DNWG

DEPARTMENT OF DEFENSE
NOISE WORKING GROUP

TECHNICAL BULLETIN

Noise –Induced Hearing Impairment

December 2013

Residents in communities surrounding airbases express concerns regarding the effects of aircraft noise on hearing. This document provides a brief overview of hearing loss caused by noise exposure. The goal is to provide a sense of perspective as to how aircraft noise (as experienced on the ground) compares to other activities that are often linked with hearing loss.

INTRODUCTION

This *Noise-Induced Hearing Impairment* bulletin is one of a series of technical bulletins issued by the Department of Defense (DoD) Noise Working Group (DNWG) under the initiative to educate and train DoD military, civilian and contractor personnel, and the public on noise issues.

In compliance with the provisions of the National Environmental Policy Act of 1969 (NEPA), the DoD predicts the environmental impacts of all major proposed changes in military operations, including the effects of the noise expected from such actions on exposed communities. The Military Services execute several planning programs, such as Air Installations Compatible Use Zones (AICUZ) and Joint Land-Use Studies (JLUS), and routinely meet with the local communities to address flight operations and noise impacts in order to foster compatible land-use development in the vicinity of DoD airfields or other environments exposed to noise from military activities. The ability to convey the effects of military aircraft noise exposure should facilitate both the public discussions and the environmental assessment process.

This Technical Bulletin explains how high noise levels can cause hearing impairment, and offers advice on how to assess the potential impairment due to military operations. The intent is to help program officials disclose the potential effects as a supplement to the environmental assessment.

BACKGROUND

Considerable data have been collected and analyzed by the scientific/medical community on the effects of noise on workers in industrial settings, and it has been well established that continuous exposure to high noise levels from any source will damage human hearing and result in noise-induced hearing loss (EPA 1974). The scientific community has concluded that there is little likelihood of hearing damage resulting from exposure to aircraft noise at commercial airports. Until recently, the same was thought true for military airbases, but the introduction of new generation fighter aircraft with high thrust to weight ratio and correspondingly high noise levels has required a re-analysis of the risk of hearing damage for those communities close to military airbases. Residents in surrounding communities are expressing concerns regarding the effects of these new aircraft on hearing.

Hearing loss is generally interpreted as a decrease in the ear's sensitivity or acuity to perceive sound, i.e. a shift in the hearing threshold to a higher level. This change can either be a Temporary Threshold Shift or a Permanent Threshold Shift.

A Temporary Threshold Shift (TTS) can result from exposure to loud noise over a given amount of time, yet the hearing loss is not necessarily permanent. An example of TTS might be a person attending a loud music concert. After the concert is over, the person may experience a threshold shift that may last several hours, depending upon the level and duration of exposure. While experiencing TTS, the person becomes less sensitive to low-level sounds, particularly at certain frequencies in the speech range (typically near 2,000 and 4,000 Hertz). Normal hearing ability eventually returns, as long as the person has enough time to recover in a relatively quiet environment.

A Permanent Threshold Shift (PTS) usually results from repeated exposure to high noise levels, where the ears are not given adequate time to recover from the strain and fatigue of exposure. A common example of PTS is the result of working in a very noisy environment such as a factory. It is important to note that TTS can eventually become PTS over time. Thus, even if the ear is given time to recover from TTS, repeated occurrence of TTS may eventually lead to permanent hearing loss. The point at which a Temporary Threshold Shift results in a Permanent Threshold Shift is difficult to identify and varies with a person's sensitivity. In general, hearing loss (be it TTS or PTS) is determined by the duration and level of the sound exposure.

Noise-Induced Hearing Loss

The 1982 EPA Guidelines for Noise Impact Analysis presents the risk of hearing loss from exposure to noise in the workplace in terms of the Noise-Induced Permanent Threshold Shift (NIPTS), a quantity that defines the permanent change in hearing level, or threshold, caused by exposure to noise (EPA 1982). It represents the difference in PTS between workers exposed to noise and those who are not exposed. Numerically, the NIPTS is the change in threshold averaged over the frequencies 0.5, 1, 2, and 4 kHz that can be expected from daily exposure to noise over a normal working lifetime of 40 years, with the exposure beginning at an age of 20 years. A grand average of the NIPTS over time (40 years) and hearing sensitivity (10 to 90 percentiles of the exposed population) is termed the Average NIPTS, or Ave. NIPTS for short. The Ave. NIPTS that can be expected for noise exposure as measured by the 24-hour average noise level, L_{eq24}, is given in Table 1 (EPA 1982).

Table 1. Ave. NIPTS and 10th Percentile NIPTS as a Function of L_{eq24}

L_{eq24}	Ave. NIPTS dB*	10th Percentile NIPTS dB*
75-76	1.0	4.0
76-77	1.0	4.5
77-78	1.6	5.0
78-79	2.0	5.5
79-80	2.5	6.0
80-81	3.0	7.0
81-82	3.5	8.0
82-83	4.0	9.0
83-84	4.5	10.0
84-85	5.5	11.0
85-86	6.0	12.0
86-87	7.0	13.5
87-88	7.5	15.0
88-89	8.5	16.5
89-90	9.5	18.0

* Rounded to the nearest 0.5 dB

Thus, for a noise exposure of 80 L_{eq24}, the expected lifetime average value of NIPTS is 3 dB.

The Ave. NIPTS is estimated as an average over all people exposed to the noise. The actual value of NIPTS for any given person will depend on their physical sensitivity to noise – some will experience more hearing loss than others. The EPA Guidelines provide information on this variation in sensitivity in the form of the NIPTS exceeded by 10 percent of the population, which is included in Table 1 in the "10th Percentile NIPTS" column (EPA 1982). As in the example above, for individuals exposed to 80 L_{eq24}, the most sensitive of the population would be expected to show a degradation to their hearing of 7 dB over time.

To put these numbers in perspective, changes in hearing level of less than 5 dB are generally not considered noticeable or significant. Furthermore, there is no known evidence that a NIPTS of 5 dB is perceptible or has any practical significance for the individual. Lastly, the variability in audiometric testing is generally assumed to be ±5 dB (EPA 1974)

In order to quantify the overall impact of noise on a community it is necessary to include the numbers of people who are exposed. This is accomplished by calculating the population average value of Ave. NIPTS, known as the Potential Hearing Loss, PHL, using the following equation:

$$PHL = \frac{\sum_i NIPTS_i \times P_i}{\sum_i P_i} \qquad (1)$$

where $NIPTS_i$ is the Ave. NIPTS for people within the i^{th} noise level band (see Table 1), and P_i is the total population living within the i^{th} noise level band. The quantity PHL represents the average change in hearing threshold, or the average hearing loss, for the local community exposed to the noise.

The actual noise exposure is determined by the portion of the time the population is outdoors and the outdoor noise levels to which they are exposed. The EPA Guidelines allows for calculating the exposure taking into account the length of time the population is indoors and exposed to lower levels. If the outdoor exposure exceeds 3 hours per day, the contribution of the indoor levels can usually be neglected.

Criteria for Permanent Hearing Loss in the Workplace

The database from which the risk of hearing loss in Table 1 was developed is based almost entirely on extensive audiometric measurements of workers in industrial settings. A considerable amount of hearing loss data have been collected and analyzed, including measurements of hearing loss in people with known histories of noise exposure. The available evidence consists of statistical distributions of hearing levels for populations at various exposure levels. Much of the analysis consists of grouping these measurements into populations of the same age with the same history of noise exposure and determining the percentile distribution of hearing loss for populations with the same noise exposure. Thus, the evidence for noise-induced permanent threshold shift can be clearly seen by comparing the distribution of a noise-exposed population with that of a relatively non-noise-exposed population (EPA 1974).

Most of these data are drawn from cross-sectional rather than longitudinal studies. That is, individuals or populations have been tested at only one point in time. Because complete noise-exposure histories do not exist, many conclusions are limited by the need to make certain assumptions about the onset and progression of noise-induced hearing loss.

Using this database, the EPA established 75 dB for an 8-hour exposure and 70 dB for a 24-hour exposure as the average noise level standard requisite to protect the most sensitive (approximately 1 percent) of the population from greater than a 5 dB permanent threshold shift in hearing. The EPA document explains that the requirement for an adequate margin of safety necessitates a highly conservative approach which dictates the prevention of any effect on hearing, defined here as an essentially insignificant and not measurable NIPTS of less than 5 dB. (EPA 1974).

The National Academy of Sciences Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) identified 75 dB as the minimum level at which hearing loss may occur from continuous, long-term (40 years) exposure (CHABA 1965).

The World Health Organization has concluded that environmental and leisure-time noise below a L_{eq24} value of 70 dB "will not cause hearing loss in the large majority of the population, even after a lifetime of exposure." (WHO 2000).

The Occupational Safety and Health Administration (OSHA) regulation of 1971 standardizes the limits on workplace noise exposure for protection from hearing loss as an average level of 90 dB over an 8-hour work period, or 85 dB over a 16-hour period (OSHA 1971). The standard is based on a 5 dB decrease in allowable noise level per doubling of exposure time. Exposure at levels greater than this require a hearing conservation program to be implemented. The maximum level for workplace exposure to continuous noise is 115 dB, and exposure to this level is limited to 15 minutes. A maximum level of 140 dB is specified for impulsive noise.

The National Institute for Occupational Safety and Health recommends a maximum exposure of 85 dB for a period of 8 hours, with a recommended exchange rate of 3 dB per doubling of exposure time (NIOSH 1998). The maximum allowable exposure level is 140 dB for both continuous and impulsive noise.

The Department of Defense requirements for hearing conservation specify that a hearing conservation program should be implemented if the 8-hour average noise level (L_{eq8}) is greater than 85 decibels (DOD 2004). The recommended exchange rate is a decrease of 3 dB per doubling of exposure time, although an alternative rate of 4 dB is allowed.

DoD Guidelines for Hearing Risk Assessment in the Community

The current DoD policy for assessing hearing loss risk as part of the EIS process is stated in the June 16, 2009 memorandum "Methodology for Assessing Hearing Loss Risk and Impacts in DoD Environmental Impact Analysis" issued by the Under Secretary of Defense (DOD 2009). The memorandum defines the conditions under which assessments are required, references the methodology from the 1982 EPA report, and describes how the assessments are to be calculated.

"*Current and future high performance aircraft create a noise environment in which the current impact analysis based primarily on annoyance may be insufficient to capture the full range of impacts on humans. As part of the noise analysis in all future environmental impact statements, DoD components will use the 80 Day-Night A-Weighted (DNL) noise contour to identify populations at the most risk of potential hearing loss. DoD components will use as part of the analysis, as appropriate, a calculation of the Potential Hearing Loss (PHL) of the at risk population. The PHL (sometimes referred to as Population Hearing Loss) methodology is defined in EPA Report No. 550/9-82-105, Guidelines for Noise Impact Analysis.*"

The 2009 DoD policy directive requires that hearing loss risk be estimated for the population most at risk, defined as the population exposed to a Day-Night Average Noise Level (DNL) greater than or equal to 80 dB, including residents of on-base housing. Limiting the analysis to the 80 DNL contour area does not necessarily imply that populations outside this contour, i.e. at lower exposure levels, are not at some degree of risk of hearing loss, but it is generally considered that this risk is small. The exposure of workers inside the base boundary area should be considered occupational and evaluated using the appropriate DoD component regulations for occupational noise exposure.

Environmental noise assessments normally estimate the number of people exposed to noise expressed in terms of the DNL noise metric, which contains a 10 dB weighting factor for aircraft operations occurring between the hours of 2200 and 0700 to account for people's increased sensitivity to noise during the normal sleeping period. However, the mechanism by which high noise levels may cause hearing impairment is physical in nature (by damaging the hair cells in the cochlear) and has no such temporal effects – noise is noise as far as the potential for hearing loss is concerned, regardless of the time of day the exposure occurs. Thus, even though the population most at risk is identified in terms of the 80 DNL contour, it is not appropriate to estimate risk using the DNL metric. The actual assessment of hearing loss risk should be conducted using 24-hour average noise levels (L_{eq24}).

DISCUSSION

Community Hearing Loss and Aircraft Noise

The preponderance of available information on hearing loss risk upon which Table 1 is based is from the workplace with continuous exposure throughout the day for many years. Community exposure to aircraft noise is not continuous but consists of individual events where the sound level exceeds the background level for a limited time period as the aircraft flies past the observer. The maximum noise levels experienced from military aircraft may be very high, and the exposure could result in a temporary threshold shift. But unless the flights are continuous, the ear may have adequate time to recover from the strain and fatigue of individual exposures, and normal hearing ability may eventually return.

There is very limited data on the effect of aircraft noise on hearing. From a civilian airport perspective, the scientific community has concluded that there is little likelihood that the resulting noise exposure from aircraft noise could result in either a temporary or permanent hearing loss (Newman and Beattie 1985). The EPA criterion (L_{eq24} = 70 dB) can be exceeded in some areas located near airports, but that is only the case outdoors. Inside a building, where people are more likely to spend most of their time, the average noise level will be much less than 70 dB (Eldred and von Gierke 1993). Eldred and von Gierke also report that "several studies in the U.S., Japan, and the U.K. have confirmed the predictions that the possibility for permanent hearing loss in communities, even under the most intense commercial take-off and landing patterns, is remote."

Military aircraft are in general much noisier than their civilian counterparts, but the available data, while sometimes contradictory, appears to indicate a similar lack of significant effects of noise on hearing. A laboratory study (Nixon 1993) measured changes in human hearing from noise representative of low-flying aircraft on Military Training Routes (MTRs). The potential effects of aircraft flying along MTRs are of particular concern as the maximum overflight noise levels can exceed 115 dB, with a rapid increase in noise level exceeding 30 dB/sec. In this study, participants were first subjected to four overflight noise exposures at A-weighted levels of 115 dB to 130 dB. One-half of the subjects showed no change in hearing levels, one-fourth had a temporary 5 dB increase in sensitivity, and one-fourth had a temporary 5 dB decrease in sensitivity. In the next phase, participants were subjected to up to eight successive overflights, separated by 90 second intervals, at a maximum level of 130 dB until a temporary shift in hearing was observed. The temporary hearing threshold shift showed a decrease in sensitivity of up to 10 dB.

In another study of 115 test subjects between 18 and 50 years old, temporary threshold shifts were measured after laboratory exposure to military low-altitude flight (MLAF) noise (Ising 1999). The results indicate that repeated exposure to MLAF noise with maximum noise levels greater than 114 dB, may have the potential to cause permanent noise induced hearing loss, especially if the noise level increases rapidly (Ising 1999).

A report prepared by researchers at the University of Southampton (Lawton and Robinson 1991) summarized the state of knowledge as of 1991. Their review of the literature indicated that the main body of information with which comparisons can be made of the hearing damage risk from military overflight noise is to be found in standards and regulatory documents published by various organizations. It was concluded that the risk of hearing loss due to a single event of 125 dB maximum level and equivalent duration of the order 0.5 seconds is small, even after repeated daily occurrences over several years. Supplementary experimental evidence, involving temporary threshold shift (TTS), showed that a small amount of TTS might be engendered by military overflight noise at the levels in question, but that this would have no significant long-term effect even on the more susceptible ears. The literature search did uncover a small number of population surveys of hearing loss related to noise, but the quantitative results were rare and only one investigation produced audiometric results linked to noise measurements.

The report concluded that there is little evidence of hearing loss risk from military overflights, either for adults or children. "Whether in the case of TTS or PTS, laboratory or field studies, adults or children, there appear to be no reports of significant hearing damage attributable to the noise of aircraft overflights."

In Japan, audiological tests were conducted on a sample of residents who had lived near Kadena Air Base for periods ranging from 19 to 43 years (Yamamoto 1999). The sample had been exposed (not necessarily continuously) to noise levels ranging from DNL 75 to 88 dB. Examinations showed that there was a one in ten chance of a NIPTS of 20 dB at 4 kHz. However, the NIPTS at 2 kHz and lower was much less, so that the value of Ave. NIPTS was on the order of 10 dB or so. These results are consistent with the "10th Percentile NIPTS" figures in Table 1.

Ludlow and Sixsmith (Ludlow 1999) conducted a cross-sectional pilot study to examine the hypothesis that military jet noise exposure early in life is associated with raised hearing thresholds. The authors concluded that there were no significant differences in audiometric test results between military personnel who as children had lived in or near stations where fast jet operations were based, and a similar group who had no such exposure as children.

In summary, aviation noise levels near commercial airports are not comparable to the occupational or recreational noise exposures associated with hearing loss, and studies of aircraft noise levels have not definitively correlated permanent hearing impairment with aircraft activity. It is unlikely that airport neighbors will remain outside their homes 24 hours per day, so there is little likelihood of hearing loss below an average sound level of 75 dB.

Near military airbases, average noise levels above 75 dB may occur, and while new DoD policy dictates that NIPTS should be evaluated, research results to date have not found a definitive relationship between significant permanent hearing impairment (greater than 10 dB) and prolonged exposure to aviation noise.

FINDINGS/CONCLUSIONS

Application of the EPA Guidelines to Airbase Noise Assessment

The At-Risk Population

The DoD policy directive requires that hearing loss risk be estimated for the at risk population, defined as the population exposed to DNL greater than or equal to 80 dB. Specifically, DoD components are directed to “use the 80 Day-Night A-Weighted (DNL) noise contour to identify populations at the most risk of potential hearing loss.” This does not preclude populations outside the 80 DNL contour, i.e. at lower exposure levels, from being at some degree of risk of hearing loss. However, the estimate should be restricted to populations within this contour area, including residents of on-base housing. The exposure of DoD employees in the area already defined as the hazardous noise will not be included in this analysis because they already fall under the occupational noise regulations and will be evaluated using the appropriate DoD component regulations for occupational noise exposure.

Assessment of Risk

Presenting the potential risk of hearing loss by use of the PHL metric is useful in gaining an overall assessment of community effects, and it does provide a single number by which the impacts of different alternatives can be compared, as required in the NEPA environmental impact analysis process. However, since it is a population weighted average, the numerical value of PHL can be influenced by the population distribution to produce inconsistent results in some cases. For example, an alternative that increased the size of a given contour could conceivably decrease the PHL if the additional area within the contour was highly populated. DNWG recommends that hearing loss risk be presented in terms of the actual number of people at risk of experiencing a noise-induced permanent threshold shift, rather than a population weighted average.

Calculation of Hearing Loss Risk

Following the DoD directive, assessment of the potential for hearing loss is limited to populations residing within the 80 DNL contour. For these populations, the risk of hearing loss is calculated in terms of Ave. NIPTS based on the L_{eq24} noise exposure from Table 1.

The actual 24-hour noise exposure (L_{eq24}) for any person living in the at-risk area is determined by the time that person is outdoors and directly exposed to the noise. Many of the people living within the 80 DNL contour will not be resident during the daytime hours – they may be at work, at school, or involved in other activities outside the at-risk area. Some will be inside their homes and exposed to lower noise levels, benefitting from the noise attenuation provided by the house structure – a minimum of 15 dB with windows open. The actual activity profile is usually impossible to generalize across the community. For the most conservative scenario, it should be assumed that people are exposed to the exterior noise levels for a full 24 hours. If information on activity profiles is available, then appropriate adjustments can be made to L_{eq24}.

The procedure for calculating hearing loss risk is as follows:

Step 1: Establish the DNL 80 noise contour and establish the population/area at risk within the contour..

Step 2: Develop L_{eq24} noise contours at 1 dB intervals within the 80 DNL contour, or calculate DNL at points of interest if the population is limited to a number of discrete locations.

For the same numerical value, an L_{eq24} contour will always be equal to or smaller than a DNL contour, the difference being related to the number of nighttime operations. As a result, it may be necessary to compute L_{eq24} contours at levels less than 80 dB to encompass all the area within the 80 DNL contour.

Step 3: Use Table 1 to determine Ave. NIPTS for each L_{eq24} contour level band.

Step 4: Estimate the population in each contour band.

Step 5: Prepare a table showing the population and Ave. NIPTS for each L_{eq24} contour band.

Determination of Exposed Population

The population living within the L_{eq24} noise contour bands can be estimated in two ways. When the population is more or less evenly distributed, a population count is best obtained using census data presented at the block level. Since the contour bands are only 1 dB wide, the bands will often cut a swath through a portion of several block counts. The standard procedure in these cases is to assume that the population is evenly distributed within each census block, and the population count is obtained using an area-proportional procedure. If a contour covers a portion of a census block, only the geographically based proportion of that block's population within the contour is counted. If a census block is contained completely by a contour, then 100 percent of the population is counted.

In the case where the population is confined to a few small locations, it may be preferable to conduct a field survey since this will be more accurate than using census data. The on-base population can be obtained from the base housing office.

Reporting of the Risk of Hearing Loss

The quantity to be reported is the number of people living within each 1 dB L_{eq24} contour band inside the 80 DNL contour, together with the Ave. NIPTS associated with that contour band.

The average nature of Ave. NIPTS means that it underestimates the magnitude of the potential hearing loss for the population most sensitive to noise. Therefore, in the interest of disclosure, the information to be reported should include both the Ave. NIPTS and the 10^{th} percentile NIPTS (see Table 1) for each 1 dB L_{eq24} contour band inside the 80 DNL contour.

This information should be included in any published assessment of hearing loss risk.

REFERENCES

CHABA (1965). Hazardous Exposure to Intermittent and Steady-State Noise, Report of Working Group 46, NAS-NRC Committee on Hearing, Bioacoustics & Biomechanics.

DOD (2004). Department of Defense Instruction No 6055.12, DoD Hearing Conservation Program, March 5.

DOD (2009). Memorandum from the Under Secretary of Defense, Methodology for Assessing Hearing Loss Risk and Impacts in DoD Environmental Impact Analysis, June 2009.

Eldred, K., and von Gierke, H. (1993). Effects of Noise on People, Noise News International, 1(2), pp. 67 89, June.

EPA (1982). Guidelines for noise impact analysis, Environmental Protection Agency Report No. 550/9-82-105.

EPA (1974). Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, Environmental Protection Agency Report No. 550/9-74-004.

Ising, H., Joachims, Z., Babisch, W., and Rebentisch, E. (1999). Effects of Military Low-Altitude Flight Noise I Temporary Threshold Shift in Humans. Zeitschrift fur Audiologie (Germany), Vol. 38, No. 4, pp. 118-127, 1999.

Lawton, B.W., and Robinson, D.W. (1991). Risk to Hearing from Overflight Noise of Military Aircraft, ISVR Technical Report No 194, May 1991.

Ludlow, B., and Sixsmith, K., (1999). Long term effects of military jet aircraft noise exposure during childhood on hearing threshold levels, Noise & Health, 5, 33-39.

Newman, J.S., and Beattie, K.R. (1985). Aviation Noise Effects. US Department of Transportation, Federal Aviation Administration Report No. FAA-EE 85.

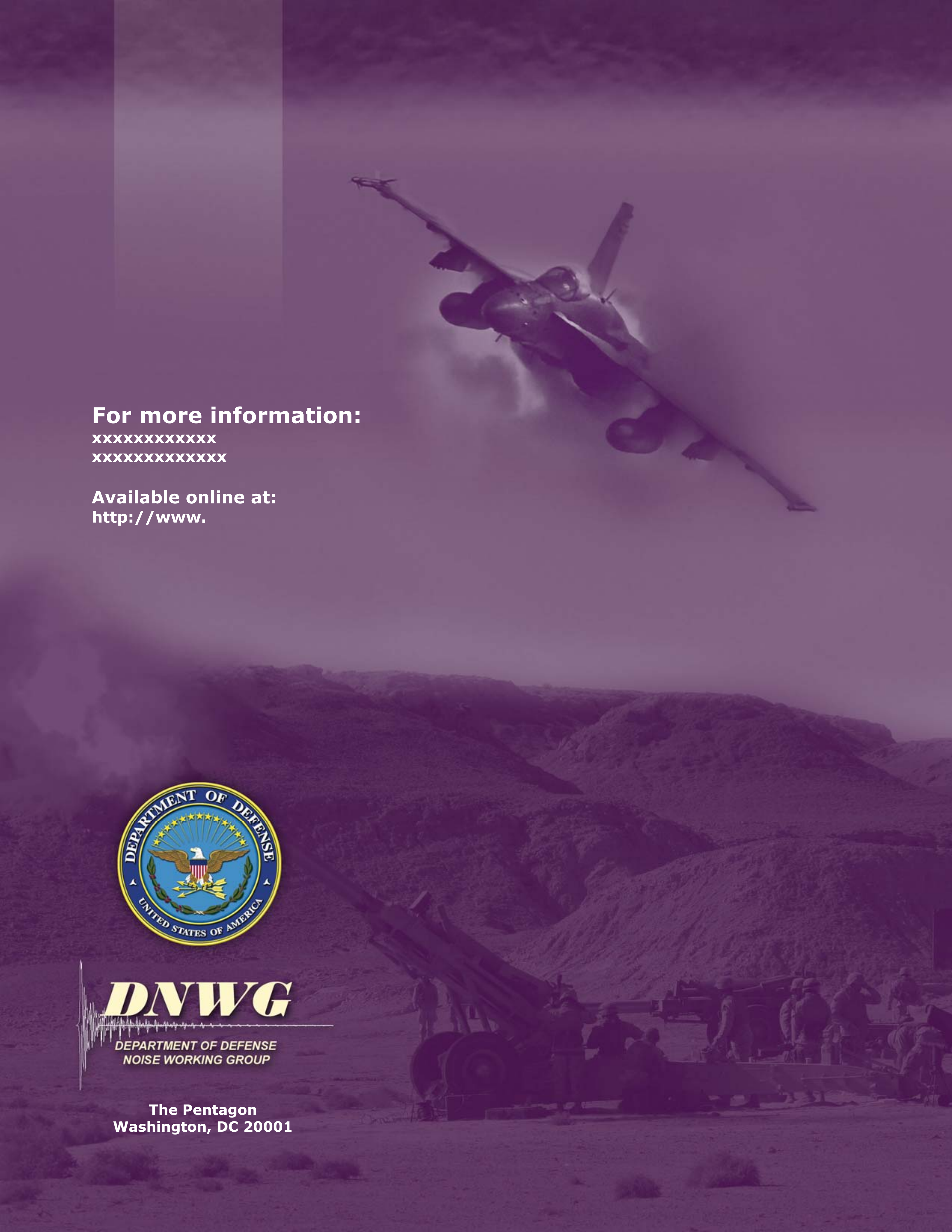
NIOSH (1998). Criteria for a Recommended Standard, Occupational Noise Exposure – Revised Criteria 1998, National Institute for Occupational Safety and Health, June.

Nixon, C.W., West, D.W., and Allen, N.K. (1993). Human Auditory Responses to Aircraft Flyover Noise. Proceedings of the 6th International Congress on Noise as a Public Problem, Nice, France I'NRETS, Volume 2.

OSHA (1971). U.S. Department of Labor, Occupational Safety & Health Administration, Occupational Noise Exposure, Standard No. 1910.95.

WHO (2000). World Health Organization. 2000. Guidelines for Community Noise

Yamamoto, T., (1999). A Report on the Aircraft Noise as a Public Health Problem in Okinawa March.



For more information:
xxxxxxxxxxxx
xxxxxxxxxxxxx

Available online at:
http://www.

DNWG
DEPARTMENT OF DEFENSE
NOISE WORKING GROUP

The Pentagon
Washington, DC 20001