do not depend on the other layer for effectiveness. So, once the best option for each of these layers is found, the best overall solution will be the combination of those two layers. To do this, the major factors which need to be considered for the helmet layer are cost, effectiveness (decibel attenuation), and compatibility with the existing systems/airframe. For the ear plug layer, an additional category of user satisfaction will be used since fit and comfort are an important part of the equation when talking about something which will be inserted into the user's ear. Based on these sets of criteria, the

various options which are currently available on the market will be evaluated, compared to the helmet/CEP setup currently being used, and then the most equitable solution for the future will be selected.

ANALYSIS OF POSSIBLE SOLUTIONS

To evaluate all of the possible configurations, each option will be given a rating in each of the stated categories. This rating will either be the actual value for the category (ie, cost will simply be a dollar value), or a score correlating to the effectiveness, with higher numbers being more desirable. Then, once all possible helmet and earplug configurations have been evaluated, the scores will be compiled in a comparison matrix and the highest scoring options will be selected as the most appropriate method for implementation.

Disclaimer: There are many commercially available methods to decrease noise levels and help protect an individual's hearing. The main methods are standard ear plugs, CEPs with foam tips that UH-1N crews are currently using, CEPs with molded ear plugs, helmets with standard ear cups, helmets with hush kits, and helmets fitted with active noise cancelling (ANR) ear cups. Although these options come in many different versions, and are produced by many different companies, the effectiveness between various companies is negligible and this analysis will compare the options as a general method, rather than as an endorsement for any one specific version or company.

Helmet Layer

Air Force helicopter crews utilize the HGU-56/P Aircrew Integrated Helmet System (AIHS). The entire helmet assembly weighs approximately three pounds and provides ballistic, hearing, and eye protection.[23] Also included in this unit is a communications assembly which

ties into the aircraft's radio and intercommunication system and then transmits information to the wearer through small speakers in the ear cup assembly. The ear cup assembly also uses multiple layers of padding to ensure a proper fit and which provide the wearer with a first level of passive noise reduction.

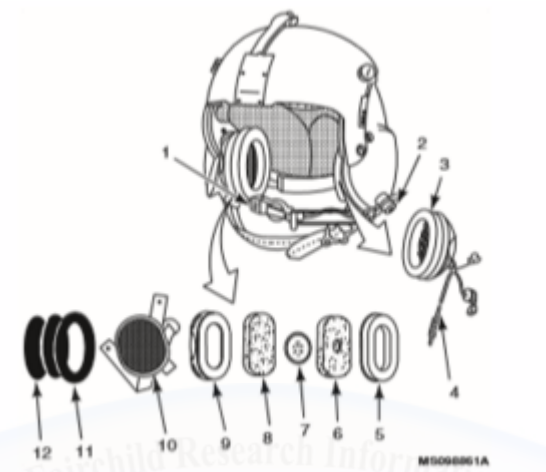


Figure 2 AIHS Ear Cups and Communications Assembly[24]

Helmet Options

This research is based on the understanding that funding is extremely limited in the Air Force. Although expenditure for a cost avoidance method can be justified, the first step before buying new equipment or systems is to evaluate all compatible options to fully understand the current capability. Therefore, only modifications to the current helmet were considered, rather than looking at completely different helmet designs. However, with that said, there is not very much variation in noise attenuation between different helmets, outside of the modification options which are being evaluated.

1. Helmet with Standard Ear Cups

The standard HGU-56/P Aircrew Integrated Helmet System (AIHS) has sound attenuation levels ranging from 17 decibels in the lower frequency bands to 42 decibels in higher frequencies.[25]

Manufacturer's description of the HGU-56/P Aircrew Integrated Helmet System.

Sound Attenuation

	Test frequency (kHz)								
	0.125	0.250	0.500	1.000	2.000	3.150	4.000	6.300	8.000
Decibels	17	14	20	21	26	38	37	44	42

Figure 3 HGU-56/P Helmet Sound Attenuation Data[26]

This attenuation is achieved through passive noise reduction as sounds are muffled coming through the foam ear cup assembly. The cost associated with this equipment is essentially zero, since this ear cup assembly comes standard on the UH-1N helmet that is already in use. This method is also completely compatible with the airframe and requires zero modification. However, the Air Force has already decided that this level of attenuation is not sufficient as a sole means of protection and requires that some other form of hearing protection be used. In fact, the UH-1N technical manual requires that "all personnel within 30 feet of the aircraft wear hearing protection."[27]

Table 1 Helmet with Standard Ear Cups

	dBA Attenuation	Cost	Compatibility
Standard Helmet	17-42	0	100%

2. Helmet with Hush Kit Ear Cups

"Hush Kits" is a term many may have heard in relation to jet engine noise attenuation. In that application, a "Hush Kit" is installed on the outside of the exhaust section of the jet engine to disperse the outflowing air over a larger area, thereby reducing the noise level associated with the jet. By reducing the overall level of noise created by the aircraft, individuals who live on or near airbases with consistent jet activity are protected from some of the hazardous noise created by those aircraft. In addition to benefiting personnel in the vicinity of the aircraft, this version of a "Hush Kit" also helps reduce the overall noise level experienced by the pilot.

In the helicopter community, however, the term "Hush Kit" has a very different meaning. To helicopter aviators, "Hush Kits" speak to a high density material that can be used in place of the standard foam ear cups inside the flight helmet. This high density material can help to muffle or decrease some of the frequencies of noise experienced by aviators in flight. In 2005, the US Army Aeromedical Research Laboratory (USARL) conducted a study on the effectiveness of the Hush Kit as it compares to the standard HGU-56P helmet.[28] This study found that in the higher frequency bands (3 kHz to 8 kHz) there was a significant increase in the noise abatement when using the Hush Kit set up as compared to the standard AIHS.[29] However, in the lower frequency bands (.125 kHz to 2 kHz), there was little to no increase in noise abatement, and in fact in the frequency band between .5 kHz and 2 kHz, the standard AIHS configuration actually outperformed the Hush Kit setup.[30]

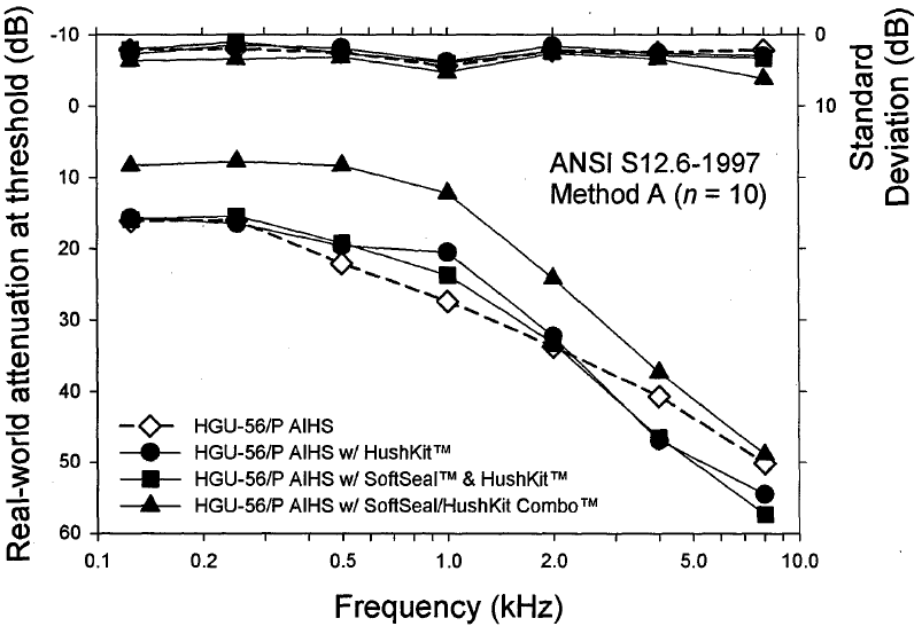


Figure 4 HGU-56/P Attenuation with and without HushKit[31]

This study showed that although the helmet outfitted with a Hush Kit provides a slightly greater noise attenuation and hearing protection in the frequency bands above 4 kHz, the standard AIHS configuration actually outperforms the Hush Kit at lower frequencies. Taking into account that most helicopter noise is in the lower frequency bands, below 300 Hz, this study proves that the standard AIHS configuration is actually preferable to UH-1N crews.[32]

Table 2 Helmet with Hush Kit Ear Cups

	dBA Attenuation	Cost	Compatibility
Hush Kit	17-54	~$95[33]	100%

3. Helmet with Active Noise Cancelling

Active Noise Cancelling (ANR) ear cups are one final option for helmet configuration which can result in higher noise attenuation at the lower frequency bands. In this type of system, the ANR components and earphone are built into the helmet ear cup, where it continuously

measures sound. Then, the system filters and reverses the phase of the measured sound, which attenuates the sound levels in the ear cup.[34] These types of systems can result in 20 dBA of attenuation at 125 Hz and up to 42 dBA at 4 KHz. Since most helicopter noise is found in the lower frequency band, this increase in attenuation could greatly benefit UH-1N aircrew.

Comparison of Effectiveness		
Frequency	**Typical ANR Helmet**	**Helmet w/ CEP®**
125Hz	20 dB	30 dB
250Hz	28 dB	34 dB
500Hz	25 dB	40 dB
1KHz	31 dB	35 dB
2KHz	28 dB	38 dB
4KHz	42 dB	44 dB

Figure 5 Comparison of Effectiveness, ANR Helmet vs. Standard[35]

However, the benefits which come from this technology definitely also have some significant costs. In a study conducted by the US Army Aeromedical Research Laboratory (USAARL) it was found that although the ANR modified helmet provided better noise attenuation than an unmodified helmet, there were some unacceptable down sides.[36] First, the ANR system is not “plug and play” compatible with the current helmets and would require modification and an additional power source. Also, these systems are fairly expensive and add extra weight to the helmet, which can be fatiguing to the crewmember or possibly even dangerous in the event of a crash (especially when paired with Night Vision Goggles or other helmet mounted systems). The report even went on to list a table with a pro/con comparison between a CEP equipped helmet and an ANR equipped helmet.

CEP	ANR
CEP advantages: 1. Speech intelligibility better than standard aircrew helmet alone, helmet with foam E-A-R™ plugs, and ANR systems. 2. Hearing protection better than standard aircrew helmet alone, and as good as ANR. 3. Light weight. 4. Requires no power sources, works off standard aircraft communications system. 5. Ten times less expensive than ANR. 6. Noise protection is not affected by wearing glasses. **CEP disadvantages:** 1. Device must be actively placed in the ear by aircrew member. 2. Soiled foam tips must be actively replaced or cleaned by aircrew. 3. Need to integrate a miniature microphone system with CEP to reduce number of wires used by current CEP prototype.	**ANR advantages:** 1. Passive system, aircrew members simply put on their helmets to use ANR. 2. Speech intelligibility better than standard helmet alone, or helmet with foam E-A-R™ plugs. 3. Better hearing protection than standard aircrew helmet alone. **ANR disadvantages:** 1. Speech intelligibility not as good as CEP. 2. Noise protection decreased by wearing glasses or poor ear cup fit. 3. Heavy weight, weight is at a premium in modern vision-coupled aircrew helmets. 4. Requires new power source not available in current aircraft communication system. 5. Ten times more expensive than CEP. 6. Current ANR systems degrade the crashworthiness of Army aircrew helmets. 7. Component reliability in operational environment is unknown.

Figure 6 Army CEP versus ANR Pros/Cons Listing[37]

Based on this pro/con analysis, the Army ultimately made the decision to go with a CEP coupled helmet, rather than spending the extra money on active noise cancelling options. The report stated that, "in their current state of development, CEP provides better hearing protection, speech discrimination, and crash protection, lower weight and cost, and less need to modify existing aircraft systems compared to ANR."[38]

Table 3 Helmet with Active Noise Cancelling

	dBA Attenuation	Cost	Compatibility
ANR Helmet	20-42	~$300[39]	Not Compatible

Earplug Layer

The second layer of hearing protection for UH-1N aircrew is provided by an earplug which is inserted into the user's ear. This second layer of passive protection augments the helmet's noise attenuation and further protects the aircrew member from hazardous aircraft noise.

Earplug Options

These earplugs come in essentially three variations with different materials and designs. Since each of these earplug options are designed to have a different level of durability, the cost category of this analysis will look at the cost for a single user over the course of one year. Other assumptions will be that the user flew three times per week, 50 weeks per year, and disposed of or replaced the earplugs in accordance with the average manufacturer's recommendation. As an example, standard earplugs are single use, so cost analysis for this method will assume a new pair is needed for each day of use.

1. Standard Foam Earplugs

Figure 7 Standard Foam Earplug[40]

The standard foam earplug comes in many shapes and sizes, but essentially all forms have the same function. The user compresses the ear plug, inserts into the ear canal, and then allows it to expand out to fill the space. The earplug then blocks incoming sound and helps protect the user from inner ear damage. These earplugs are extremely cheap, at about 36 dollars per box of 200 pairs (or if you buy in bulk, 32 dollars per box), and are intended to be single use.[41] Although the specific attenuation levels vary depending on the style, the standard version which is available at most UH-1N bases provides approximately 11 dBA of attenuation.[42] There is very little room for user error with this method, but over time there can be some discomfort to the user as the earplug attempts to return to its cylindrical shape. Additionally, this earplug requires the aircraft communications systems to be turned up higher so that the helmet ear cup speakers can still be heard.

Table 4 Standard Foam Earplugs

	dBA Attenuation	Cost	Compatibility	Satisfaction
Foam Earplug	11	$24/year	100%	4.2

2. CEPs with Foam Tips

Figure 8 CEP with Foam Tips[43]

The traditional CEP setup comes with foam tips which are compressed, then inserted into the ear, much like the standard foam earplug. As the foam material expands back out it creates a seal inside the ear which helps dampen out external sources of noise. The small holes in the center allow sound from the speakers through the center of the plug and directly into the ear. They are fully compatible with the HGU-56/P helmet and the foam tips come in various sizes so they can be approximately fit to the individual user. However, there can still be some issues with the size and fit, since the plugs have to be compressed and fit each time they are used. It is easy to not get the plugs inserted fully, or have them become partially unseated during use. When used properly, these earplugs have a real ear attenuation of almost 30 dBA in the low frequencies and up to 46 dBA in the high frequencies.

Real-ear attenuation characteristics of the communications earplug per ANSI S3.19-1974 using standard and slim size eartips. Test were conducted by Aearo Company's E•A•RCAL[SM] Acoustical Laboratory, May 2000. NRR per EPA-1979 is 29.5

Test Frequency (Hz)	Mean Attenuation (dB)	Standard Deviation (dB)
125	29.7	5.3
250	34.2	5.9
500	39.7	4.7
1000	42.1	5.1
2000	38.0	3.2
3150	43.2	3.2
4000	43.5	3.5
6300	47.5	4.5
8000	46.1	4.4

Figure 9 Real-ear Attenuation of Standard Earplugs[44]

These plugs are relatively inexpensive, with the cord costing about 135 dollars and the tips only costing three dollars per pair.[45] However, the tips are not very durable, and need to be replaced about once per month during normal use. The cords, on the other hand, are very durable and would only be expected to need replacement about once every three years. Additionally, these attenuation levels are measured under ideal conditions. These CEPs are a great addition to the system, but do not come without limitations. During actual usage, it is very easy to get the cords caught on the seat, or other parts of the aircraft, partially removing or unseating the foam earplug portion. Or, if rushed while putting them in, crewmembers often do not get a good seal to begin with

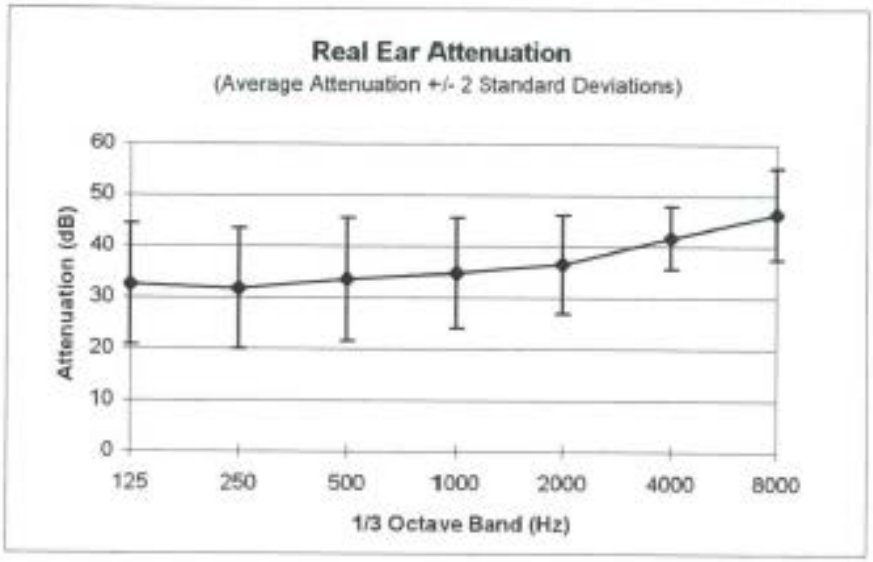
Table 5 CEP with Foam Tips

	dBA Attenuation	Cost	Compatibility	Satisfaction
CEP w/ Foam	30-46	$81/year	100%	6.3

3. ACCES Earplugs With Molded Tips

Figure 10 Molded ACCES Earplugs[46]

Finally, there are a few companies which make molded ear plugs to be used with communication wires, like CEPs. These molded earplugs offer many potential advantages over the traditional foam tips. Since they are fitted to the individual aircrew member, there is less room for error when using them. Additionally, they tend to stay in place better since they fit the exact curvature of the inner ear. Furthermore, they show marked improvement in noise attenuation over other non-custom options. In fact, the Air Force Research Laboratory (AFRL) at Wright Patterson AFB, OH actually tested the Attenuating Custom Communication Earpiece System (ACCES) produced by Westone.[47] The testing used an HGU-55/P helmet, which is typically used in fixed wing aircraft, but has similar noise attenuation values as the HGU-56/P helmet used by UH-1N aircrew. In this study, the research lab found that the ACCES earplugs provided a real ear attenuation of about 33 dBA in lower frequency bands and 46 dBA in higher frequency bands.[48]



Real Ear Attenuation Data

Octave Band Data

Freq (Hz)	125	250	500	1000	2000	4000	8000
Mean	33	32	34	35	37	42	46
Std dev	6	6	6	5	5	3	4
Mean - Std dev	27	26	28	29	32	39	42
Mean - 2*SD	21	20	22	24	27	36	37

Figure 11 ACCES Earplug Attenuation Data[49]

These earplugs come at a significantly higher cost at approximately 145 dollars for the tips, but due to more durable materials do not need to be replaced nearly as often.[50] Under normal use, it is expected that these plugs would last at least two years. They also use a cord which is very similar to the CEP cord and which would have similar cost/durability values. Additionally, because these earplugs are fitted to the individual's ear, they tend to be more comfortable over long periods of time, and have less room for error when inserting or during use. They still use a cord to connect to the helmet/intercom system, but because they are fitted, they have less of a tendency to get caught and unseated during use. One possible downside to this type of earplug is that they have such a good seal in the ear canal, that it could be dangerous during a rapid accents and descents or rapid decompression. However, considering the altitudes

in which UH-1N aircraft operate and the fact that they are non-pressurized aircraft, this risk is essentially reduced to zero. Also, from a compatibility standpoint, the ACCES earplug requires a one-time adjustment to the aircrew helmet to install a new receptacle for the earplug attachment. But, this adjustment only takes a few minutes and is otherwise compatible with the current helmet configuration.

Table 6 ACCES Earplugs with Molded Tips

	dBA Attenuation	Cost	Compatibility	Satisfaction
ACCES	33-46	~$117.5/yr	98%	8.5

CURRENT UH-1N OPTIONS

To move forward with this discussion and attempt to find a solution to the issue, it is important to first look at what configuration of protective equipment the UH-1N is already using to reduce the damages associated with high cockpit noise levels. Then, that configuration will be compared with the other possibilities to see which option is best suited for the environment. Currently, aircrews in the UH-1N community are using one of two methods. First, is the more preferred method of the HGU-56/P helmet paired with a foam tip CEP. Second is the HGU-56/P helmet paired with just a foam earplug.

1. Helmet Plus CEP

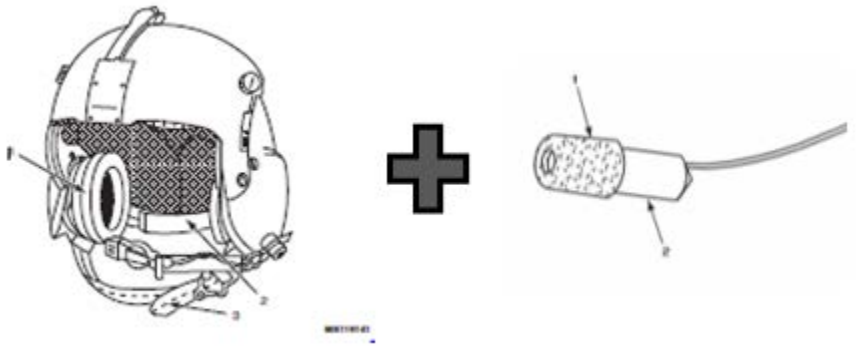


Figure 12 Helmet and Communications Earplug (CEP)[51]

In addition to the communications assembly built into the helmet unit, most UH-1N crews choose to use a Communications Earplug (CEP) to add an additional layer of passive noise reduction and transmit communications information directly into the ear. This provides the second layer of required protection, but also typically allows for better communication since the speakers are included in the earbud. All UH-1N helmets are outfitted with the CEP receptacle on the back side and are compatible with this configuration.

2. Helmet and Standard Foam Earplugs

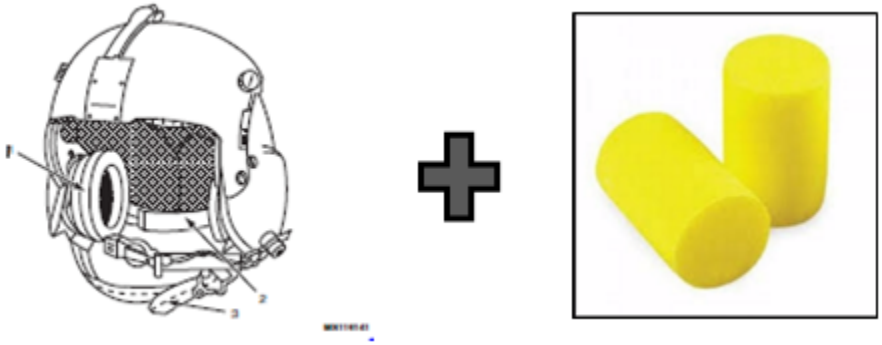


Figure 13 Helmet with Standard Foam Earplugs[52]

The second, but not nearly as popular option which UH-1N crews may choose, is to simply replace the CEP system with standard foam earplugs, then turn the volume up on the helmet so that the ear cup speakers can still be heard. This alleviates the problem of getting the CEP cord caught, and some crew members feel they get a better fit/higher level of protection by using this method. However, in this configuration, it is sometimes difficult to get the aircraft intercommunication system (ICS) turned up loud enough so that the helmet ear cup speakers can be clearly heard through the earplugs. Additionally, if one member of the crew is using this method and the rest of the crew are using CEPs, the volume difference can be uncomfortable for other crewmembers.

ANALYSIS OF OPTIONS

Now that each of the options has been explained and dissected, they can be compared in a fair a logical manner to determine the best option. First, looking at the helmet options compared side by side, the data almost surprisingly points to keeping the standard HGU-56/P helmet already in use, without modification.

Table 7 Helmet Comparison Matrix

	dBA Attenuation	Cost	Compatibility
Standard Helmet	17-42	0	100%
Hush Kit	17-54	~$95	100%
ANR Helmet	20-42	~$300	Not Compatible

At first glance, it would appear that the Hush Kit option might be worth the marginal cost in order to gain an extra 8 dBA in the high frequency range. However, despite the Hush Kit

equipped helmet providing better noise attenuation in the higher frequency bands, there was no improvement in the low frequency bands. Additionally, the Hush Kit helmet performance dropped off significantly as the frequency bands increased and was actually worse than a standard helmet in the mid-range frequencies. Since most helicopter noise is in the low to mid frequency range, the extra cost of adding a Hush Kit to the HGU-56/P helmet system, in both materials and manpower, is not warranted. A similar analysis can be made for the active noise reduction helmets. Although these ear cups performed better in the low frequency bands, where protection is needed, these systems came with other unforeseen compatibility problems. Weight, power source, clarity of communication, and expense all offset the marginal sound attenuation benefits these types of systems produce. For overall utility and protection, the best choice for helmet is the standard HGU-56/P helmet system already in use.

Next, a determination needs to be made on which secondary protection method is best. This analysis included the same three criteria as the helmet layer, but also added a more subjective category of satisfaction. For this category, a small focus group consisting of six aviators with experience using all three options was utilized. These members were asked to rank each of the options on a scale from one to ten, with ten being the highest rating. Satisfaction was a function of the comfort, fit, ease of use, clarity of communication, and perceived sound attenuation.

Table 8 Earplug Comparison Matrix

	dBA Attenuation	Cost	Compatibility	Satisfaction
Foam Earplug	11	$24/year	100%	4.2
CEP w/ Foam	30-46	$81/year	100%	6.3
ACCES	33-46	$117.50/year	98%	8.5

The criteria analysis for the earplug options was pretty close to what might be expected. In the compatibility category, the analysis discovered virtually no advantage to any of the options, since they are all compatible with the current helmet with little to no modification. For the other categories, the general trend was that the more robust the options got, the more expensive they were, the more noise attenuation they provided, and the more satisfied the user was with their performance. First, looking at the attenuation data, it is pretty clear that the foam earplugs are not a good option for the majority of scenarios. They are an important personal protective device to be kept in the squadron for smaller projects or when briefly working near aircraft, but at only 11 dBA of attenuation, they really should not be used for daily operations in the aircraft. The analysis becomes a little bit more complicated when looking at the foam tip Communications Earplugs versus the molded ACCES earplugs. The noise attenuation difference is 3 dBA in the lower frequencies and is unchanged in the higher frequencies. However, keeping in mind that the decibel scale is logarithmic in nature, a decrease of just a few decibels can make a significant difference, especially when applied across an entire flying career. In fact, this decrease would almost double the amount of time a user could be subjected to the hazardous noise before experiencing negative effects. Additionally, the added category of user satisfaction really sets the molded ACCES plugs apart. With users experiencing better communications quality, with less background noise and greater comfort, this option really begins to outpace the CEP competitor. Based on the annual increase of only about thirty six dollars per person, compared to the twenty five percent increase in user satisfaction and 3 dBA decrease in hazardous noise levels, the ACCES earplug should be a clear choice. Then, the decision really just becomes how much money is it worth to have a high satisfaction level and a moderate

increase in noise reduction. When factoring in the cost of post-retirement treatment for hearing related issues, the thirty six dollar difference seems very worth it.

FINAL RECOMMENDATIONS BASED ON FINDINGS

The data compiled for this report makes a strong case for implementing an ACCES style molded earplug in conjunction with the HGU-56/P helmet. These two options provide the best mix between hearing protection, ease of implementation, and cost. By pairing these two attenuation methods, the Air Force could provide UH-1N aircrew with a sustainable, cost effective option to preserve their hearing and avoid permanent hearing loss or other hearing related issues. The HGU-56/P helmet is already in use and meets the design goal of providing quality crash protection and noise reduction. The ACCES style earplugs have been implemented across other helicopter platforms and could easily be paired with the helmet to add a second level of optimized protection for UH-1N crews. For only thirty six dollars per person, per year, the Air Force could make a significant impact on aircrew lives both during their years of service, and then after as they continue their civilian lives. Not only this, but the Air Force could help save taxpayers from some portion of the seven billion dollar treatment bill being accrued by the Department of Veterans Affairs. This clear choice needs to be implemented and molded earplugs with the HGU-56/P helmet need to be made available to UH-1N aircrew immediately.

CONCLUSION

If the Air Force hopes to maintain its status as the world's greatest air and space force, it must start by taking care of its people. Humans are at the center of the machine, providing the creativity, the spirit, the passion, and the driving force of everything that the Air Force does. To continue operations into the future, this central element must be protected to the maximum extent

possible. This means continuing a calculated process to either remove hazards through design measures or limit the hazards through personal protective equipment. The ideal solution for human safety is to provide an engineering solution for a given problem. For example, remotely piloted aircraft remove the pilot from the cockpit, essentially reducing the risk of loss of life zero. However, this type of design change is not always possible. So, other solutions are sometimes necessary. In the case of the helicopter rescue community, a method for removing the crew from the aircraft environment has not yet been found so other safety measures must be taken. This means equipment such as helmets, gloves, fire resistant clothing, seats which are designed to absorb impacts and other technologies must be leveraged to make this operational environment as safe as possible. In many cases these systems are already in place and are protecting the human element every day. However, in other cases, like hearing protection for UH-1N aircrew, there is still room for significant improvement and the time for change is now.

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