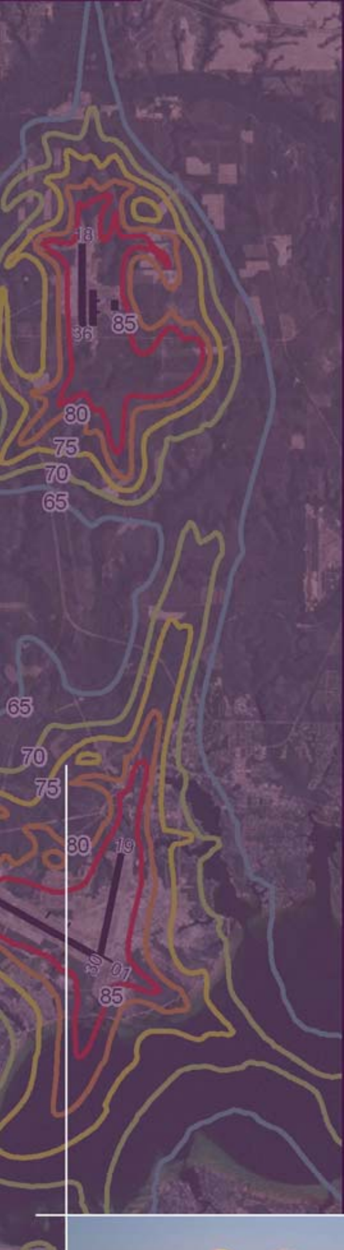


DEPARTMENT OF DEFENSE
NOISE WORKING GROUP

TECHNICAL BULLETIN

Speech Interference from Aircraft Noise

December 2013

Speech interference associated with aircraft noise is a primary cause of annoyance for communities in homes, classrooms, and the workplace. Disrupting speech in the classroom is a primary concern. This Technical Bulletin offers advice on how to evaluate the potentially interfering effects of military aircraft flights as part of the environmental assessment.

INTRODUCTION

This *Speech Interference from Aircraft Noise* 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.

Under the terms of the National Environmental Policy Act of 1969 (NEPA), the DoD must consider the environmental impacts of all major proposed changes in military operations. Among these are the effects of the noise expected from such actions on exposed communities. The Military Services carry out 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 to foster compatible land-use development around 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 military aircraft operations interfere with speech communication with special emphasis on effects in classrooms, and offers advice on how to assess speech interference in both homes and schools. The intent is to help program officials disclose the potential effects to supplement the environmental assessment.

BACKGROUND

Interference with speech communication in the home and in classrooms is often an issue for communities exposed to aircraft noise. The effects of speech disruption are included to some extent in the general annoyance that a person expresses about aircraft noise. However, an expression of annoyance may have many causes, some of which are not directly related to noise itself. Speech interference is by definition directly related to noise alone, and can be addressed separately using established noise criteria.

Disrupting routine activities in the home, such as radio or television listening, telephone use, or family conversation, can result in frustration and irritation. The quality of speech communication is important in classrooms due to the potential for adverse effects on children's learning ability. In industrial settings, communicating over the noise can cause fatigue and vocal strain. The focus of this bulletin is on the disruptions in homes and schools resulting from exposure to aircraft noise.

There are two aspects to speech comprehension:

(1) *Word Intelligibility* - the percent of words transmitted and received. This might be important in schools for students in the lower grades who are learning the English language, and particularly for students who have English as a Second Language (ESL).

(2) *Sentence Intelligibility* – the percent of sentences transmitted and understood. This might be important for high school students and adults at home who are familiar with the language, and who do not necessarily have to clearly hear each word to understand sentences.

As might be expected, word intelligibility is the more critical of the two, requiring lower noise levels to achieve the same intelligibility rating. For students to understand their teacher, regular voice communication must be clear and uninterrupted. Not only does the background sound level have to be low enough for the teacher to be heard, but intermittent outdoor noise events also need to be minimized. In assessing speech communication it is therefore important to consider the steady background level, the level of voice communication, and the single-event level from aircraft overflights that might interfere with speech.

DISCUSSION

Many research studies have been conducted over the last 50 years and guideline documents developed resulting in a consistent set of noise level criteria for speech interference. This section provides a review of the results of these studies as they apply to residential areas and classrooms.

Residential Speech Interference

Speech communication is the most convenient form of human expression. Interference with speech disturbs normal social activities and can be a leading contributor to annoyance. Of chief concern in residential areas is the effect of aircraft noise on face-to-face conversations, telephone conversations, and television use. The degree to which noise disturbs speech depends on many factors, including speaker voice level, background noise level, the distance between speakers, and room acoustics. Research on speech intelligibility has produced considerable information on how these factors interact, allowing for speech intelligibility to be reliably predicted.

A primary effect of noise is its tendency to drown out or "mask" speech, making it difficult to carry on uninterrupted conversations.. Figure 1 below presents typical distances (on the x-axis) between speaker and listener for satisfactory conversations in the presence of a steady A-weighted background noise level (on the y-axis). According to this figure, two people can hold a relaxed conversation at a normal speaking distance of 6 feet when the background noise level is 50 dB or lower.

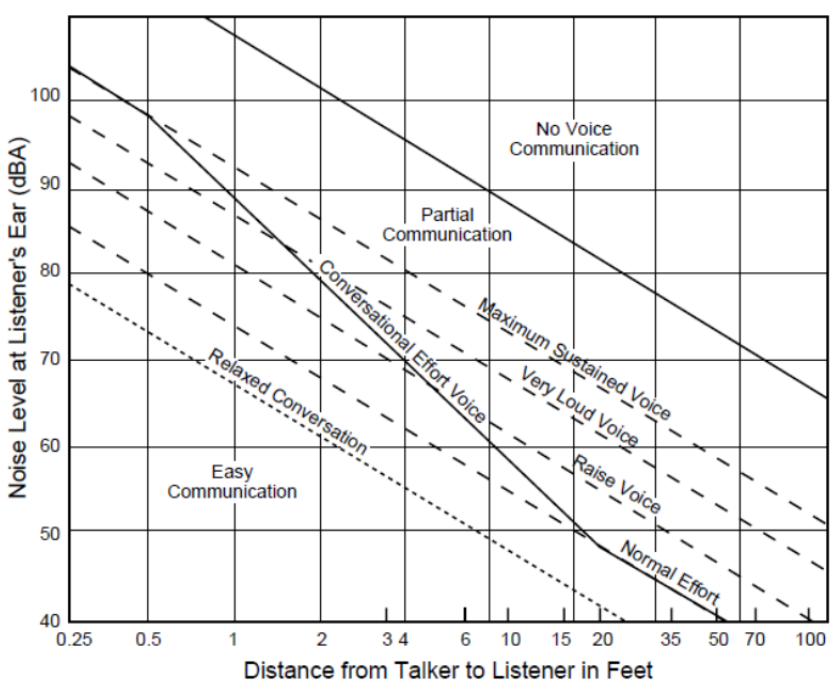


Figure 1. Distance at which speech can be understood

Source: EPA Report 550/9-73-002, Public Health and Welfare Criteria for Noise, July 27, 1973 (reprinted from FICON 1992)

Based on this and other information, the EPA identified a goal of an indoor 24-hour average noise level, L_{eq24}, of 45 dB to minimize speech interference in the home, allowing relaxed conversation to be understood at distances of 10 to 15 feet (EPA 1974). The FAA has adopted these guidelines for noise insulation funding for residences specifying a design objective of the Day-Night Average Sound Level (DNL) 45 dB for aircraft operations at commercial airports (FAA 1985).

When the intruding noise is not continuous, as with aircraft noise, then a criterion based on an average level may not allow for relaxed conversation to be understood all of the time. To provide for such situations, the Federal Interagency Committee on Noise (FICON 1990), formed to review Federal procedures for aviation noise assessments, suggested the use of the supplemental metric Time Above (TA), which is the total time the noise level exceeds a “threshold” level during a specified interval (DNWG 2009). It provides a useful “single number” indicator of the potential for speech interference. For specific locations at which speech interference is a critical concern, FICON suggested tabulating individual aircraft operations affecting the location, including the number of each type of operation by aircraft type, the noise levels associated with each type of event, and the timing of the events, to provide the most useful information.

Classroom Speech Interference

In classrooms, speech communication between teacher and student is the primary activity sensitive to noise intrusion from aircraft. It is an essential part of the educational process for the student to hear clearly every word spoken by the teacher so that unfamiliar words and concepts can be understood. Children are not as familiar with language as adults and hence may miss some of the verbal cues and redundancies which aid adults in communication. For this reason, background noise levels should be lower for children to achieve the same level of speech comprehension as adults. This is particularly true at the lower grade levels, for language classes, and for students with learning disabilities.

Both the American National Standards Institute (ANSI 2002) and the American Speech-Language-Hearing Association (ASLH 1995) recommend at least a 15 dB signal-to-noise ratio in classrooms. This is the minimum ratio to ensure that children with hearing impairments and language disabilities can enjoy high speech intelligibility. Assuming the average adult male or female voice registers a sound level (L_{max}) of 50 dB in the rear of the classroom, the ANSI standard requires that the continuous background noise level indoors must not exceed an average sound level (L_{eq}) of 35 dB during school hours.

The World Health Organization (WHO 1999) reported that, for a speaker-to-listener distance of about 1 meter, empirical observations have shown that speech in relaxed conversations is 100 percent intelligible in steady background noise levels of about 35 dB, and speech can be fairly well understood in the presence of background levels of 45 dB. The WHO recommends a guideline value of L_{eq} of 35 dB for continuous background levels in classrooms during school hours.

However, as noted above, aircraft noise is not continuous and consists of individual events where the sound level exceeds the background level for a limited time period as the aircraft flies over. The magnitude and frequency of individual aircraft flyover events determine the degree of speech interference. Therefore, a time-averaged metric alone, such as L_{eq}, is not necessarily suitable when evaluating overall effects. As well as background level criteria described above, single-event criteria, which account for sporadic intermittent outdoor noisy events, are also essential to specifying speech interference criteria.

In 1984, Sharp and Plotkin, in a report to the Port Authority of New York and New Jersey, recommended using the Speech Interference Level (SIL) metric for classroom noise criteria. This metric is based on the maximum sound levels in the frequency range (approximately 500 Hz to 2,000 Hz) that directly affects speech communication. Their study identified an SIL (the average of the sound levels in the 500, 1000, and 2000 Hz octave-bands) of 45 dB as the desirable goal, which was estimated to provide 90 percent word intelligibility for the short time periods during aircraft over-flights. Although early classroom level criteria were defined by SIL, the use and measurement of L_{max} as the primary metric has since become more popular. Both metrics consider the maximum sound levels associated with intermittent noise events and can be related to existing background levels when determining speech interference percentages. An SIL of 45 dB is roughly equivalent to an A-weighted L_{max} of 50 dB for aircraft noise.

Lind, Pearsons, and Fidell also concluded that if an aircraft noise event's maximum indoor noise level (L_{max}) reached the speech level of L_{max} 50 dB, 90 percent of the words would be understood by students seated throughout the classroom (Lind 1998). Since intermittent aircraft at lower levels does not appreciably disrupt classroom communication, Lind recommended an indoor L_{max} of 50 dB as the maximum single-event level permissible in classrooms. Note that this limit was set based on students with normal hearing and no special needs; at-risk students may be adversely affected at lower sound levels.

Bradley (1993) recommends the sound exposure level (SEL) as a better indicator of indoor estimated speech interference in the presence of aircraft overflights. For acceptable speech communication using normal vocal efforts, Bradley concludes that 95% intelligibility would be achieved when indoor SEL values do not exceed 60 dB. This SEL value approximates an L_{max} value in the range 50 to 55 dB.

WHO does not recommend a specific indoor L_{max} criterion for single-event noise, but does place a guideline value at L_{eq} of 35 dB for overall background noise in the classroom (WHO 1999). However, WHO does report that "for communication distances beyond a few meters, speech interference starts at sound pressure levels below 50 dB for octave bands centered on the main speech frequencies at 500 Hz, 1kHz, and 2 kHz." One can infer that this can be approximated by an L_{max} value of 50 dB.

The United Kingdom Department for Education and Skills (UKDFES 2003) established in its classroom acoustics guide a 30-minute time-averaged metric [$L_{eq(30min)}$] for background levels and $L_{A1,30\ min}$ for intermittent noises, at thresholds of 30-35 dB and 55 dB, respectively. $L_{A1,30\ min}$ represents the A-weighted sound level exceeded 1 percent of the time (in this case, during a 30 minute teaching session) and is generally equivalent to the L_{max} metric.

The current ANSI Standard (ANSI 2010) states that the criteria for allowable background noise level, namely L_{eq} 35 dB, is still appropriate in the presence of intermittent noise events, such as aircraft overflights.

Table 1 summarizes recommended classroom noise level criteria from the scientific literature.

Table 1. Summary of Classroom Noise Level Criteria Based on Speech Intelligibility

Source	Metric/Level (dB)	Effects and Notes
U.S. FAA (1985)	L_{eq}(during school hours) = 45 dB	Federal assistance criteria for school sound insulation; supplemental single-event criteria may be used
Lind et al. (1998), Sharp and Plotkin (1984), Wesler (1986)	L_{max} = 50 dB	Single event level permissible in the classroom
Bradley (1993)	SEL 60 dB (~L_{max} 50-55 dB)	95% intelligibility
WHO (1999)	L_{eq} = 35 dB L_{max} = 50 dB	Assumes average speech level of 50 dB and recommends signal to noise ratio of 10 dB
U.S. ANSI (2010)	L_{eq} = 35 dB	Acceptable level for continuous and intermittent noise in the classroom
U.K. DFES (2003)	$L_{eq(30min)}$ = 30-35 dB L_{max} = 55 dB	Minimum acceptable in classroom and most other learning environs

FINDINGS/CONCLUSION

Previous speech interference studies only considered steady state noise in setting guidelines for residences and classrooms. However, aircraft noise is not continuous and consists of individual events where the sound level exceeds the background level for a limited time period as the aircraft flies over.

This is particularly important in the classroom where, in addition to the requirements for the physical reception and recognition of spoken sounds, a satisfactory noise environment is important for two other reasons. First, short-term classroom disruption from noisy aircraft overflights results in a loss of lesson flow. A survey of teachers in schools exposed to aircraft noise from London Heathrow Airport found that interference with verbal communication and the resulting disruption was the most often cited nuisance of aircraft noise intrusions. Second, to maintain good communication, the teacher will automatically raise his/her voice to overcome the aircraft overflight noise intrusions. Repeatedly increasing vocal efforts can cause fatigue, and force the teacher to modify his/her instruction method.

For continuous indoor noise levels less than a certain minimum, generally considered to be about 35 dB, there is essentially no speech communication interference. As the level increases, the teacher has to raise his/her voice until the point is reached where the levels are too high to permit speech communication, whereupon the teacher stops and the lesson is disrupted. If the noise is not continuous but due to aircraft overflights, a teacher may be able to maintain a reasonable flow if there are only occasional disruptions, but as the number of overflights increases, there comes a time when any teaching continuity is completely lost. Under this condition, increasing the number of overflights and disruptions has only a slight effect on the ability to teach, to learn, and to maintain discipline – it is just an added aggravation on an already impossible situation.

The conclusion that can be drawn is that the acceptability of aircraft noise in a classroom is determined not only by the maximum noise levels generated by aircraft overflights, but also by the number of overflights. The same is true for speech communication in the home. This conclusion points towards the need for considering numbers of events in assessing speech interference in homes and classrooms.

Upon reviewing existing guidelines, the scientific findings on speech interference, and taking into account the limits of the guidelines and findings as they pertain to intermittent noise from aircraft overflights, DNWG recommends the noise metrics and thresholds shown in Table 2.

To communicate with residential communities how often speech interference may occur during the 15 hour daytime period for an average day, DNWG (2009) recommends the use of the $NA75L_{max}$ metric (the number of aircraft events that exceed a maximum level of 75 dB).

For assessments involving schools, DNWG (2009) suggests a 3-step process, using L_{eq} for scoping, together with NA (Number Above) to examine the magnitude of classroom interference, and TA (Time Above) to convey the magnitude in terms of time, if needed. The analysis should separate the aircraft operational data during school day hours from the total day operations to assess classroom speech interference.

Table 2. Guideline Values for Noise Assessment Studies

*Unit values for plotting contours on study area map.

Application	Metric	Unit	Time Period	Recommended Outdoor Unit Values*
Residential Speech Interference	NA (L_{max})	Number Of Events	15hr Day	15, 30, 45, 60 events (Above 75 dB)
Classroom Speech Interference	L_{eq}	dB	School Hours (8hr)	60 dB (for scoping)
	NA (L_{max})	Number Of Events	School Hours (8hr)	8,16,24,32 events (Above 75 dB)
	TA	Minutes	School Hours (8hr)	2, 4, 6, 8 minutes (Above 75 dB)

For scoping purposes, DNWG recommends using the 60 L_{eq} contour to provide a first indication that aircraft noise might be a problem at a particular school because at this outdoor level the indoor classroom noise levels could exceed the 35 dB background noise level. Once schools within this contour have been identified, the next step is to assess the magnitude of classroom interference using NA75 and TA75.

DNWG recommends NA75L_{max} (outdoor level) because in a 'windows closed' school environment with an average Noise Level Reduction (NLR) of 25 dB, the resulting indoor level of 50 dB is the widely accepted single event criteria threshold level for classroom speech interference (see Table 1). Producing NA75 for events in multiples of 8 events (i.e., 8, 16, 24, 32) per 8-hour time period also provides the effects of multiple aircraft events per hour (1, 2, 3, and 4 or more).

If classroom speech interference is of particular concern, DNWG suggests TA analysis to supplement the NA analysis. TA analysis would show the number of minutes on average that class time is interrupted by aircraft intrusions.

The combined NA and TA analyses communicate not only how many events occur, but the total time they will be above 75 dB. While NA analysis alone is effective in communicating noise exposure, TA results without NA results are much less effective. NA and TA results can be presented in contour format and in more detail in tabular format. If TA is presented in contour format, then the increments in minutes should be selected based on operational levels. The more operations during the selected time period, the larger the increments can be to best show the amount of time noise will exceed the selected threshold level. If operations are few, then one-minute increments should be used.

Presenting NA and TA results for selected geographic locations in a study area in tabular form over a range of threshold levels is highly effective in communicating the number and duration of noise events that may be intrusive at each school located in a study area. This method is useful to compare and show the noise exposure changes that will occur from various operational scenarios. It highlights the smaller changes that are difficult to communicate by comparing DNL contours alone on a background map. NA and TA break the total sound energy that comprises DNL into its component parts, and these supplemental metric results are much easier for the average person to grasp than DNL. When these results show the number (NA) and total time (TA) of intrusive noise events in the classroom is low, public acceptance of the proposed action is more likely.

Experience has shown the key to presenting this information is to make it as simple and easy-to-understand as possible. Most project stakeholders and the public do not want to wade through pages of technical data. Presenting straightforward noise exposure data in the main text typically results in parties responding positively and quickly. Detailed tabular data should be placed in an appendix for those wishing to see the complete technical information. For instance, the classroom analysis should focus on the one sound level threshold that best equates to speech interference and leave more-detailed information on other effects or thresholds to an appendix to the analysis. Experience has shown that most of the intended audience wants to know simply what the effects are on them and what they should expect.

REFERENCES

ANSI (2002). American National Standards Institute, Inc. (ANSI). Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools. ANSI S12.60-2002.

ANSI (2010). American National Standards Institute, Inc. (ANSI). Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools. Part 1 Permanent Schools. ANSI S12.60-2010.

ASLH (1965). American Speech-Language-Hearing Association. *Guidelines for Acoustics in Educational Environments*, V.37, Suppl. 14, pgs. 15-19.

Bradley, J.S. (1993). *NRC-CNRC NEF Validation Study: Review of Aircraft Noise and its Effects*, National Research Council Canada and Transport Canada, Contract Report A-1505.5.

DNWG (2009). Improving Aviation Noise Planning, Analysis and Public Communication with Supplemental Metrics, Defense Noise Working Group December.

EPA (1973). Public Health and Welfare Criteria for Noise, Environmental Protection Agency Report 550/9-73-002, July 27.

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.

FAA (1985). Federal Aviation Administration (FAA), *Airport Improvement Program (AIP) Handbook*, Order No. 100.38.

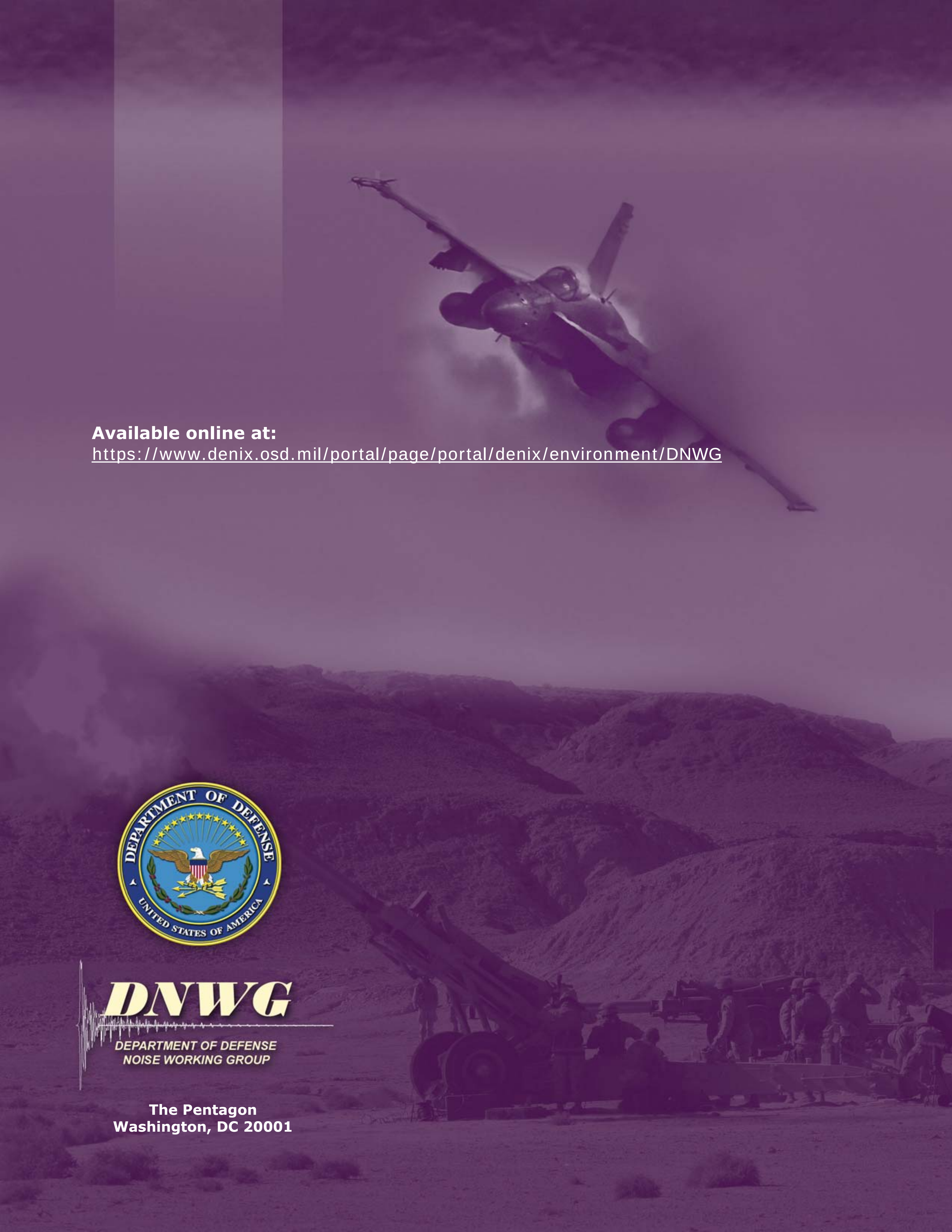
FICON (1992).), Federal Agency Review of Selected Airport Noise Analysis Issues, Federal Interagency Committee on Noise, August.

Lind S.J., Pearsons K., and Fidell S., (1998). *Sound Insulation Requirements for Mitigation of Aircraft Noise Impact on Highline School District Facilities*, Volume I, BBN Systems and Technologies, BBN Report No. 8240.

Sharp, B.H., and Plotkin, K.J. (1984). *Selection of Noise Criteria for School Classrooms*, Wyle Research Technical Note TN 84-2 for the Port Authority of New York and New Jersey, October.

UKDFES (2003). *Building Bulletin 93, Acoustic Design of Schools - A Design Guide*, United Kingdom Department for Education and Skills (UKDfES), London: The Stationary Office.

WHO (1999). *Guidelines for Community Noise*. World Health Organization .



Available online at:
https://www.denix.osd.mil/portal/page/portal/denix/environment/DNWG

DNWG
DEPARTMENT OF DEFENSE
NOISE WORKING GROUP

The Pentagon
Washington, DC 20001