Reno, Nevada
NOISE-CON 2007
2007 October 22-24

Airborne Weapons Noise Prediction Model

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ABSTRACT

The development of an air-gunnery noise model that calculates both single event noise as well as cumulative noise is described. The basis of the model's calculations will be the positive impulse and spectral time histories. Based on field measurements, correlations between the positive impulse and other acoustical metrics are developed so that various acoustical metrics may be used to assess potential impacts. The model is composed of a two step modeling processes. The initial step calculates a noise footprint for a unique operation at a given range (e.g. A-10 low angle strafe on lane 3 at Poinsette Range). This calculation includes the effects of linear propagation, topography, and spatial distribution of the firing points in the calculation of the noise footprint. The next step sums all of the operations scaled by their number of occurrences. Using this two step process, a detailed noise calculation is performed only once, but a user can easily and quickly recalculate the noise contour for different operational scenarios while maintaining highly accurate results without the need for a complete reanalysis.

1. INTRODUCTION

A number of aircraft noise models have been developed over the past 30 years to estimate noise levels from military aircraft operations near airbases, along training routes, and within special use airspaces. The predictions from these models are used to assess the potential for community and environmental impacts from current and proposed flight operations. The US Army has developed noise models for blast noise and supersonic shock waves due to ground-based weapon systems. Current Department of Defense (DoD) noise models all use common aircraft and weapon system source noise databases, which are maintained by the Air Force Research Laboratory (AFRL), US Army Construction Engineering Research Laboratory (CERL), and Navy Facilities Engineering Command (NAVFAC). However, these models and databases do not include the noise contribution from air-gunnery operations.

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This omission of an important and significant source of noise has and will become more troublesome as range operations come under greater scrutiny from the public. In the Republic of Korea strafing operations have been greatly restricted based on noise complaints from local communities. Currently, the range commanders have no tools to counter these restrictions.

A new model is needed that can calculate the air-borne weapon noise that occurs in air-weaponry operations. The goal of this project is the development of an air-gunnery noise model that will calculate both single event and cumulative noise in addition to providing acoustic visualizations for both planners and the public. Providing an accurate noise model that can quickly create scenarios for study without sacrificing accuracy for speed is critical.

One of the complexities involved is aircraft rarely fly the exact attack run profile prescribed, and in some cases the attack run is simply a generalized fan where the pilot can approach the target from a range of headings. To solve this problem of an unknown source location, a generalized statistical firing space is used. This space is defined by the parameters of the attack run with a three dimensional Gaussian distribution of firing points. The noise footprint from this space is then calculated to represent the noise from a single bullet fired from within the space. This statistical method is not representative of a single bullet fired, but is rather the average noise expected once a statistically large number of bullets have been fired (such as after a year of simulated combat operations). The noise footprint can then be included in a larger environmental noise model that determines the noise contour from a whole range of operations.

2. NOISE MODEL FORMULATION

A. Statistical Volume

The first step in calculating the noise from a full air-gunnery range is to calculate the three-dimensional statistical volume for each unique firing profile. A graphical user interface has been created to design these attack runs. Figure 1 shows part of a screen capture of this interface.

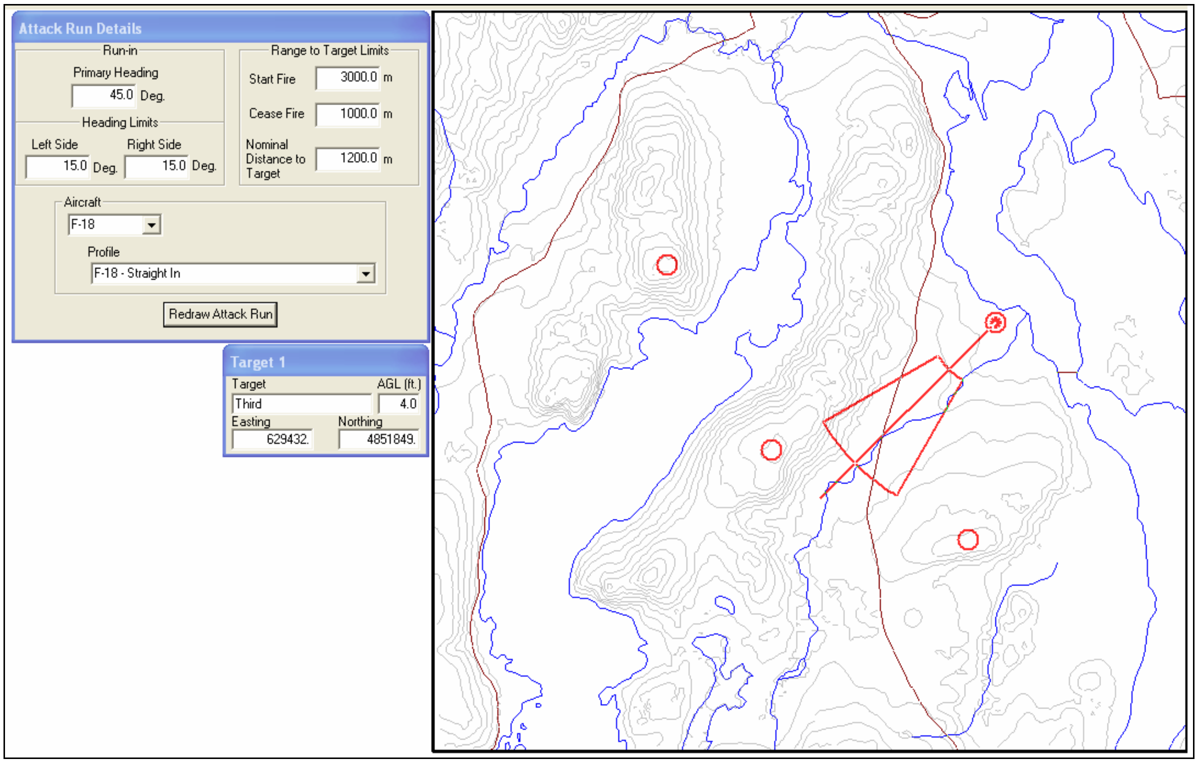

Figure 1: Screen capture of the attack-run design window for the new Air-Gunnery Noise Model.

Through this interface, the user first selects the aircraft type, then the attack profile for that aircraft type. For example, a straight in approach or high angle strafing run could be selected. The attack profile is used to determine the flight angle that the aircraft will take as it approaches the target and is specific to each aircraft and attack run type (eg. low-angle strafe). There are also upper and lower flight angle limitations to this, helping to complete the three-dimensional volume defined by this attack run.

The approach vector of the attack is then selected, along with start-fire and cease-fire lines, as well as a range of heading angles available for approaching the target. Finally, there is a nominal firing distance to target, which is the optimal distance to fire from and is used in the statistical calculations.

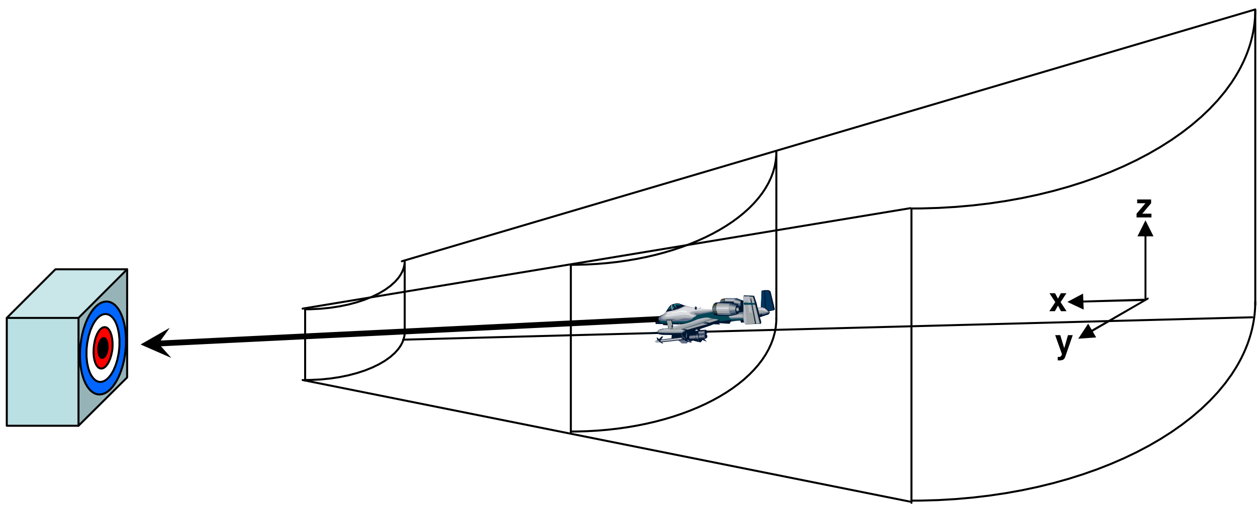

Figure 2: Representative statistical volume for an A-10 strafing run.

This volume represents the most likely location that the aircraft will be when it fires its gun. It is defined as a fan with circular arcs. Once this volume is defined, it is then sliced into 'rectangular' slices in the Y-Z plane. These slices are actually curved segments, centered on the target being fired at. However, these slices can be unfolded into true rectangles. Each of these slices has a probability that a bullet was fired within it based on how far it is from the nominal firing distance. For example, moving the nominal firing distance to the front of the firing volume will skew the statistics so that positions in the front have a higher probability than positions towards the rear of the volume.

Each rectangular slice also has its own two dimensional probability distribution. Figure 3 shows a representation of the firing point distribution in both the flight path direction (x) and the planar directions (y and z). With the selection of the approach heading and the range of left-right vectors it is possible to skew these probabilities as well. The probability that a bullet is fired on any give position of this rectangle is then related to how close to the nominal approach vector it is. For simplicity the graphic in Figure 3 simply shows a symmetric distribution in both the X direction and in the Y- Z plane.

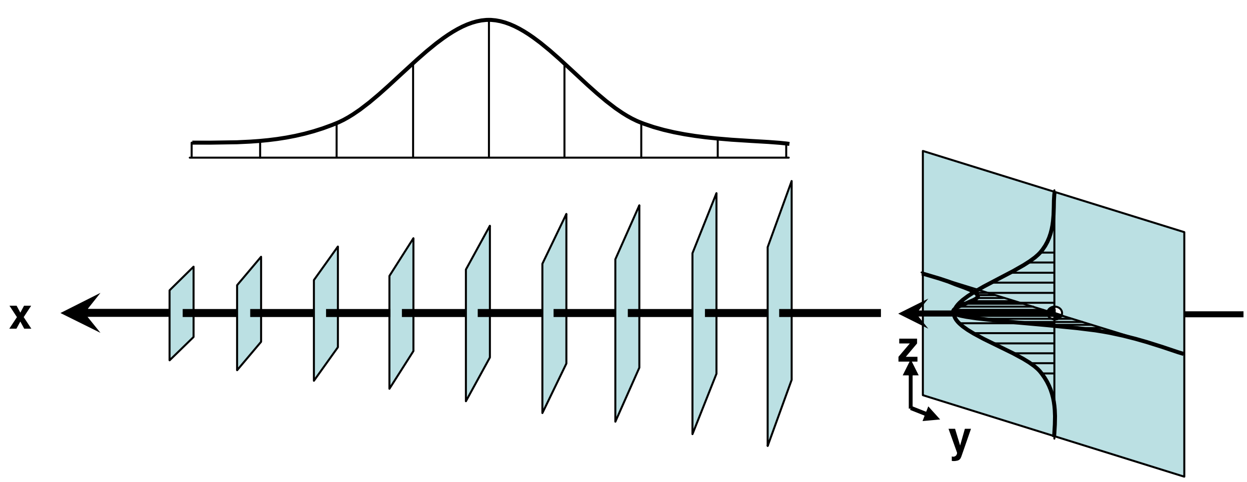

Figure 3: Probability distributions for the axial (x) and planar positions (y and z) of the aircraft firing points.

The rectangles are subdivided into individual grid points where the probability is specifically defined based on the probability distributions. The probability that a bullet is fired at any arbitrary grid point within the statistical volume is then the multiplication of the probability of the slice where the bullet is fired times the probability of the grid point where the bullet is fired.

The end result is a three dimensional set of grid points, each with its own probability. The probability of all of the grid points in this volume are then normalized such that they all sum to one. The result is therefore a three dimensional probability distribution for where a single bullet was fired.

B. Noise Calculation

Once the probability distribution is completed, the model is ready to compute the noise footprint. First, the noise from each grid point in the probability distribution is propagated to a grid on the ground. The propagation algorithms used here are the same used in NMSim[1] and take into account atmospheric absorption, terrain effects, and the effects of differeing ground impedance. After the noise grid for each firing point in the statistical volume is calculated, the entire grid noise level is multiplied by the probability fraction for that firing point. Then the noise grids from all of the firing points in the statistical volume are summed up. The result is a statistical representation of the noise on the ground from the firing of a single bullet. This is NOT representative of a single bullet, and can not be used for a single event. This result is only valid for a statistically large number of bullets fired from a large number of different attack runs on the same pattern.

The computational time required for this analysis can be long – on the order of hours per attack run depending on the level of detail needed for the noise contours. Doing an entire range could be prohibitively costly in terms of time when there are several different attack run possibilities. However, once one of these single-bullet footprints has been computed for a given attack run, the results can be stored in a grid and do not need to be recomputed. The results are stored in a noise library that contains all of the footprints from all of the possible attack runs at a given range.

To compute the overall noise contour for a range, the model multiplies the results for each attack run by the total number of rounds used on that run, then sums the result with the similar results from all of the other attack runs. The computational burden is limited to the time when the range data is initially entered, and the time required to create a new noise contour is minimal since it only requires some computationally quick multiplications and additions. The final results are then stored in a standard NMPlot[2] grid format. The results form the air-weaponry calculations can be easily combined with results from other noise models, such as one that computes the noise from the aircraft itself.

C. Sample Results

For a test case, a target was set up for strafing runs from an Apache helicopter. Three distinct attack runs were set up. One attack run has a nominal heading of 135 degrees (magnetic), and another from 45 degrees (magnetic). Each of these was designed to allow a +/- 10 degree variation in the approach angle. The third run was designed with a nominal approach heading of 315 degrees (magnetic), but with only a +/- 2 degree variation allowed in the approach vector. It was assumed that an equal number of rounds were fired from each of these attack runs. The results for this one target are shown in Figure 4.

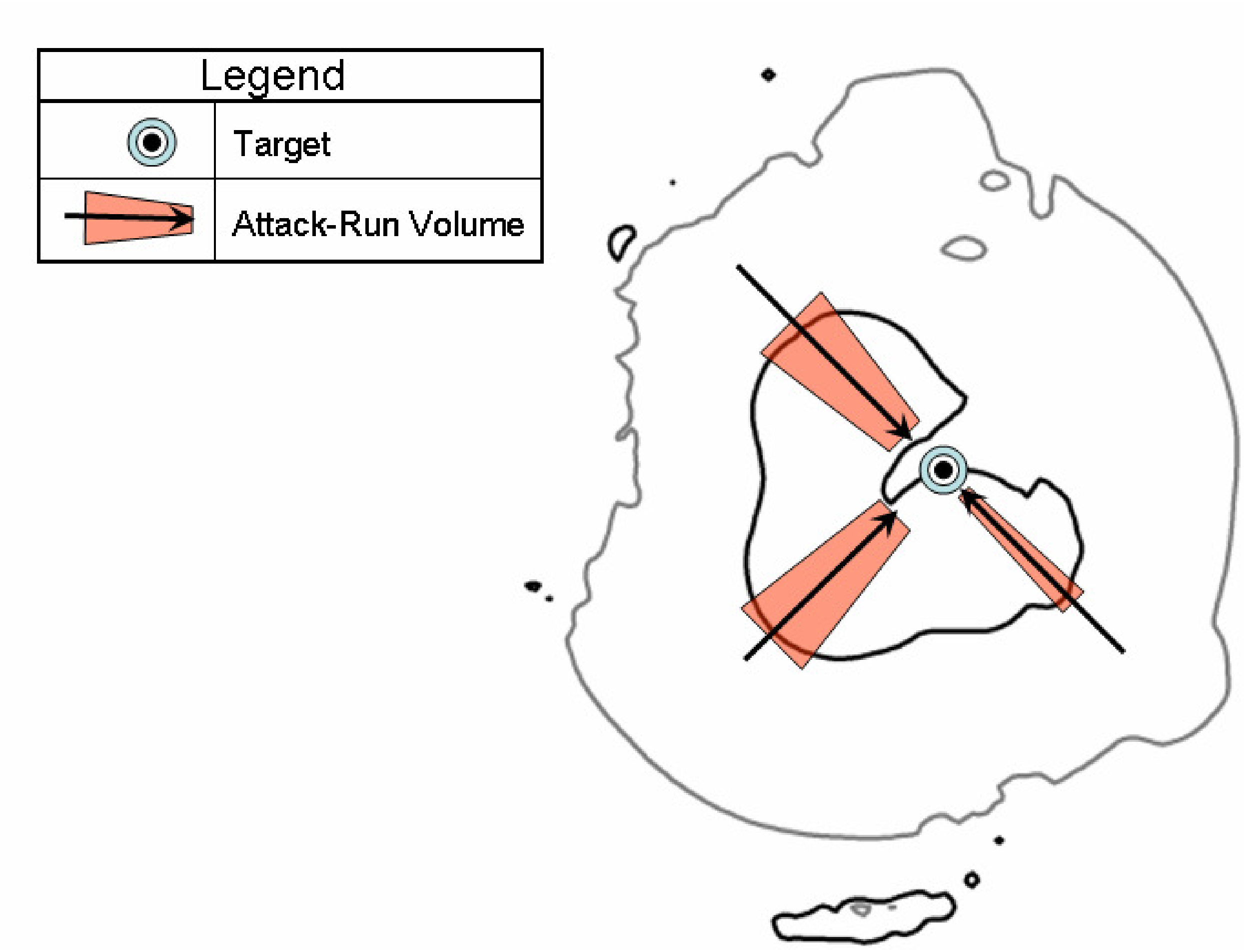

Figure 4: Sample noise contours for a single target with three different attack runs.

The results from each of the three attack runs are visible in this plot as distinct lobes in the noise contour. There are added complexities to the contour due to the effects of terrain and over-water propagation. While this is representative of only a single target in an air-weaponry range, combining multiple targets will produce the expected noise footprint for the entire range.

CONCLUSION

A novel approach has been presented for calculating the noise footprint from air-weaponry operations. The approach utilizes a statistical volume of space for determining the distribution of firing points. The noise from this statistical volume is then computed and scaled for the actual number of bullets fires. By combining the results of several of these statistical volumes it is possible to compute the noise contour for an entire range.

An approach of storing the individual noise footprints from each statistical volume allows the program to rapidly calculate the overall noise contour without having to do the costly noise calculations repeatedly. The result is a noise model that retains the detail and accuracy of a simulation model without having to spend the time for each noise calculation to be completed.

ACKNOWLEDGEMENTS

This research was supported wholly by the U.S. Department of Defense, through the Strategic Environmental Research and Development Program (SERDP).]

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