USER MANUAL

Advanced Acoustic Model Technical Reference and User Manual

SERDP Project WP-1304

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1.0 Introduction

1.1 Background and Scope

The Advanced Acoustic Model (AAM) is a suite of computer programs that predicts far-field noise for single or multiple flight vehicle operations of fixed wing or rotary wing aircraft. It is a time simulation model, evolved from Noisemap Simulation Model (NMSim)[1,2,3] and the Rotorcraft Noise Model (RNM),[4,5] that computes time varying noise levels for each step in a user-defined flight trajectory. It was developed under Strategic Environmental Research and Development Program project WP-1304, in response to a need to address nonlinear sound propagation and complex directivity patterns from modern high thrust combat aircraft. It fits within the current NOISEMAP[6] system of aircraft noise modeling, and will eventually replace NOISEMAP as updated noise sources are developed. AAM includes all of the capabilities of RNM.

AAM is based on three dimensional noise sources defined about a vehicle moving along a trajectory. Three dimensional source modeling includes the effect of thrust vectoring, implicit for rotorcraft and present on certain fixed wing aircraft. Propagation from the vehicle to receivers accounts for geometric spreading, air absorption and finite ground impedance. For high thrust military aircraft, nonlinear propagation effects associated with high noise levels are computed. It can optionally account for varying ground terrain or atmospheric gradient effects. Sources are generally defined as one-third octave band spectra. A Narrowband and pure tone modes are available, should there be a particular need. The Doppler shift associated with vehicle motion is included in the analysis, as is the propagation time from the source to the receiver. Nonlinear propagation effects are addressed using the theory developed by Gee[7,8] et al. Nonlinear propagation can affect spectra, noise metrics and the perceived quality of high amplitude jet noise.[9]

When invoked, the effects of sound propagation over varying ground terrain employs the geometrical theory of diffraction algorithms developed by Rasmussen.[10] The effects of propagation through wind and temperature gradients over uniform terrain uses theory developed by Plotkin and Huber.[11,12]

AAM calculates the noise levels in the time domain and with a variety of integrated metrics at receiver positions on or above the ground at specific points of interest and over a uniform grid. Vehicle operations are defined as either single flight tracks (Figure 1-1) or as multiple flight tracks with varying vehicle types and flight profiles. Acoustic properties of the noise source(s) are defined as sound spheres (Figure 1-2) and may be obtained from flight test or wind tunnel measurements, or theoretical predictions. The vehicle source characteristics may be described in any combination of broadband (in the form of one-third octave band levels) narrow band (user defined bandwidth and spacing with arbitrary bands permitted) or as pure-tone data (in the form of specific frequency sound pressure levels and phase). Vehicle source characteristics are prescribed as a function of vehicle operating state along a defined flight trajectory. This acoustic source characteristic database lookup procedure allows the code to be utilized for numerous flight vehicles such as conventional fixed wing aircraft, thrust-vectored fixed wing aircraft, rotorcraft, and tilt-rotor vehicles. It can also be used for ground-based vehicles.

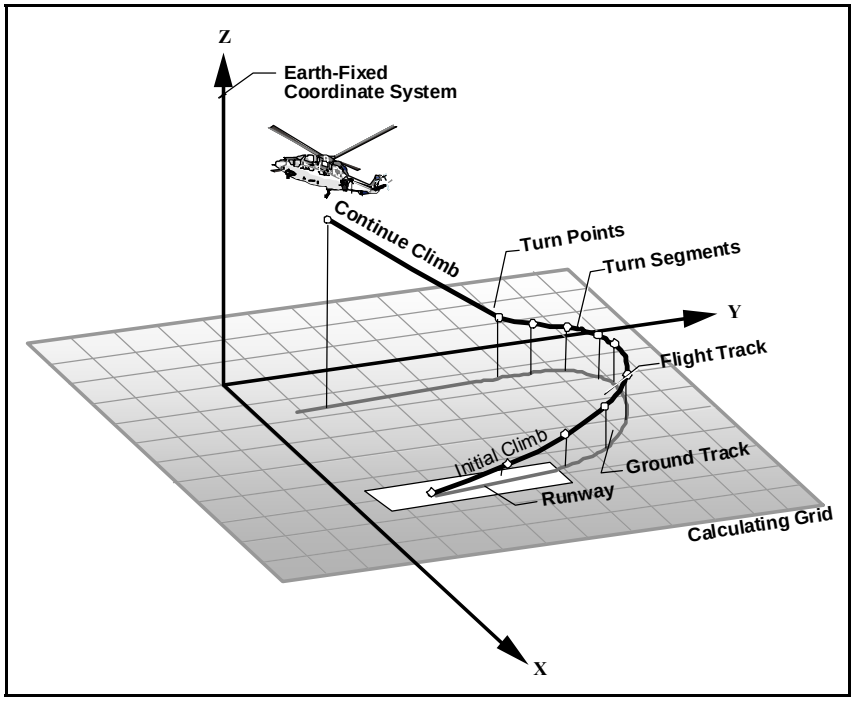

Figure 1-1. Example: Single Flight Track

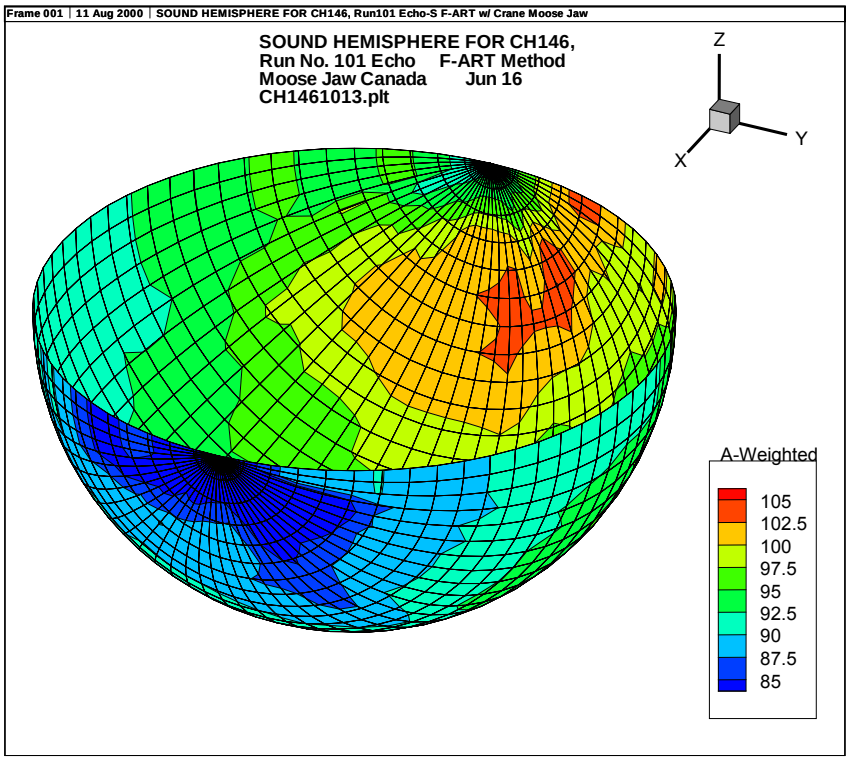

Figure 1-2. Sample Sound Sphere

AAM is capable of presenting the time history of a noise event at a single observer position, the noise footprint on the ground at a given time, or the noise contours for many different noise metrics, including accounting for the acoustic impacts of extreme natural terrain, such as that found in the Grand Canyon.[13] At present echo effects are not incorporated into AAM. AAM is also capable of outputting the results in a file format that can be imported into a Geographical Information System (GIS). The noise contours that are generated can be overlaid to scale on a background map—a utility ideal for performing noise abatement studies—evaluating noise impacts at airports and vertiports, and performing land-use noise studies. Multiple sources may be modeled, allowing for rotorcraft and tilt rotor operations. Multiple vehicles, such as those in formation flight may also be modeled.

For environmental planning applications, AAM operates within the same user environment as NOISEMAP.[6] Data is entered via BaseOps,[14] and grid output data are output in NMBGF[15] format for display by NMPlot.[16] AAM may also be used to generate acoustic animations of operational procedures. Demonstrating the effects of atmospheric propagation in the surrounding area by means of a sound visualization video is a powerful tool for providing an inherent understanding of the vehicle source characteristics and the effect of weather and intervening terrain.

The basic computational module is capable of calculating single event and cumulative noise exposures such as maximum A-weighted sound level (L_{max}), Sound Exposure Level (overall, C-, A-weighted) (SEL), Perceived Noise Level (PNL), Tone-Corrected Perceived Noise Level (PNLT), Effective Perceived Noise Level (EPNL), Day-Night Average Sound Level (DNL), Community Noise Equivalent Level (CNEL), Noise Exposure Forecast (NEF), and Weighted Equivalent Continuous Perceived Noise Level (WECPNL).

Many of the propagation algorithms in AAM and RNM have been based on the same analytical techniques that are contained in the NASA Aircraft Noise Prediction Program (ANOPP).[17,18,19,20] Since the early 1980's, ANOPP has served as the primary noise model that NASA uses in its aero-acoustic research. The algorithms in ANOPP, and in turn RNM, have been validated through many years of testing. Additionally, the RNM model has been applied and compared with 1994 NATO experimental measurements of an F-16 simulated runway departure and flight over mountainous terrain in Narvik, Norway.[21] NMSim was developed and validated from those flight tests. RNM sound spheres for that propagation test were created based on the same 1991 USAF reference noise measurement data used in NMSim. Time history predictions using RNM at various measurement locations agree well with measured data,[1,22] as did predictions via NMSim.[21,23] Rasmussen's geometric diffraction algorithms, as implemented in NMSim, have also been tested extensively during measurements made at Grand Canyon National Park.[13] The calculation and aircraft type capabilities of AAM are a superset of those in RNM and NMSim.

Noise source spheres may be prepared from flight test data using a combination of AAM/RNM and the "Acoustic Repropagation Technique" program ART. The physics and geometry are calculated by AAM directly, by first computing propagation effects (spherical spreading, air absorption, and ground effect). ART then subtracts these from measured noise levels yielding the source characteristics. This procedure, which is called "depropagation," provides a source level at the test flight conditions and the angles θ (fore-aft direction) and ϕ (roll direction) corresponding to the geometry of the flight, arrival and propagation times and microphone location. By performing depropagation for a variety of times and microphones, levels on a spherical set of (θ, ϕ) are obtained.

The sphere construction procedure was originally developed using a depropagation procedure developed from an early version of the NMSIM single event noise model.[24,25] In order to allow the user the capability of the advanced propagation techniques in AAM/RNM (namely varying ground effects and weather, as well as narrow band analysis), all the propagation physics are output for use by the source assembly module ART. The role of ART is the creation of an AAM/RNM-format (NetCDF) noise sphere, while the primary role of AAM/RNM is the atmospheric propagation of sound. Additional enhancements to this procedure allow the averaging of multiply defined propagation results within a specified grid area. This feature also allows the user to utilize measurements from arbitrarily positioned microphones.

A key feature of the noise sphere system is that each aircraft has its own set of spheres, independent of other aircraft. The source database is prepared by copying the sphere files into the appropriate directory, as described in Chapter 5. This is in contrast to models such as INM and NOISEMAP, where all aircraft are contained in a monolithic database that is generally not accessible to users. This flexibility allows users to create their own sources as needed, and also permits partial distribution of sources that may have ownership restrictions.

Military fixed wing aircraft that have been modeled via the ART process include the F-35A, F-15C, F-16PW220, F-16GE, F-18A+, and AV8B. A number of civil aircraft have also been modeled, with spheres created from data in the INM database or from specialized measurements such as air tours over national parks.13 Rotorcraft that have been modeled include CH-146, MV-22, AH-1W, SH-60B, CH-53E, TH-57, CH-46, MD-900, XV-15 and more. There are current plans to generate spheres from existing NOISEFILE data, or from measurements at the US Air Force's Aeroacoustics Research Complex.

Currently, distribution of noise sources is separate from distribution of the software, and source data for the CH-146 and Bo-105 are included with the initial distribution. It is expected that DoD will provide a suitable source data package with the public release of AAM.

1.2 Organization of Report

This report is organized into the following chapters:

2.0 Advance Acoustic Model Technical Reference – documentation of the physical processes and equations incorporated in the model.

3.0 Advance Acoustic Model User's Guide – a detailed description of the operation, inputs and outputs of the noise calculation model.

4.0 Utility Programs – a detailed description of the operation, inputs and outputs of supporting program modules.

5.0 User Manual and Tutorials – the user's manual demonstrates, by tutorials and examples, how to use AAM.

2.0 Advanced Acoustic Model Technical Reference

AAM is a simulation program that predicts how sound will propagate through the atmosphere and accumulate at receiver locations for single- and multiple-vehicle flight operations. At the core of AAM are the vehicle sources defined as sound spheres. As the vehicle "flies" along its prescribed flight trajectory the source sound propagation is simulated and accumulated €fgat the receiver locations (single points of interest or multiple grid points) in a methodical manner. These sound signals at the receiver locations may then be analyzed to obtain single event footprints, integrated noise contours, time histories, or numerous other results. AAM may also be used to generate raw one-third octave band time history data over a uniform grid for the creation of single event sound animation videos.

AAM systematically propagates and accumulates sound emitted from vehicles performing a user-specified series of flight operations. Figure 2-1 shows the file and data flow structure of AAM. The input text file contains computational parameters, a description of the calculating grid or points of interest, and a definition of the flight trajectory including the aircraft operating conditions. The input files are keyword structured with specific formatting requirements for each keyword. The single operation format is designed for studying in detail propagation effects, low noise takeoff and landing profiles and evaluating multiple sound source propagation from a single vehicle. The multiple operation format is structured to model annual flight operations at an airport or vertiport. This format is consistent with the way operational data is logged and collected by personnel at such facilities and the way environmental impact statements are currently performed by the acoustics community. The details of the file input structure are provided in Chapter 3.

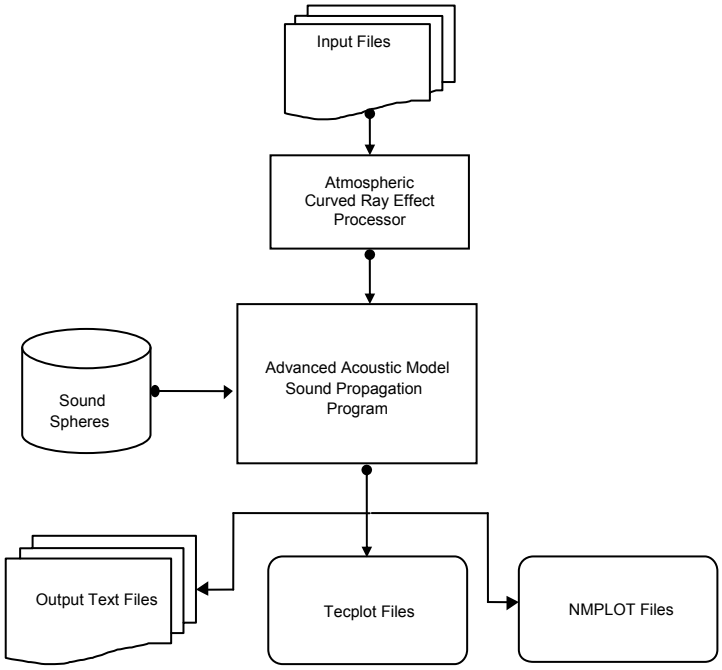

Figure 2-1. Advanced Acoustic Model File and Data Flow Overview

Figure 2-2 shows the organization of the major modules that form the AAM sound propagation program. These represent specific AAM functions: processing the input data, scanning and sorting the vehicle noise data, the core atmosphere propagation, and output reporting. Pre- and post- processing modules, such as weather, nonlinear propagation, audibility detection and animation are not included in this flowchart.

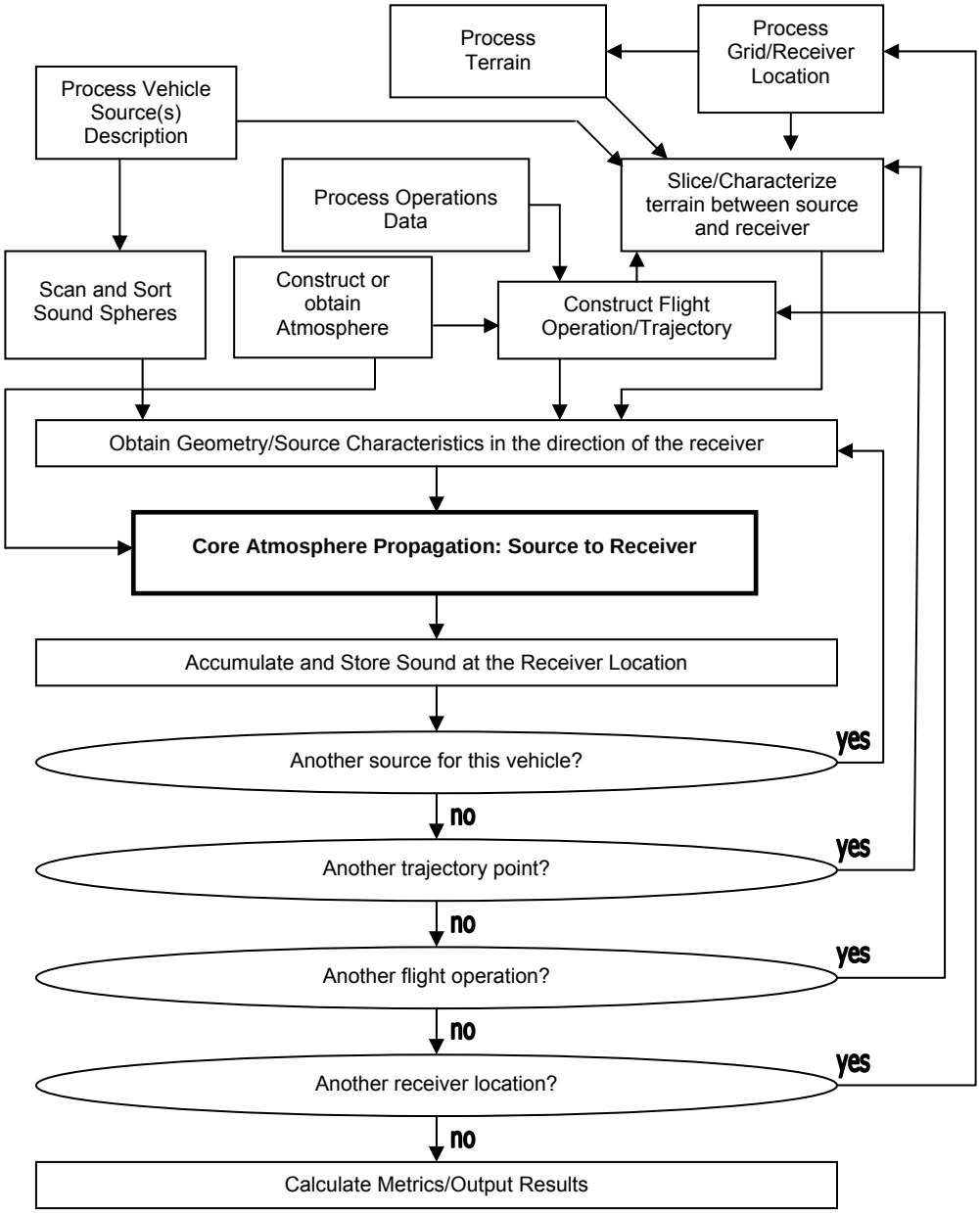

Figure 2-2. AAM Sound Propagation Model

After reading the input file and checking it for errors, AAM reads the acoustic source data, from which it constructs a data condition matrix. The noise generated by a flight vehicle is described in terms of a set of broadband and narrow band and/or pure tone with phase sound pressure spheres, which may be obtained from either measured test data or computational models. Source definition in terms of sound spheres is required due to the complex three-dimensional directivity patterns associated with various operating conditions. A sound sphere is stored as a single computer file that contains either broadband or pure-tone noise data for a single flight condition. The data is stored in a packed binary file format using Network Common Data Form (NetCDF).[26] Details of the NetCDF file format are presented in Section 4.1.5 of this manual.

The core algorithms are contained in the propagation module, which is nested inside several loops that increment the vehicle source, the types of aircraft, and the receiver locations. Receiver locations are described either as the location of specific points under the flight track or as a uniform grid of points either on a flat ground or at a specified height above the local terrain. The flight track module is capable of handling point to point integrated 3D flight paths, or vectored flight tracks and separate profiles. In single track mode either form of track definition may be utilized. For multiple operation analyses the vectored flight track and separate flight profile input form must be used. The input data are integrated and interpolated (when required) to a default of 2.0 seconds flight trajectory spacing. The user may also specify alternate time spacing increments for single track analyses. The flight track module outputs are vehicle location (x,y,z) and orientation (roll, angle of attack, yaw, and operating state (thrust, thrust vector angle), as well as vehicle trajectory (heading, flight path angle, velocity, turn rate) in the earth- fixed coordinate system. This is passed directly to the propagation module, which constructs the sound spectra at each receiver position as a function of time. The sound is summed at the receiver locations and binned according to arrival time. The broadband, narrowband, and pure-tone sound (with phase) are tracked independently and combined as required accounting for phase and coherence in order to calculate the requested output metrics.

The user has a myriad of output formats and detailed acoustic calculations to choose from. The program will output a text file that echoes the input operation data, as well as the computed noise results. In addition, the program will output ASCII and binary grid files that are used by Tecplot[27] and NMPlot[16] to graphically display the noise results. Tecplot is a commercial product that is available from Amtec Engineering, Inc. (http://www.amtec.com). NMPlot is the Air Force's standard noise contouring plotting program. A free copy of NMPlot can be obtained from the Wasmer Consulting Web page (http://www.wasmerconsulting.com).

2.1 Input Module

AAM reads the input files, which define the analysis grid, flight operations and analysis options, and performs rudimentary error checking. Inputs are structured using a keyword format for maximum flexibility and modularity. If an error is detected, AAM will display a message with the line number in the input file which generated the error and echo the appropriate portion of the input file. An expanded error message listing is included in Section 3.6. The input module calls various routines, which interpolate and integrate flight tracks and profiles into a series of trajectory, orientation, and vehicle state points. Defined at each point are the X, Y and Z values for the flight track in the earth-fixed coordinate system, the vehicle speed, yaw angle, the angle of attack, roll angle, and engine operating state parameters, such as thrust and thrust vector angle.

AAM then reads the NetCDF sound spheres. AAM reads from each file header block the sphere type (broadband, narrow band, or pure tone), the flight path angle (for rotorcraft), the pylon (for rotorcraft) or thrust vector angle (for fixed wing aircraft), the airspeed (the rotorcaft), the thrust setting (for fixed wing aircraft), the radius, Doppler state, and origin. This information is tabulated and sorted. Additional discussion of the sphere selection process is given in Section 2.5.1.

2.2 Propagation Model Overview

In general, sound levels at a distance r from the source can be expressed as the sum of the source sound level, the spherical spreading loss, the atmospheric absorption, ground reflection and attenuation (with terrain if applicable), and the effects due to wind. This may be written mathematically as:

$$L(r) = L(r_0) + A_{spread} + A_{atm} + A_{grd} + A_{topo} + A_{wind} + A_{nlin}$$

where:

$L(r_0)$ = Free field loss-less sound level at a distance r_0 from the source directed from the source to the receiver.

A_{spread} = Geometrical spherical spreading loss (point source).

A_{atm} = ANSI/ISO atmospheric absorption standard.[28]

A_{grd} = Ground reflection and attenuation losses, caused by the ground and the resultant interaction between direct and reflected acoustic rays. The ground surface is characterized by a complex acoustic impedance. The calculations are based on the work by Chien and Soroka[29] and then by Chessel[30] with the corrections noted by Daigle.[31] The algorithm uses the Doppler shifted frequencies that are based on the speed of the vehicle and its direction relative to the receiver. Within the model, the topography propagation module combines both the ground reflection and attenuation, $A_{grd,}$ and topographic attenuation, $A_{topo,}$ as a single term.

A_{topo} = Topographic attenuation, caused by the reflections and absorption that occurs from barriers formed by the terrain located between the source and the receiver as developed by Rasmussen.[10] In the limit as the terrain approaches a flat plate divided by a thin screen, Rasmussen's algorithms asymptote to Maekawa's[32] thin screen theory. Within AAM, the topography propagation module combines the ground reflection and attenuation, A_{grd}, and topographic attenuation, $A_{topo,}$ into a single term. Echo effects, as would be found in deep caverns or from surfaces behind the receiver relative to the source, are not currently treated by AAM.

A_{wind} = Wind attenuation or amplification, caused by the wind profile that exists between the source and the receiver. This module is common to both RNM and AAM. A technical description of the weather module pre-processor RNMwea is given in Section 2.2.3.

A_{nlin} = Nonlinear propagation correction. A technical description of the nonlinear propagation can be found in Section 2.2.4.

The propagation algorithms are embodied within the core computational model loop, which advances point by point through the flight trajectory (Figure 2-2). For each vehicle position the individual noise sources are propagated independently. The simulation is based on the flight track time definition. Sound is "binned" at the receiver locations based on the arrival time. Only after the propagation has been completed are the receiver sounds interpolated onto a uniform time mesh and added.

There are two levels of fidelity for modeling the effects due to weather and atmospheric variations. The first is via the atmospheric module. This allows the user to specify a horizontally stratified atmosphere in the input deck. The propagation assumes straight rays; however, atmospheric absorption is calculated based on the user defined atmospheric profile. The second manner of computing weather effects is via the use of the weather module (RNMwea) pre-processor. This module calculates the effect of a horizontally stratified atmosphere with winds by utilizing a curved ray tracing methodology. The technical details are described in Section 2.2.3 and operation of the RNMwea module is described in Section 4.15.

2.2.1 Ground Model

As noted earlier, the interaction of direct and reflected waves due to flat ground are modeled based on a study made by Chien and Soroka[29] and then later by Chessell[30] with corrections noted by Daigle.[31] The acoustical properties of the ground (expressed as a flow resistivity) in combination with the geometric orientation determine the combined signal (direct and reflected rays) amplitude and phase at the receiver. Typical flow resistivity values are given in Table 2-1 and are applicable to both the flat earth and terrain propagation algorithms. When exercising the flat terrain algorithms, broadband and narrow band signals are summed incoherently over one-third octave bands while pure-tone signals are added considering the single frequency phase shift due to the reflection. The user may also apply turbulent decoherence effects as described by Chessell[30] by specifying a non-zero turbulence parameter. A typical value for the turbulence parameter is $2 \bullet 10^{-4}\ \mathrm{rad \cdot sec \cdot \sqrt{ft}}$. To disable turbulent decoherence, use a value of $0\ \mathrm{rad \cdot sec \cdot \sqrt{ft}}$.

Table 2-1. Typical Flow Resistivity (Per Unit Thickness) Parameters

Material	Flow Resistivity, CGS Rayls
Concrete	$1 \bullet 10^6$
Asphalt	$5 \bullet 10^4$
Gravel	20
Sand	100–2000
Soil	200–1000
Soil and Grass	200–2000

The computational methodology for ground reflection and attenuation over areas where topographic features are significant is twofold. First, the effect of terrain and receiver altitude relative to vehicle location (slant range) are computed. Second, the effects of terrain and ground cover on ground reflection and attenuation due to the multiple ray paths are computed with Rasmussen's algorithms. These algorithms account for shielding (modeled as wedges) and structures (modeled as thin screens), multiple reflections in valleys and the effects of ground impedance.[10]

Rasmussen's theoretical model for the calculation of sound propagation over varying terrain is based on the Geometrical Theory of Diffraction (GTD). AAM contains the extensions of the GTD to finite impedance terrain, by means of physical formulae. The effects of wind and temperature gradients are not included in the current topography model. The sound field at a receiver point can be described as the sum of direct, reflected and diffracted waves. The GTD was originally introduced by Keller.[33] Rasmussen, by hypothesis, developed a technique for predicting diffracted waves, as determined by local geometry between the source and receiver. A series of approximate solutions based upon the assumption that the distances are long with respect to the wavelength are categorized and implemented for several geometric configurations.

The model performs a geometric "slice" through the three-dimensional terrain from the source to the receiver location, and using a numerical fitting technique classifies the principal features into one of the following geometric models:

1. Two points: flat terrain.
2. Three points, concave: uphill or valley.
3. Three points, convex: down hill.
4. Four points: wedge or screen with one flat.
5. Five points: wedge or screen with two flats.

Figure 2-3 contains the classifications for the various terrain models. Only the terrain either in the line of sight or the broken line of sight is considered. The shielding algorithms transition continuously from a Pierce wedge[34] to a Maekawa[32] screen. The effect of terrain on the sound propagation is then applied to each one-third octave band in turn for each source and receiver point along the flight trajectory. When terrain is flat, Rasmussen's algorithms[10] reduce to the flat earth ground attenuation model described earlier in this section.

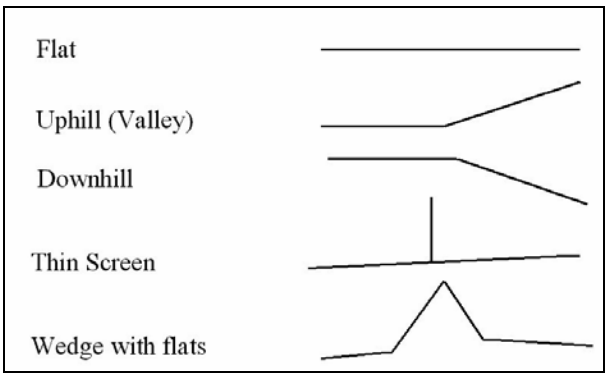

Figure 2-3. Geometric Terrain Models

This topographic model has been applied and compared with 1994 NATO flight test measurements of an F-16 simulated runway departure and flight over mountainous terrain in Narvik, Norway.[21, 22] Sound spheres were created based on 1991 USAF noise measurement data. Time history predictions at various measurement locations agree well with the 1994 NATO experimental data. Results of the application of this implementation of the topographical model and comparison with the Narvik measurement data were presented at the American Helicopter Society Technical Specialists meeting in January, 2002.[22]

2.2.2 Atmospheric Absorption Module

The atmospheric absorption model for straight ray computational modes are calculated using a horizontally stratified temperature and pressure profile (no winds). For a description of the absorption effects included in the curved ray module, please see Section 2.2.3 and Reference 12. The atmospheric profile (pressure, temperature, humidity) may be user input for single- or multiple event analysis. The default atmosphere is the U.S. Standard Atmosphere, 1976[35] (Table 2-2). The sound speed is calculated directly from the temperature profile using ideal gas law. The air absorption coefficients are determined using methods described in American National Standards Institute (ANSI) S1.26 (R2004)[28] based on the input humidity profile. Weighted averages of sound speed and air absorption coefficient are calculated at each altitude. The sound speed and the air absorption coefficients are tabulated at 1,000-foot intervals and accessed without interpolation by the propagation module.

Table 2-2. U.S. Standard Atmosphere,1976[35]

Altitude (ft)	Pressure (lb/ft^2)	Temperature (degree ^oR)	Sound Speed (ft/sec)
0	2,118	518.7	1,118.1
1000	2,045	515.1	1,114.3
2000	1,972	511.5	1,110.4
3000	1,899	508.0	1,106.6
4000	1,831	504.4	1,102.7
5000	1,765	500.8	1,098.8
6000	1,699	497.3	1,094.8
7000	1,635	493.7	1,090.9
8000	1,576	490.2	1,087.0
9000	1,516	486.6	1,083.0
10000	1,457	483.0	1,079.0
11000	1,403	479.5	1,075.1
12000	1,349	475.9	1,071.1
13000	1,295	472.4	1,067.0
14000	1,246	468.8	1,063.0
15000	1,198	465.2	1,059.0
16000	1,149	461.7	1,054.9
17000	1,104	458.1	1,050.8
18000	1,060	454.5	1,046.7
19000	1,017	451.0	1,042.6
20000	975	447.4	1,038.5
21000	936	443.9	1,034.4
22000	897	440.3	1,030.2
23000	858	436.7	1,026.0
24000	823	433.2	1,021.8
25000	788	429.6	1,017.6
26000	754	426.1	1,013.4
27000	722	422.5	1,009.2
28000	691	418.9	1,004.9
29000	660	415.4	1,000.6
30000	631	411.8	996.4

The atmospheric module is exercised once and a data table containing the sound speed and air absorption coefficients is built for subsequent module access. The weighted average sound speeds and air absorption coefficients are tabulated at 1,000-foot intervals. Input to the modules is the atmospheric pressure, temperature profiles, and the relative humidity. The user has the option of entering a specific profile or using by default the U.S. Standard Atmosphere[35] and 70% relative humidity. Table 2-2 contains the 1976 U.S. Standard Atmosphere pressure and temperature profiles at 1000 foot intervals. The fourth column, the speed of sound, is calculated using the ideal gas law.

Air absorption becomes large at higher frequencies and for propagation over long distances. Often air absorption is a dominating factor in A-weighted sound attenuation from flight vehicles. However, for small elevation angles between the source and receiver, attenuation is largely influenced by ground effects and reflection losses. Air absorption loss is based on a empirical and theoretical evaluation of experimental data obtained through laboratory and field studies.[28] This methodology has been validated over a wide range of meteorological conditions, accurate (within ± 10 percent) for frequencies ranging between 50 and 10,000 Hz, temperatures between 0° and 40° C, and relative humidities between 10% and 100%.

2.2.3 Weather and Curved Ray Module

RNM Version 4.0 introduced the curved ray atmospheric propagation capability, which is also shared by AAM.[36] This module is structured as a pre-processor. For an omnidirectional point source over flat, uniform terrain, a ray tracing simulation is performed for a range of source heights (chosen to reflect the source profile). The spectral attenuation over a regular ground mesh is stored in a binary weather file (filename.RAZ). The ground effect, spherical spreading and atmospheric absorption (as calculated *a priori* in the RNMwea pre-processor) is effected by performing a table lookup based on the geometry of the source and receiver. At present, the ability to consider curved rays has only been implemented in the single event analysis mode over uniform flat terrain. Instructions on running RNMwea are found in Chapter 4.

The propagation weather module was developed by Wyle Laboratories as part of a project to determine the effects of atmospheric gradients on airport noise contours.[12] This module was adapted slightly in order to use the same absorption algorithms as AAM and RNM, and calculate weather effects down to 10 Hz. Additionally, the flow resistivity parameter is now a user-defined variable.

Sound propagation from an elevated source to the ground, in the presence of a wind gradient, is sketched in Figure 2-4. Key elements are:

- Sound is refracted downward in the downwind direction, and upward upwind.
- A receiver above the ground receives both direct and ground-reflected sound.
- Downwind, there can be multiple reflected paths.
- Upwind, shadow zones can form.
- Shadow zones can be partially filled in by diffraction.

Ray paths in the presence of gradients can be computed by integration of the eiconal. This is a common procedure in sonic boom propagation codes, such as References 37 and 38 and was applied in References 11 and 12. Algorithms from the PCBoom sonic boom program[38] were employed. The specific routines are for a horizontally stratified media, generally a good assumption for large scale propagation in the atmosphere.

Reflection from the ground is a key part of propagation outdoors: this directly accounts for excess attenuation due to ground impedance. The customary formulation of ground impedance is sketched in Figure 2-5. The direct and reflected rays are summed as:

$$\phi = \frac{\exp(ikr_1)}{r_1} + \frac{\exp(ikr_2)}{r_2}\left[(1 - R_p)F + R_p\right] \qquad (1)$$

where:

ϕ = wave field at receiver

k = wave number

r_1, r_2 = propagation distances of direct and reflected rays

R_p = plane wave reflection coefficient

F = function describing interaction of curved wave with flat impedance surface

Because of the spherical geometry embodied in function F, the net result is considerably more complex than might be thought from simple plane wave reflection. Embleton[39] provides an excellent description of the phenomena involved.

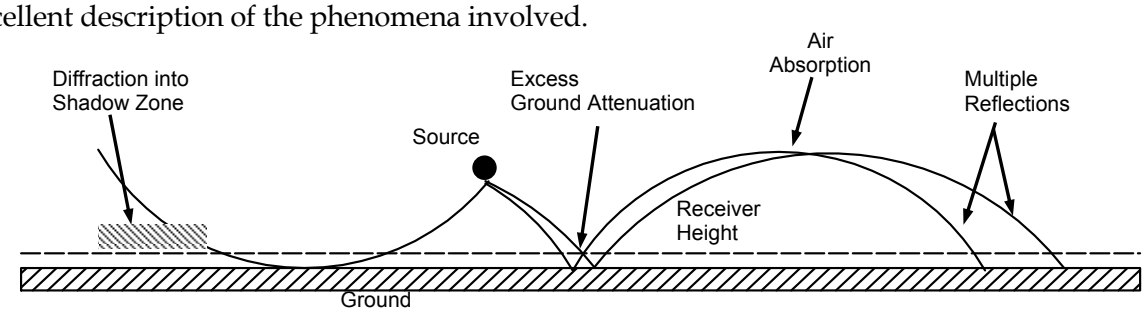

Figure 2-4. Air-To-Ground Sound Propagation Through Atmospheric Gradients

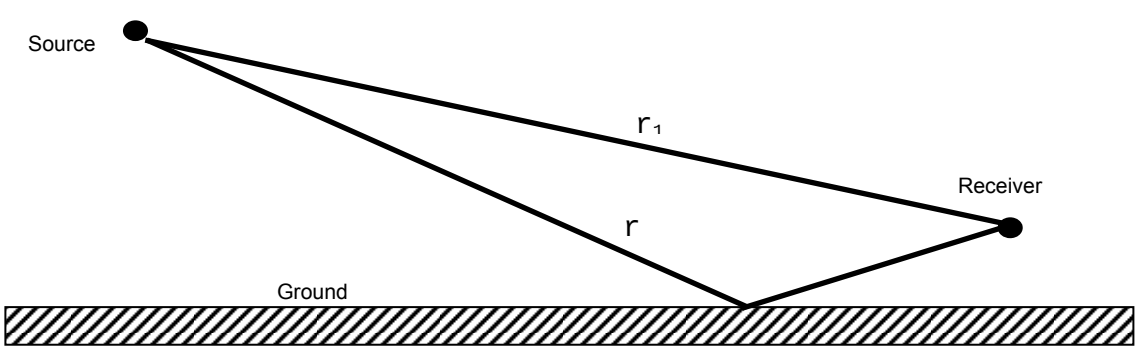

Figure 2-5. Ground Attenuation Geometry: Direct and Reflected Rays

Equation (1) is written for straight rays in a uniform medium. The key parameters can, however, be represented by the incidence angle of the ray striking the ground and the phase difference between the direct and reflected rays. If there are wind and/or temperature gradients, as in Figure 2-4, Equation (1) can be written in terms of those two quantities. This method was successfully employed in a number of studies, including References 40 and 41.

A practical issue when applying Equation (1) to curved rays is that it is not straightforward to identify the particular rays that will arrive at a given receiver. It is customary to use a shooting iteration method. For the current weather module, where the intent is to compute regular grids, an iterative scheme would have posed significant computation time issues. Accordingly, the following method is used:

- Rays are launched from a source at some height above the ground. This is done for a set of initial heading and vertical angles such that the ray ground impact points have a density comparable to the desired regular grid density.
- For each ray, the coordinates where it passes through a plane at the receiver height, the coordinates of the reflection point, and the coordinates where the reflected ray passed though the receiver height plane are stored. The incidence angle at the ground, and the propagation time to each of the three coordinate points, are also stored.
- The stored coordinates, arrival times and reflection angles are treated as sets of random control points. A Laplacian interpolation gridding routine from the PLOT88 software package[42] is used to interpolate each of these onto a regular grid. These quantities are then used in a phase/incidence version of Equation (1) to obtain the ground effect at each grid point.

The specific version of Equation (1) used was that of Chessel,[30] which includes adjustments for one-third octave bands and turbulent de-coherence of direct and reflected rays. Ground impedance used the porous material model of Delaney and Bazeley,[43] where impedance of a locally reacting surface is based on flow resistivity. Multiple downwind reflections were accounted for by tracing rays to a third intersection with the receiver elevation plane. If this third intersection exists, enhancement is computed by Embleton's method,[44] which is applicable to soft ground. Multiple downwind paths are not yet addressed.

Diffraction of sound into a shadow zone is calculated by the method of Berry and Daigle.[45] Absorption of sound by molecular relaxation processes in the atmosphere is computed according to the current ANSI/ISO standard.[28]

Examples of the weather effects are described here. Consider a situation with winds approximately blowing from NW to SE. Figure 2-6 illustrates the effect at 1000 Hz on a 32,000 by 32,000 ft ground mesh for a source height of 32.8 ft above uniform soft (flores=200) terrain. This example is included in the distribution case RNOavg.wea. All bands specified in the input are calculated. Only the single frequency is shown here. By comparison, a test case with a uniform atmosphere and no winds and the same ground temperature is given in Figure 2-7. This test case is included with the software as Nowea.wea.

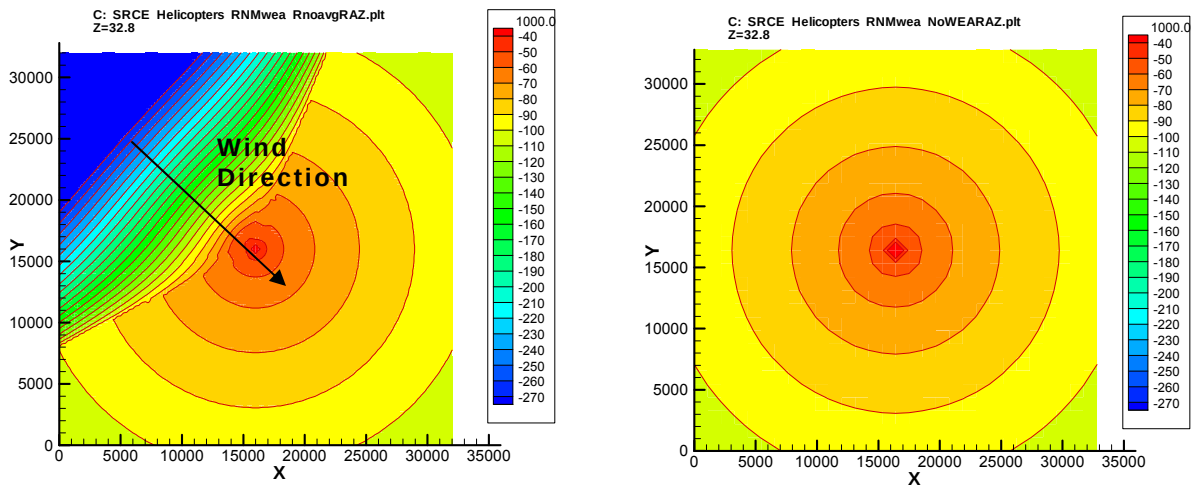

Figure 2-6. Weather Propagation with and without Winds

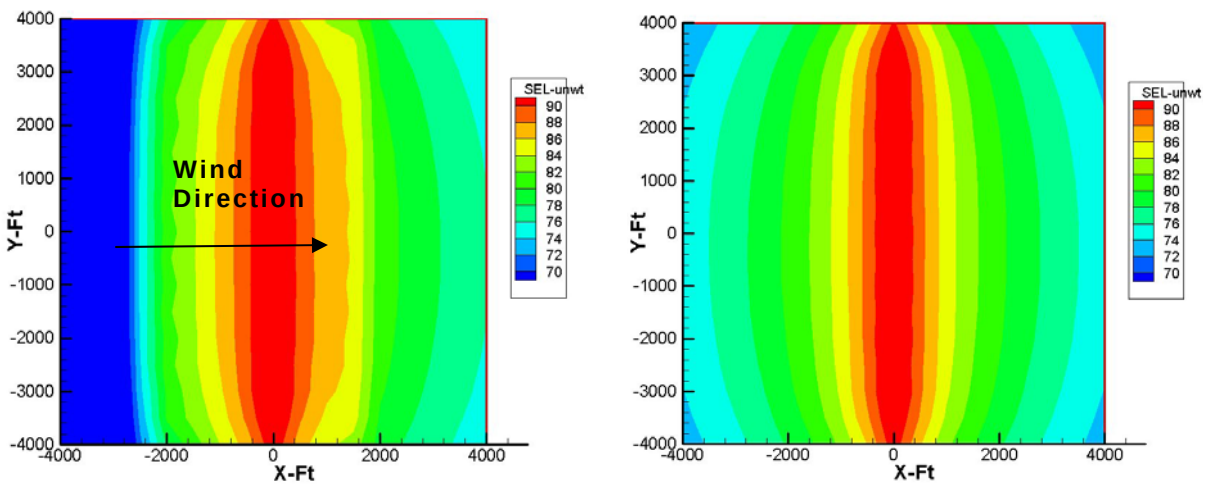

Figure 2-7. Weather Effect on Noise with and without Winds

An illustration of the effects of a wind blowing out of the west, towards the east may be seen in Figure 2-7. Figure 2-7 is a calculation of the SEL ground contour from an omnidirectional source who traveled from south to north in a quiescent atmosphere, compared with that same source traveling the same path through an atmosphere with winds blowing to the East. One can clearly see the effect on the propagation caused by the winds.

2.2.4 Nonlinear Propagation

High amplitude sound, such as that emitted by modern high thrust jet engines, tends to propagate in a nonlinear manner, where the speed of propagation varies with amplitude. Figure 2-8 shows this effect. Figure 2-8, part a shows linear propagation, where every part of the wave propagates at the same ambient sound speed, and the shape remains the same. Figure 2-8, part b shows nonlinear propagation, where each part of the wave propagates faster or slower than the ambient sound speed, proportional to its amplitude. The wave shape distorts in two

ways. One is that positive slope regions steepen, forming shock waves. The other is that negative slope regions stretch. In the frequency domain, this results in energy shifting from mid frequencies to low and high frequencies. Figure 2-9 shows a spectral result of nonlinear propagation.[8] A near field measurement of noise from a stationary source was projected to a larger distance using linear acoustics (bottom line) and nonlinear acoustics (top line). The actual measured spectrum is also plotted, and is very close to the nonlinear projection. In this example, the shift to high frequencies is very apparent, and jet noise tends to cause a noticeable difference in the quality of the sound.[9]

In AAM, nonlinear propagation is computed using the method developed by Gee.[7] A sample of measured near-field noise data is propagated by time-step numeric solution of the Burgers[46] equation. The algorithm is one that has successfully been applied to sonic boom shock structures.[47] A parallel linear calculation is also performed. The difference between linear and nonlinear results is cast in the form of nonlinear gain coefficients. A set of coefficients, A_{nlin}, is prepared for each power setting and incorporated into the corresponding noise sphere. In principle, these should be prepared separately for each direction, as has been done for static runups.[48] In practice, for a flyover the only near field position is at $\theta = 90°$, when the aircraft is at its point of closest approach. For measurements with ground microphones, this also corresponds to $\phi = 0°$. While nonlinear gain coefficients are not, in general, universal, for a given aircraft they are similar across θ and ϕ.

Preparation of the nonlinear gain coefficients is part of the ART process, and the coefficients are included in the noise sphere file. They are applied within AAM via the general propagation equation presented in Section 2.2.

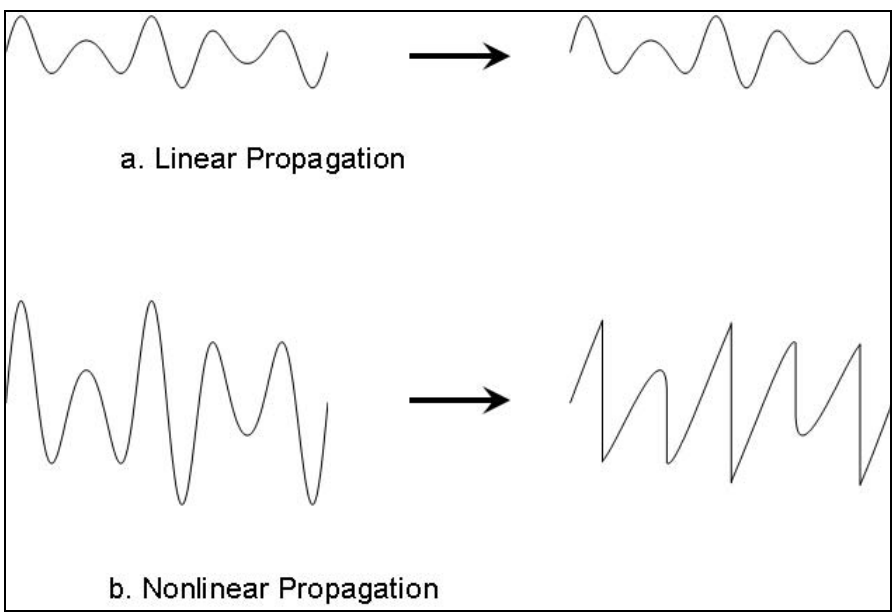

Figure 2-8. Acoustic Wave Shapes for Linear and Nonlinear Propagation

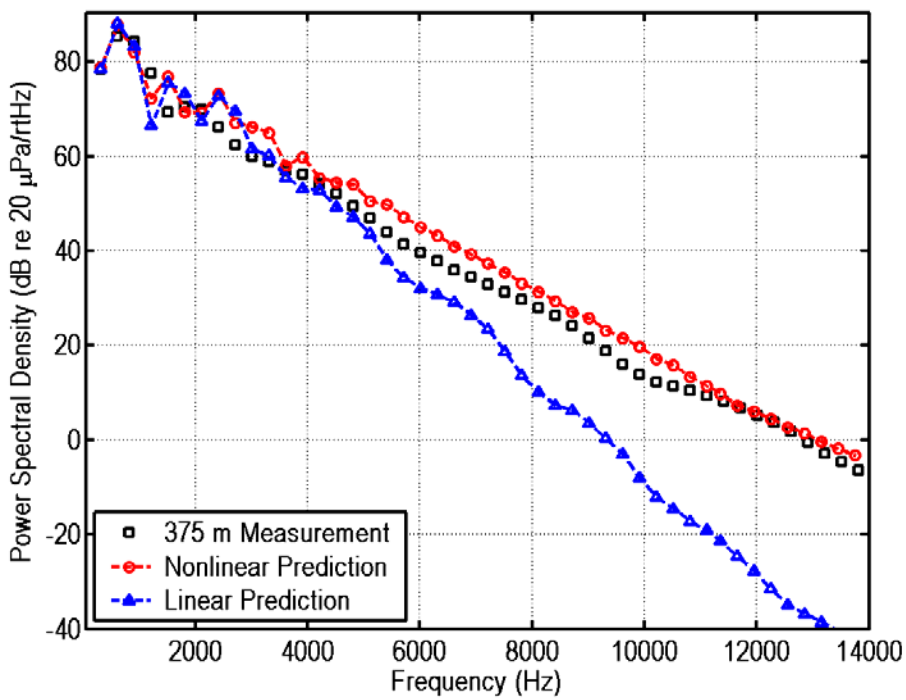

Figure 2-9. Spectral Effects of Nonlinear Propagation

2.3 Flight Trajectory Model

The location of the vehicle origin in the ground-based reference system (x,y,z), the aircraft's operating state (velocity, flight path angle, and nacelle tilt angle), as well as the vehicle orientation are user defined in terms of the input flight track and flight profile. The vehicle orientation is defined in terms of a flight path angle (+=climb), heading angle (N=90°, E=0°), pitch (+=nose up), roll (+=left down) and yaw (+=facing left) as illustrated in Figures 2-10, 2-11, and 2-12.

If the input deck contains the TIMESPACING keyword and a user defined time increment in seconds, then AAM will subdivide the input segments in order to provide to the computational module a higher resolution flight path description. When exercising the model in multiple track mode, a default maximum track point spacing of 2.0 seconds is used.*

* Generally, a 500 foot or coarser ground mesh is used for community environmental noise impact analysis. A forward flight speed in the vicinity of the airfield for a typical operation, yields a flight path spacing commensurate with this ground mesh resolution. If higher resolution results are required the single track analysis method with the TIMESPACING should be used and the ground noise contours summed using NMPLOT.

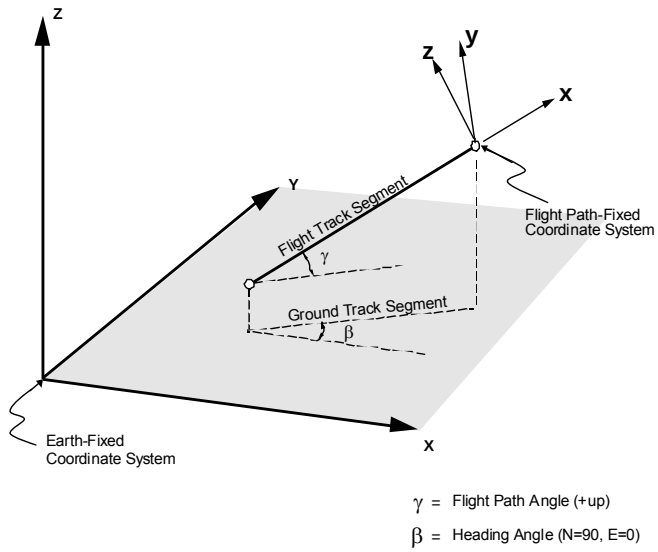

Figure 2-10. Earth-Fixed and Flight Path-Fixed Coordinate Systems

In order to interpolate between input segments containing an integrated flight track and profile as defined by the user, AAM uses a kinematic relationship based on constant acceleration. A combination of straight and curved segments are interpolated linearly and the vehicle location, orientation, and operating state calculated. The aircraft state parameters, roll, pitch and yaw are interpolated linearly. Engine operating state (thrust) is interpolated using a stair stepping technique in order to preserve constant throttle settings for the duration of an entire flight segment with discrete transitions in operating state between other fixed wing hover models, such as NOISEMAP[6] and the FAA's Integrated Noise Model INM[49]. For aircraft with varying thrust vector angles, the orientation angle is interpolated linearly throughout the entire flight operation. The interpolated flight trajectory is written to the main output file. If video generation is enabled, a separate trajectory file is also created.

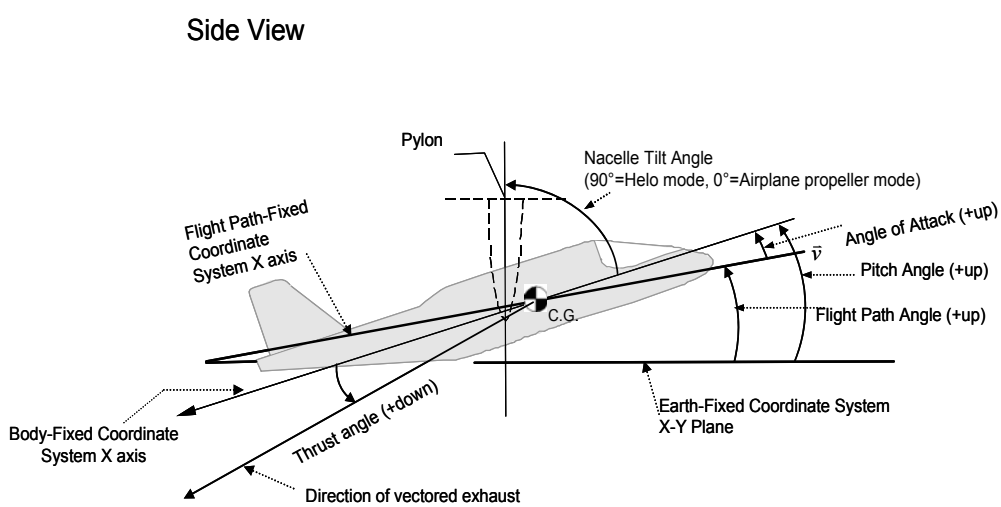

Figure 2-11. Example of Nacelle Tilt Angle

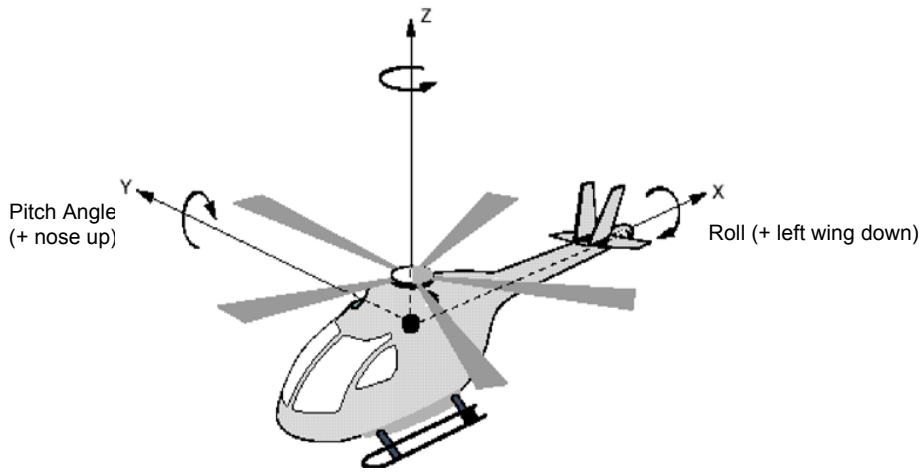

Figure 2-12. Body-Fixed Coordinates

INM,[49] NOISEMAP,[6] and AAM all accept the location of the aircraft defined by a separate set of vectored ground tracks and flight profiles. Additionally, NMSim,[3] RNM,[4] and AAM in single track mode, accept a three-dimensional integrated flight track and profile as input. A vectored ground track is defined by a series of straight line and turn segments. A departure track begins at the airfield and proceeds in the direction of travel. The starting point is defined when the vehicle lifts off the ground. An arrival track is defined in a sequence opposite the actual direction of flight. When running in NOISEMAP (multiple track) mode, an arrival track is defined from the helipad or runway and proceeds as if the aircraft is flying away from the airfield rather than towards the airfield. The acoustical analysis simulates motion in the true direction of travel.

The aircraft flight profile is a table that describes the aircraft altitude above the reference ground level, indicated airspeed, yaw angle, angle of attack, roll angle for fixed wing aircraft, the engine operating state (throttle setting and thrust vector angle), and for tilt rotors, the pylon angle, as a function of the cumulative flight track ground distance. The cumulative flight track ground distance is a running index constructed in the same order as the ground track. One role of the flight trajectory module is to combine the ground track and flight profile into an integrated trajectory in the earth-fixed coordinate system.

The vectored flight track segmentation sequence is as follows:

1. Determine the starting point of the flight track in earth-fixed coordinates accounting for terrain if specified.
2. Calculate the integrated ground track distance at the vectored track turn points. Circular segments are divided into straight line segments. The model approximates a turn with an even number of straight line segments having a composite length equal to the arc length of the curved flight track. The formulation implemented here (shown in Figure 2-13), was derived by Eldred and Miller[50] with a segmentation requirement that θ be less than or equal to 30°. This may result in smaller time steps than the user input time spacing.

3. Based on the ground track distance, merge the ground track with the flight profile using the minimum number of points to define the integrated trajectory. A merged flight track combines the ground track with the aircraft altitude (AGL), indicated airspeed, yaw angle, angle of attack, roll angle, heading angle, engine operating state, thrust vector, and nacelle pylon angle. At this point in the analysis, the local ground altitude is compared with the flight altitude. If the vehicle is below ground, program execution will halt with an error message.

2.4 Geometry Module

As the vehicle advances from point to point along the flight track, the primary Euler angles for each sound sphere source location must be calculated in the ground-based frame of reference. The value for θ and ϕ on the sound sphere (for obtaining the source level, frequency, and phase) are evaluated by the dot product between the vehicle orientation vector and the line of sight vector between the source center and receiver location. Depending on the particular geometric situation, a first order or exact (iterative) solution to the Euler angles will be used. This algorithm is defined in Reference 51 and its implementation is described below.

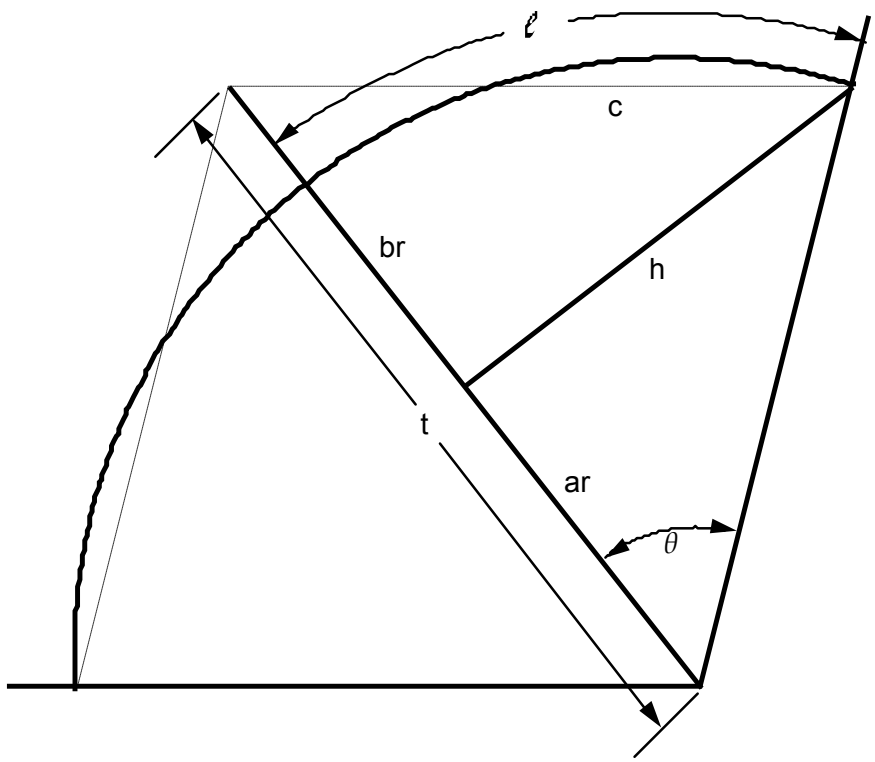

Figure 2-13. Geometry Used to Segment a Circular Flight Track Segment

2.4.1 Calculating the Sound Sphere Angles Theta (θ) and Phi (ϕ)

The sound propagating in the direction of the receiver is obtained from the location on the source sphere intersected by a straight line between the source center and receiver. These spherical angles (θ and ϕ) are the sphere azimuth and elevation, and are dependent on the location of the source (x_0,y_0,z_0) and the location of the receiver (x_1,y_1,z_1) in the earth-fixed coordinate system and the vehicle orientation relative to the flight path-fixed coordinate system (Figure 2-14). The sound sphere azimuth angle θ is 0° at the nose and 180° at the tail. The elevation angle ϕ is –90° to port, 0° below, and +90° at the starboard hub plane. It is customary to place the sound sphere origin at the center of gravity for fixed wing and tilt rotor aircraft and at the rotor hub for helicopters.

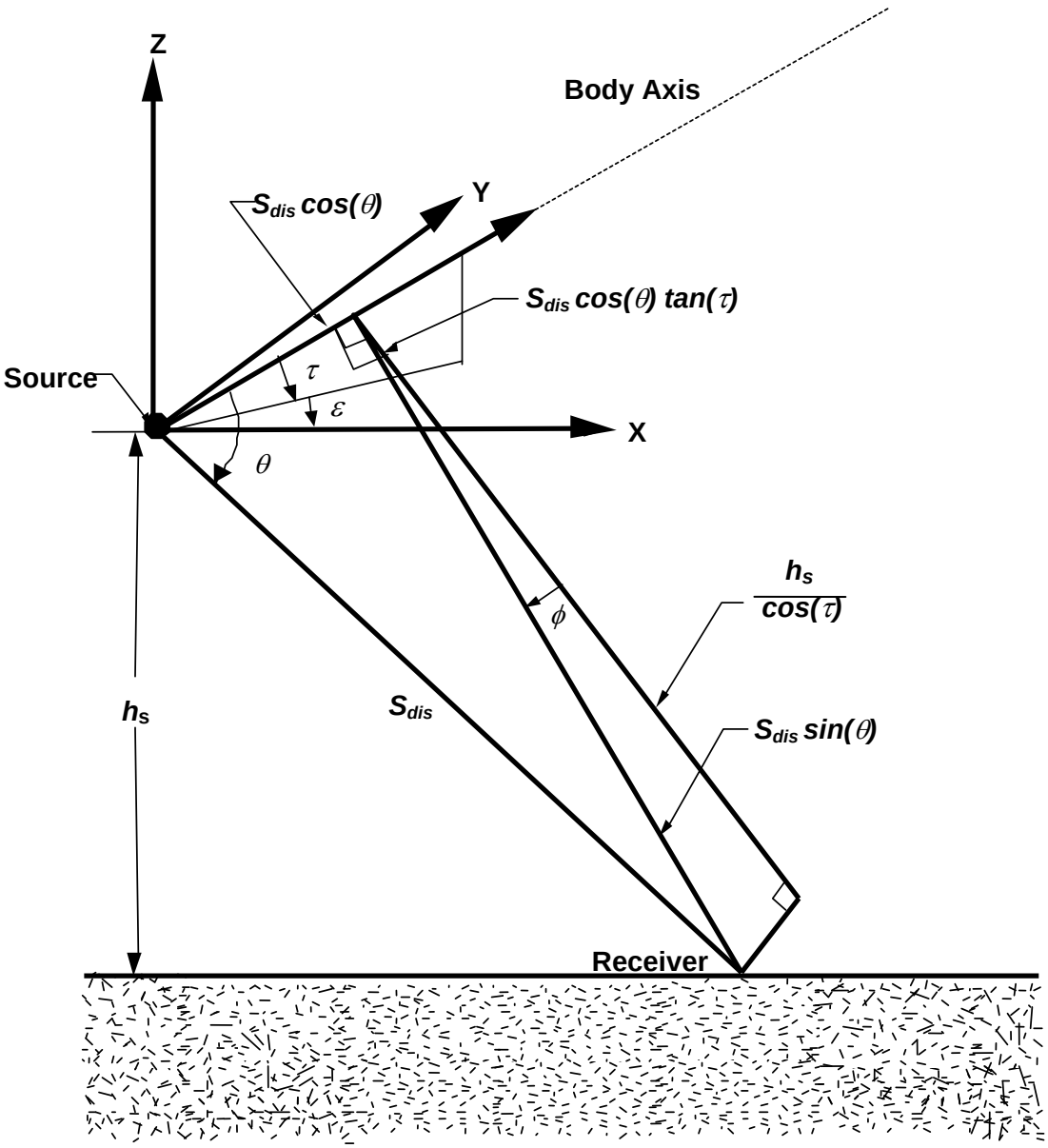

Figure 2-14. Geometry Used to Describe Spherical Angles θ and ϕ

From the angles τ and ξ the three components of the aircraft unit direction vector are determined as follows:

$$\vec{A}_c = \cos(\tau)\cos(\xi)\vec{i} + \cos(\tau)\sin(\xi)\vec{j} + \sin(\tau)\vec{k} \qquad (2)$$

The three components of the vector pointing from the source to the receiver are calculated by

$$\vec{S} = \frac{(x_1 - x_0)}{S_{dis}}\vec{i} + \frac{(y_1 - y_0)}{S_{dis}}\vec{j} + \frac{(z_1 - z_0)}{S_{dis}}\vec{k} \qquad (3)$$

where S_{dis} is the distance from the source to the receiver and is calculated as follows:

$$S_{dis} = \sqrt{(x_1 - x_0)^2 + (y_1 - y_0)^2 + (z_1 - z_0)^2} \qquad (4)$$

The spherical angle θ is then calculated by taking the dot product of the two vectors

$$\theta = \cos^{-1}\left(\vec{A}_\ell \bullet \vec{S}\right) \qquad (5)$$

The angle ϕ is determined directly from the following relationship

$$\phi = \cos^{-1}\left[\frac{\dfrac{h_s}{\cos(\tau)} + S_{dis}\cos(\theta)\tan(\tau)}{S_{dis}\sin(\theta)}\right] \qquad (6)$$

where h_s is the height of the source above the ground level.

This geometric implementation (subroutine ANGLES) remains unchanged since RNM Version 1.0. It assumes a zero roll angle and makes small angle approximations for all angles except yaw and heading when computing the sound sphere (θ, ϕ). For small angles of roll and sideslip, this difference is minimal. Under the circumstances listed in Table 2-3, these simplifications can introduce errors when analyzing vehicles with non-zero roll pitch or yaw, or when considering vehicles defined with multiple sources, especially when performing a pure-tone and phase analysis. The Euler angle geometric solver was adapted based on the methodology defined in Reference 51. When the criteria defined in Table 2-3 are met, an iterative Newton method solver is automatically utilized in order to obtain the sound sphere *(θ, ϕ)*. This feature may, however, be enabled always or never via the EULER keyword.

Table 2-3. Euler Angle Iterative Solver Criteria

Parameter	Iterative solver enabled when…
|Yaw|	Exceeds 2º
|roll|	Exceeds 5º
|pitch|	Exceeds 2º
Σ|yaw|+|roll|+|pitch|	Exceeds 3º
EULER	Keyword set to ON
broadband spheres	More than 1 and spacing over 10 ft
narrow band spheres	More than 1 and spacing over 10 ft
pure-tone spheres	More than 1 and spacing over 10 ft

Note: These criteria are set as parameters and cannot be changed by the user.

2.4.2 Calculations in the Earth-Fixed Coordinate System

The orientation of an aircraft relative to the earth-fixed coordinate system is specified in terms of a flight path-fixed coordinate system and three Euler angles. The flight path-fixed coordinate system is translated in the X, Y and Z directions, rotated to be coincident with the local flight trajectory, and oriented accounting for the heading angle (β), the flight path angle(γ), and the roll angle (ϕ). Relative to the flight path-fixed coordinate system (Figure 2-11), the body fixed coordinate system (Figure 2-12) is rotated about the X-axis (roll angle), the Y-axis (pitch angle), and the Z-axis the (yaw angle).

The position of the sound sphere is user defined in terms of a body-fixed coordinate system and its center must be determined in an earth-fixed coordinate system. If the roll, pitch, and yaw angles were zero and the sound sphere centered at the vehicle origin, then the position of the sound sphere in an earth-fixed coordinate system could be easily found using equations derived from Figures 2-14 and 2-15.

$$x_0 = x_{ac} + \cos(\beta)\left(-x_{body}\cos(\gamma) - z_{body}\sin(\gamma)\right) + y_{body}\sin(\beta) \qquad (7)$$

$$y_0 = y_{ac} + \sin(\beta)\left(-x_{body}cos(\gamma) - z_{body}\sin(\gamma)\right) - y_{body}\cos(\beta) \qquad (8)$$

$$z_0 = z_{ac} - x_{body}\sin(\gamma) + z_{body}cos(\gamma) \qquad (9)$$

The variables x_{body}, y_{body}, z_{body} define the center of the sound sphere in a body-fixed coordinate system. Variables x_{ac}, y_{ac}, z_{ac} specify the origin of the flight path-fixed coordinate system in an earth-fixed coordinate system and x_0, y_0, z_0 specify the center of the sphere in an earth-fixed coordinate system.

With the addition of vehicle orientation and non-centered sound spheres, the calculations become considerably more complex. The process for determining the center of an arbitrarily located and oriented sound sphere in earth-fixed coordinates requires a series of translations and rotations of the body-fixed coordinate system. The sequence of translations and rotations is as follows:

1. Rotate the Y and X axis of the aircraft-fixed coordinate system so that it is parallel with the earth-fixed coordinate system.
2. Translate the origin of the aircraft-fixed coordinate system to be coincident with the earth-fixed coordinate system.
3. Rotate the body axes by the vehicle roll, pitch, and yaw flight conditions.
4. Translate the origin of the aircraft-fixed coordinate system back to its original position.
5. Rotate the Y and X axis of the aircraft-fixed coordinate system back to the original position.

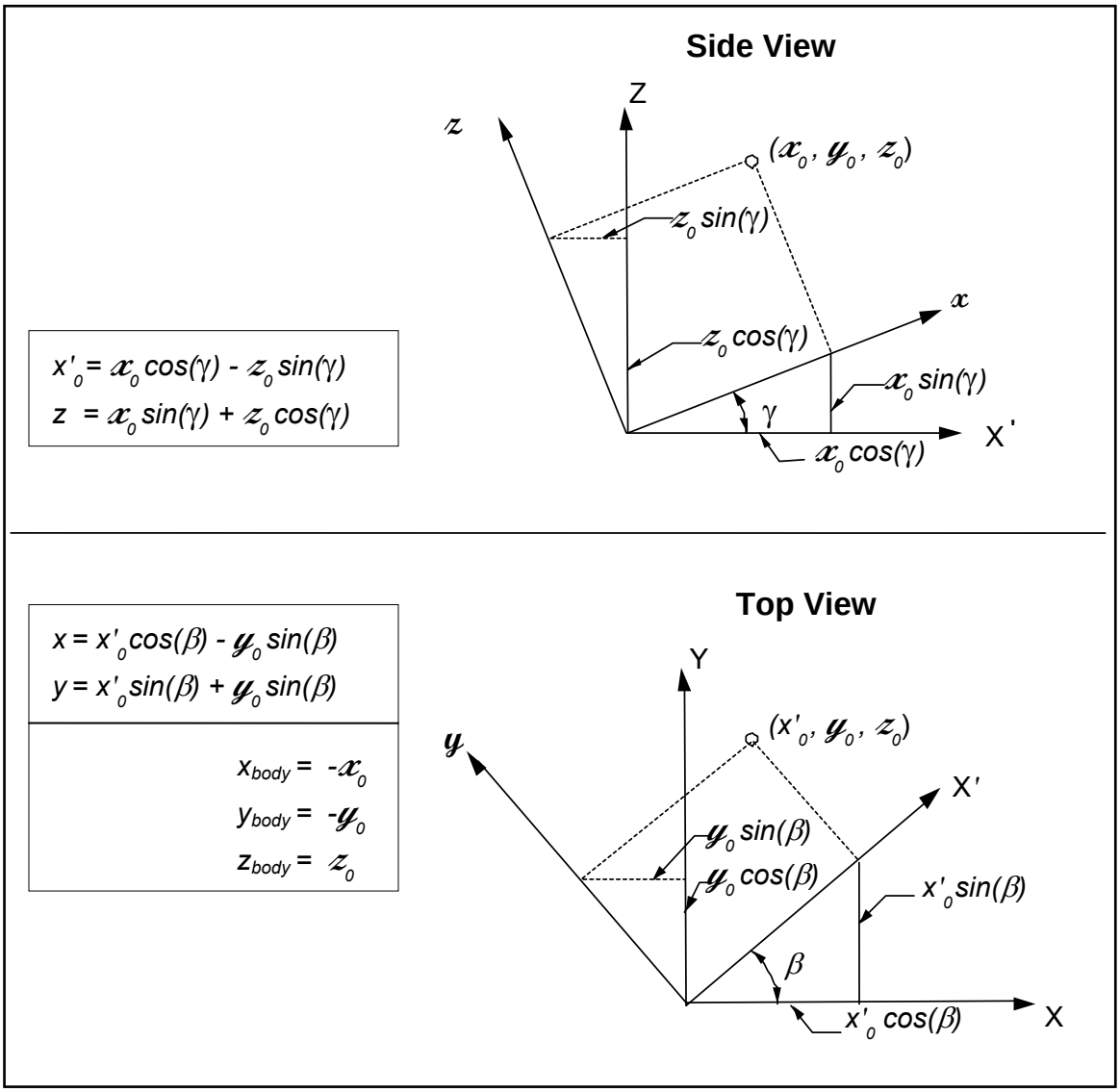

Figure 2-15. Geometry Used to Translate Body-fixed Coordinates to Earth-fixed Coordinates

These calculations may be described in the form of matrices. The total transformation requires nine matrix multiplications. The final result is the position of the sound sphere in an earth-fixed coordinate system. The following are the matrices are used to compute the geometric translations and rotations:

$$[M_1]=\begin{vmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -x_{ac} & -y_{ac} & -z_{ac} & 1 \end{vmatrix} \qquad [M_2]=\begin{vmatrix} \cos(-\beta) & -\sin(-\beta) & 0 & 0 \\ -\sin(-\beta) & \cos(-\beta) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{vmatrix}$$

$$[M_3]=\begin{vmatrix} \cos(-\gamma) & 0 & -\sin(-\gamma) & 0 \\ 0 & 1 & 0 & 0 \\ \sin(-\gamma) & 0 & \cos(-\gamma) & 0 \\ 0 & 0 & 0 & 1 \end{vmatrix} \qquad [M_4]=\begin{vmatrix} \cos(\psi) & \sin(\psi) & 0 & 0 \\ -\sin(\psi) & \cos(\psi) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{vmatrix}$$

$$[M_5]=\begin{vmatrix} \cos(\theta) & 0 & -\sin(-\gamma) & 0 \\ 0 & 1 & 0 & 0 \\ \sin(\theta) & 0 & \cos(\theta) & 0 \\ 0 & 0 & 0 & 1 \end{vmatrix} \qquad [M_6]=\begin{vmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos(\phi) & \sin(\phi) & 0 \\ 0 & -\sin(\phi) & \cos(\phi) & 0 \\ 0 & 0 & 0 & 1 \end{vmatrix}$$

$$[M_7]=\begin{vmatrix} \cos(\gamma) & 0 & -\sin(-\gamma) & 0 \\ 0 & 1 & 0 & 0 \\ \sin(\gamma) & 0 & \cos(\gamma) & 0 \\ 0 & 0 & 0 & 1 \end{vmatrix} \qquad [M_8]=\begin{vmatrix} \cos(\gamma) & \sin(\beta) & 0 & 0 \\ -\sin(\beta) & \cos(\beta) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{vmatrix}$$

$$[M_9]=0\begin{vmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ x_{ac} & y_{ac} & z_{ac} & 1 \end{vmatrix} \qquad (10)$$

The matrices are multiplied together in the following sequence:

$$[x_0 \;\; y_0 \;\; z_0 \;\; 1][M_1][M_2][M_3][M_4][M_5][M_6][M_7][M_8][M_9] = [x_1 \;\; y_1 \;\; z_1 \;\; 1] \qquad (11)$$

The variables x_0, y_0, z_0 specify the center of the vehicle (origin) in an earth-fixed coordinate system prior to the vehicle rotation about its center. The variables x_{ac}, y_{ac}, z_{ac} specify the location of the source in the body-fixed coordinate system. The variables x_1, y_1, z_1 specify the resultant center of the particular sound sphere after the full vehicle rotation in the earth-fixed coordinate system. When calculating the location of the individual sound source spheres the model rigorously accounts for a full complement of vehicle orientation angles (roll, angle of attack, and yaw).

2.5 Source Acoustic Data Description

AAM has the capability to accept either analytically or experimentally generated sound spheres for multiple sources in broadband format (in the form of one-third octave bands), in narrow band format (in user defined, arbitrarily selected bands), and as single frequencies as pure tone with phase. The analytical data may be created using computational fluid dynamics or other techniques and interfaced via the sphere sound files. Broadband and narrow band vehicle source descriptions may be created from experimental flight test data using the Acoustic Repropagation Technique described in Chapter 4.0 of this document. AAM will perform the atmospheric propagation of all noise sources for a given vehicle and sum them accordingly, presenting integrated metric results as dictated by the user input stream.

Source level noise data is presented in the form of a single sound sphere or multiple spheres (Figure 2-16) containing one-third octave band, narrow band or pure tone and phase sound levels. Points on the sphere are described in terms of a fixed radius and two spherical angles. The spherical coordinate system requires the origin of the coordinate system to be located at the center of the noise source and the X-axis aligned with the body fixed coordinate system. The direction angle, θ, points from the center towards the bow of the vehicle where theta is zero, and from the center towards the stern where theta is 180 degrees. Phi is zero directly underneath the vehicle, positive 90 degrees on the starboard side, and minus 90 degrees on the port side. This notation is consistent with that used by the Aircraft Noise Prediction Program (ANOPP),[17,18,19,20] and is used to facilitate comparison between the two systems (Figure 2-7).

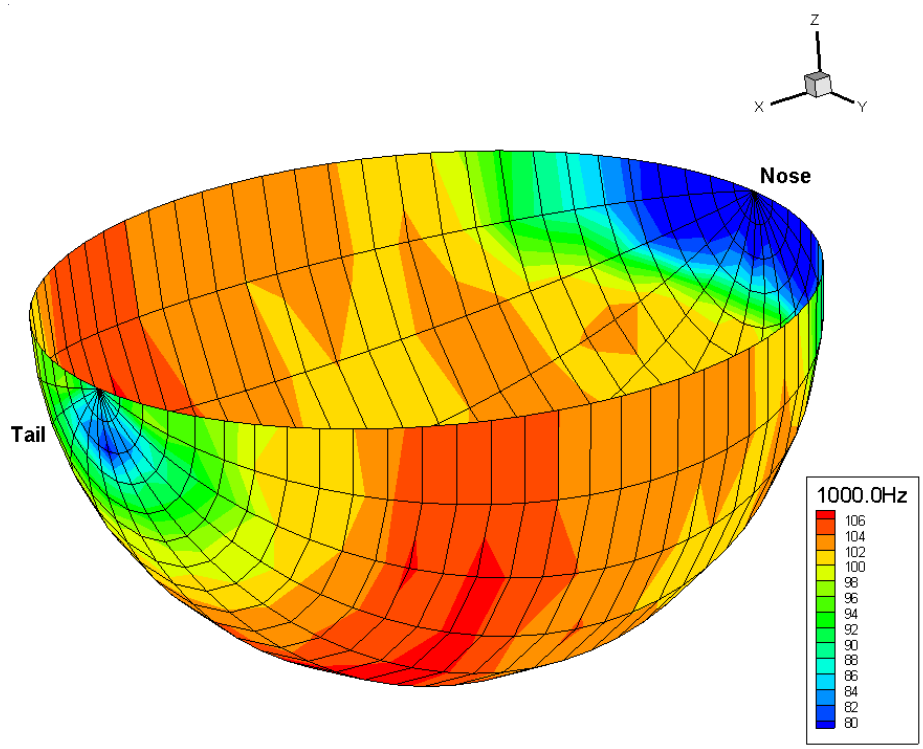

Figure 2-16. Sample Sphere for an F-22 Raptor Fixed Wing Aircraft in Afterburner Mode with a Reference Distance of 1000 Feet

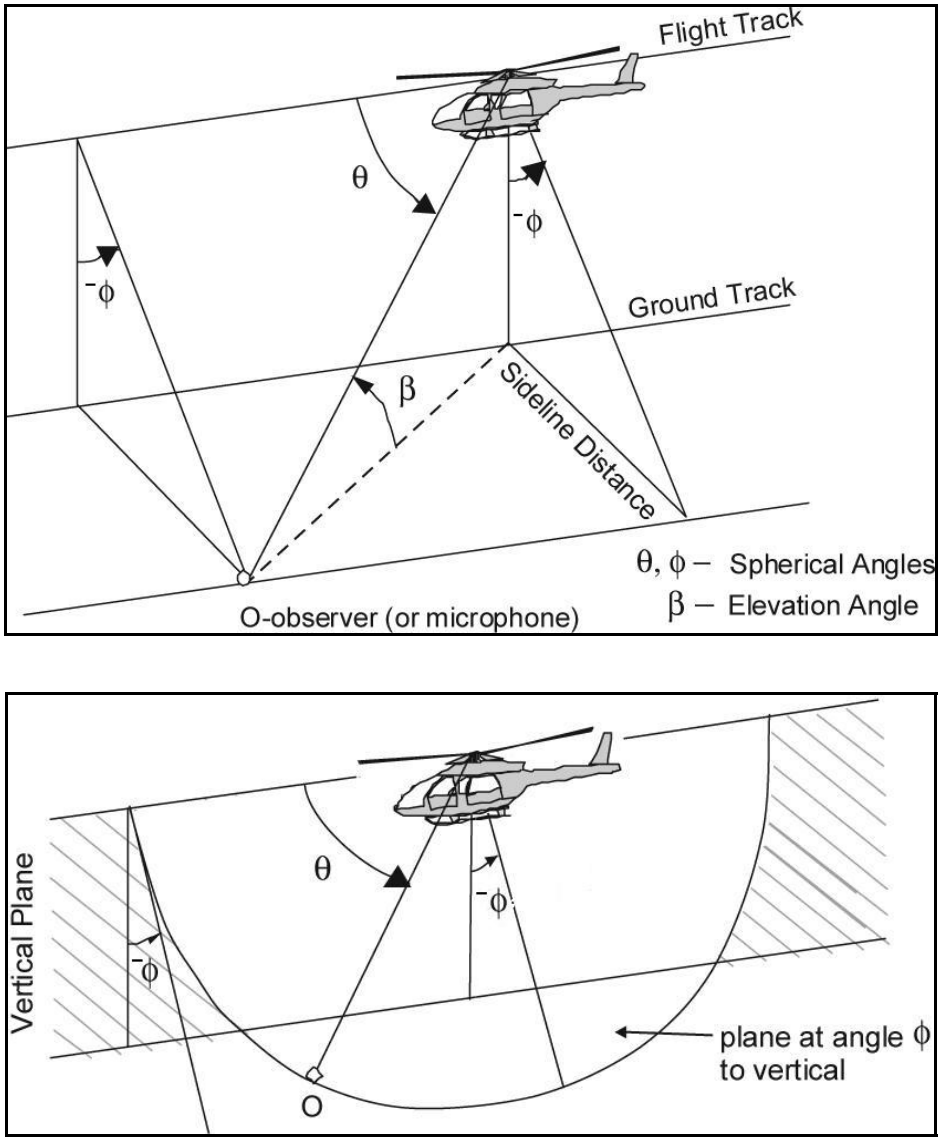

Figure 2-17. Spherical Angles

Sound sphere (or hemisphere) files each contain for one noise source for a single flight condition. The NetCDF format is self-describing. Each file contains a set of variables and attributes which define the flight condition and the location of the noise data on the sphere. The three independent variables that describe the quasi-steady flight condition for a rotorcraft are the flight path angle, the pylon angle, and the airspeed. For conventional helicopters, only flight path angle and airspeed are needed. For fixed wing aircraft the engine state (thrust and vector angle), as well as the nonlinear propagation corrections (if any), are described within the NetCDF file. There may be more than one sound sphere for each set of conditions. For instance, there may be one broadband and one pure-tone sound sphere. For each set of flight conditions there can be up to ten broadband and ten pure-tone sound spheres centered at different points on the vehicle (i.e., engine, main rotor, tail rotor, and MR/TR wake interference).

2.5.1 Source Database Lookup and Selection

One of the primary differences between fixed wing and rotary wing aircraft lies in the physical parameters governing the source characteristics. The fundamental drivers of helicopter noise are aerodynamic in nature and due to the rotor system. Fixed wing vehicles are dominated on the other hand by engine operating state (thrust level and vector orientation). For this reason there are two distinct modes of source noise sphere selection in AAM: (1) rotary wing aircraft (Section 2.5.1.1), and (2) fixed wing operations, consistent with legacy noise models, such as NOISEMAP (Section 2.5.1.2).

2.5.1.1 Source Database Lookup and Selection – Rotary Wing Aircraft

The first version of Rotorcraft Noise Model[53] considered only airspeed when linearly interpolating between sound spheres for obtaining the rotorcraft source characteristics. The present version has two distinct modes of operation. The first source lookup methodology performs a two-dimensional interpolation considering both airspeed and flight path angle. The second source lookup technique allows the user to specifically identify for each segment of defined flight trajectory the specific source characteristic (.NC) file to use. This feature is accessed using the NCSPEC keyword. When enabled, each sound sphere represents constant airspeed conditions for a given flight path angle. RNM performs a prioritization of the available sound spheres utilizing a hierarchical search of nacelle angle, flight path angle and aircraft speed. At each point along the flight trajectory the source sound characteristics are extracted from the sphere files using a linear interpolation at the required airspeed, followed by a second linear interpolation on the vehicle flight path angle. These interpolation procedures are utilized when sufficient sphere flight resolution is available. For vehicles with sparsely populated acoustic spheres flight conditions, the prior RNM methodology of selecting the closest matching flight condition available sphere, without interpolation, is utilized.

Due to the methodology in ART, which assigns a nominal flight condition (speed and flight path angle) based on averaging the input trajectory parameters, it became necessary to modify the sphere sorting algorithm. Beginning with RNM Version 7, AAM rounds the input .NC file elevation angles to the nearest 1-degree increment before sorting rotorcraft noise spheres. This change is evident in Figure 2-18.

Before any acoustic interpolation between sound spheres can occur, the available data must be sorted and organized in a methodical fashion. All spheres matching the vehicle type(s) specified in the RNM input deck are sorted in the priority order given in Table 2-4.

Table 2-4. Sphere Parameter Sorting Sequence for Rotary Wing Aircraft

1. Vehicle type.
2. XYZ Sphere Center (lowest to highest X,Y,Z in X,Y,Z sequence).
3. Sound type (Broadband, Narrow band, or Pure tone).
4. Nacelle Tilt Angle (lowest, 0 deg to highest, 90 deg).
5. Flight Path Angle (lowest, approach to highest, departure).
6. Speed, knots (lowest to highest).

The sorted list is echoed in the RNM detailed output listing for each vehicle in the analysis. A sample output is included in Figure 2-18.

```
NETCDF FILES (SORTED)     Path to .NC c:\srce\helicopters\rnm\ncfiles\
     Number  Rotor Run    Flight Nacl  Speed Climb  Broad Narr Pure Cent  Cent  Cent Doppler
             craft Number Path   Tilt  Knots Rate   Band  Band Tone X     Y     Z    State
             Type         Angle  Angle       ft/min                  ft    ft    ft
F=Moving
                          Deg.   Deg.                                                     T=Stat.
       1    ch146   189    -13.0   90.0   58. -1325.0  1   0    0   0.0   0.0   0.0  F
       2            188   -12.00   90.0   80. -1686.4  1   0    0   0.0   0.0   0.0  F
       3            179    -7.00   90.0   62.  -767.7  1   0    0   0.0   0.0   0.0  F
       4            171    -7.00   90.0  104. -1284.0  1   0    0   0.0   0.0   0.0  F
       5            181    -6.00   90.0   58.  -616.3  1   0    0   0.0   0.0   0.0  F
       6            175    -6.00   90.0   84.  -884.6  1   0    0   0.0   0.0   0.0  F
       7            173    -6.00   90.0  107. -1136.4  1   0    0   0.0   0.0   0.0  F
       8            183    -5.00   90.0   44.  -388.7  1   0    0   0.0   0.0   0.0  F
       9            120    -1.00   90.0   78.  -137.1  1   0    0   0.0   0.0   0.0  F
      10            121    -1.00   90.0  120.  -212.4  1   0    0   0.0   0.0   0.0  F
      11            122    -1.00   90.0  126.  -222.4  1   0    0   0.0   0.0   0.0  F
      12            105     0.00   90.0   98.     0.0  1   0    0   0.0   0.0   0.0  F
      13            101     0.00   90.0   99.     0.0  1   0    0   0.0   0.0   0.0  F
      14            170     0.00   90.0  100.     0.0  1   0    0   0.0   0.0   0.0  F
      15            104     0.00   90.0  102.     0.0  1   0    0   0.0   0.0   0.0  F
      16            194     0.00   90.0  102.     0.0  1   0    0   0.0   0.0   0.0  F
      17            117     0.00   90.0  119.     0.0  1   0    0   0.0   0.0   0.0  F
      18            118     0.00   90.0  126.     0.0  1   0    0   0.0   0.0   0.0  F
      19            110     0.00   90.0  127.     0.0  1   0    0   0.0   0.0   0.0  F
      20            106     1.00   90.0   81.   143.7  1   0    0   0.0   0.0   0.0  F
      21            114     1.00   90.0   98.   173.2  1   0    0   0.0   0.0   0.0  F
      22            124     1.00   90.0  111.   196.6  1   0    0   0.0   0.0   0.0  F
      23            112     1.00   90.0  128.   227.0  1   0    0   0.0   0.0   0.0  F
      24            222     1.00   90.0  129.   227.8  1   0    0   0.0   0.0   0.0  F
      25            152     3.00   90.0   83.   440.3  1   0    0   0.0   0.0   0.0  F
      26            130     4.00   90.0   78.   552.5  1   0    0   0.0   0.0   0.0  F
      27            128     4.00   90.0   82.   577.6  1   0    0   0.0   0.0   0.0  F
      28            154     4.00   90.0   88.   620.9  1   0    0   0.0   0.0   0.0  F
      29            126     5.00   90.0   80.   709.7  1   0    0   0.0   0.0   0.0  F
      30            180     9.00   90.0   73.  1156.1  1   0    0   0.0   0.0   0.0  F
      31            176     9.00   90.0   94.  1486.7  1   0    0   0.0   0.0   0.0  F
      32            178     9.00   90.0   96.  1518.1  1   0    0   0.0   0.0   0.0  F
      33            182    10.00   90.0   67.  1172.9  1   0    0   0.0   0.0   0.0  F
      34            174    10.00   90.0   76.  1328.2  1   0    0   0.0   0.0   0.0  F
      35            166    11.00   90.0   62.  1201.0  1   0    0   0.0   0.0   0.0  F
      36            184    11.00   90.0   98.  1886.8  1   0    0   0.0   0.0   0.0  F
      37            172    12.00   90.0   74.  1567.0  1   0    0   0.0   0.0   0.0  F
      38            160    15.00   90.0   60.  1567.4  1   0    0   0.0   0.0   0.0  F
      39            158    15.00   90.0   61.  1596.7  1   0    0   0.0   0.0   0.0  F
```

Figure 2-18. Sample Sorted .NC File Output for a Helicopter

After the spheres have been sorted, they are searched systematically and up to four spheres are selected for interpolation. There may be conditions under which only 1, 2 or 3 spheres are selected for interpolation. These indices are itemized in the detailed output if keyword DIAGNOSTICS is enabled. The search procedure is done in stages, with the initial search identifying those cases where the physical parameters are matched identically and no interpolation is required. Within the sorted list of available spheres, interpolation is performed using criteria given in Table 2-5.

Table 2-5. Acoustic Source Search Priority and Criteria for Rotary Wing Aircraft

Parameter	Criteria
1) Vehicle Type	Must match, no interpolation
2) Acoustic File (broadband or pure tone)	Must match, no interpolation
3) Sphere Location (X,Y,Z)	Must match, no interpolation
4) Nacelle Angle	No interpolation, closest chosen
5) Flight Path Angle	Linear interpolation, dFPA deg max
6) Speed, knots	Linear interpolation, dSPD kts max

The search routine systematically narrows down the search range to a smaller subset of sequentially available spheres for vehicle type, acoustic file type (broadband or pure tone) and sphere location (Table 2-5, items 1-3). If any of these three critical items are not matched identically with at least one of the available spheres, program execution is halted and an error message is reported to the user.

Only a single nacelle tilt angle is permitted for all four sources. This will be the closest numerical match to the specified flight condition nacelle angle. In cases where the specified nacelle angle is exactly centered between two available nacelle angles, spheres with the largest nacelle angle will be chosen.

By the completion of this portion of the search algorithm a sequential set of inclusive indices have been identified, from which the four (or fewer) interpolation spheres will be chosen. Interpolation limits have been established as parameters for cases where source sphere conditions are too distant for valid interpolation (Table 2-6).

Table 2-6. Physical Parameter Interpolation Limits for Rotary Wing Aircraft

Parameter	Limit
Approach Flight Path Angle	2.0 degrees
Departure Flight Path Angle	5.0 degrees
Flight Speed	20.0 knots

The outcome of the search routine is the identification of up to four sound spheres. These four spheres will then be linearly interpolated in decibels based first on speed and second on flight path angle. Figure 2-19 illustrates the interpolation procedure graphically.

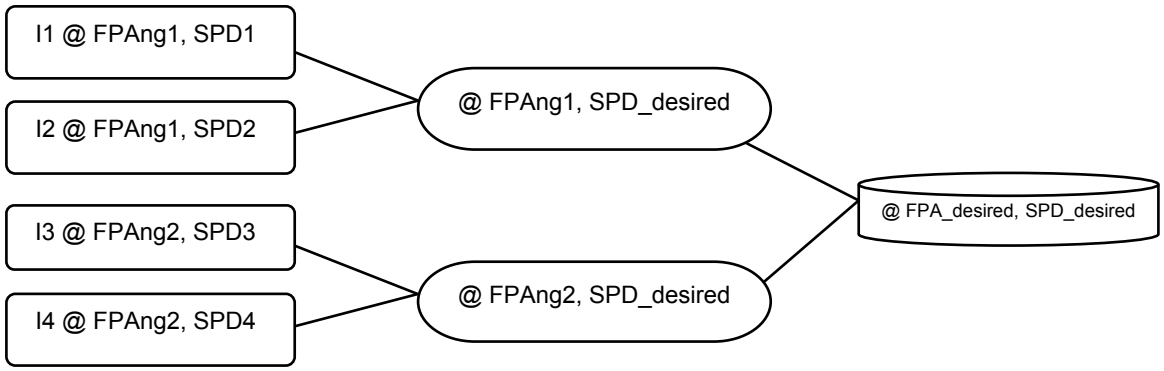

Figure 2-19. Interpolation Procedure

Indices I1, I2, I3 and I4, as shown in Figure 2-19, are selected by using the rules given in Table 2-6. The numerical interpolation procedures are an extension of the algorithms contained in prior versions of RNM. Although the code was significantly restructured, the physical interpolation procedure remains the same, namely a linear interpolation on decibels. The dependent variables of the interpolation are flight path angle and airspeed. The interpolation is done in two passes with the first two sets of two sources interpolated to the desired flight path angle and then these resultant spheres linearly interpolated to the desired airspeed. A summary of the interpolation and source selection rules is given in Table 2-7.

Table 2-7. Interpolation and Source Selection Rules for Rotary Wing Aircraft

Separate dFPA criteria are to be used for Approaches and Departures, such as:

- A single dSPD criteria will be applied across all operation types.
- FPA selections occur before SPD selections. (A duration adjustment will be made by RNM in the course of its normal calculation procedure).
- If the FPA_desired is available, then interpolation on FPAng will not occur.
- FPA selections will guide selection and MAY disqualify .NC files.
- SPD selections will guide selection, may NOT disqualify .NC files (i.e., in the absence of flight data within the specified dSPD criteria, *ANY* available sphere speed may be chosen).
- The dSPD criteria will only be used to guide interpolation applicability.
- I1,I2 will span SPD_desired or match it exactly within the (vel2-vel1 .ge.dSPD) criteria; otherwise, the closest available velocity to SPD_desired will be selected.
- I3,I4 will span SPD_desired or match it exactly within the (vel2-vel1 .ge. dSPD) criteria; otherwise, the closest available velocity to SPD_desired will be selected.
- I1,I2 will be at the same FPAng1.
- I3,I4 will be at the same FPAng2.
- FPAng1 will be less than or equal to FPA_desired.
- FPAng2 will be greater than or equal to FPA_desired, unless (FPAng2 = FPAng1).
- In the case where the FPA_desired is exactly centered between two angles which lie outside the 2dFPA criteria, the following will be used to determine which FPA is to be selected:
  - Approaches (FPA>0.0) Use the higher value of FPA.
  - Departures (FPA<0.0) Use the lower value of FPA.
- In the case where the SPD_desired is exactly centered between two speeds, which lie outside, the 2dSPD criteria, the largest speed source file will be selected (generally a conservative result).
- In cases where the exact nacelle angle is not available, the closest nacelle angle will be chosen.
- If the desired nacelle angle is exactly centered between two sets of data, the largest value of nacelle angle will be selected.

2.5.1.2 Source Database Lookup and Selection – Fixed Wing Aircraft

Noise from fixed wing aircraft with no thrust vectoring is primarily driven by the engine's power setting; however, configuration state such as thrust vector angle and flap / gear status impacts the noise emission. Each sphere contains a value for power in its associated units along with a thrust vector angle and configuration status. Regardless of the power unit used – whether it be %N1, EPR, or otherwise – a linear interpolation is always performed and this interpolation does not extend to power settings of different units for a single aircraft. The user must know what the value and units of power are in the noise spheres and build their trajectory inputs accordingly.

An additional restriction is implemented such that spheres may only be interpolated when they are of the same aircraft configuration type. These types include "clean," "flaps," "flaps + gear," and "static run-up." Each sphere file contains an integer in its header, which portrays the aircraft configuration type the data represents. More details on aircraft configuration types may be found in Section 4.1.3.

Some fixed wing data sets contain spheres with values for thrust vectoring angle in degrees. If this is the case, and the user's trajectory data contains non-zero values for thrust angle, linear interpolation over thrust angles will occur in addition to linear interpolation over power settings. The interpolation limit for thrust angle is 20°. The default thrust vector angle 0˚, which is representative of no thrust vectoring and represents a configuration where the nozzle is pointed directly aft at an azimuthal angle of 180° relative to the nose.

AAM contains two primary methods for determining the source sphere for a user specified profile and trajectory. The first source lookup methodology performs a two-dimensional interpolation based on thrust setting and thrust vector angle among spheres which match the vehicle configuration state (flaps / gear setting). The second source lookup technique allows the user to explicitly identify for each segment of defined flight trajectory the specific source characteristic (.NC) file to use. This second feature is accessible in single track mode only by using the NCSPEC keyword. When the first method is enabled, each sound sphere represents a specific power setting and thrust vector angle for the specified configuration state. AAM performs a prioritization of the available sound spheres utilizing a hierarchical search of configuration state, thrust vector angle, and thrust value. At each point along the flight trajectory the source sound characteristics are extracted from the sphere files using a linear interpolation at the required thrust angle, followed by a second linear interpolation on the vehicle power setting. These interpolation procedures are utilized when sufficient resolution of the sphere conditions are available in the data set. For vehicles with sparsely populated acoustic sphere flight conditions, the methodology of selecting the closest matching flight condition sphere is utilized without interpolation. A sparsley populated condition exists when the interpolation limits defined in Table 2-10 are not met.

ART assigns a nominal flight condition (thrust setting, thrust vector angle and configuration state) to each noise sphere. Before any acoustic interpolation between sound spheres can occur, the available data must be sorted and organized in a methodical fashion. All spheres matching the vehicle type(s) specified in the AAM input deck are sorted in the priority order given in Table 2-8.

Table 2-8. Sphere Parameter Sorting Sequence for Fixed Wing Aircraft

1. Vehicle type.
2. XYZ Sphere Center (lowest to highest X,Y,Z in X,Y,Z sequence).
3. Sound type (Broadband, Narrow band, or Pure tone).
4. Configuration State (Clean, Flaps, Flaps + Gear, Static Run-Up).
5. Power Unit.
6. Thrust Vector Angle.
7. Power Setting.

The sorted list is echoed in the AAM detailed output listing for each vehicle in the analysis. A sample output is included in Figure 2-20.

```
NETCDF FILES (SORTED)     Path to .NC c:\data\ncfiles
     Number  Fixed Run     Thrust  Power Speed  Climb  Broad Narr Pure Cent  Cent  Cent Doppler   Vehicle   Interp.
             Wing  Number  Vector        Knots  Rate   Band  Band Tone X     Y     Z    State     Config.   State
             Type          Angle                ft/min                  ft    ft    ft   F=Moving            0 = No Interp.
                           Deg.                                                         T=Stat.             1 = Interpolate
       1    av8b_   108      0.0    73.0  252.     0.0   1    0    0   0.0   0.0   0.0  F          0         1
       2            105     0.00    80.0  219.     0.0   1    0    0   0.0   0.0   0.0  F          0         1
       3            952     0.00    99.3  404.     0.0   1    0    0   0.0   0.0   0.0  F          0         1
       4            135     0.00   111.0  391.     0.0   1    0    0   0.0   0.0   0.0  F          0         1
       5            107    25.00    73.0  230.     0.0   1    0    0   0.0   0.0   0.0  F          0         1
       6            109    40.00    75.0  205.     0.0   1    0    0   0.0   0.0   0.0  F          0         1
       7            111    60.00    91.0  164.     0.0   1    0    0   0.0   0.0   0.0  F          0         1
       8            239    72.00   105.0  162.     0.0   1    0    0   0.0   0.0   0.0  F          0         1
       9            121    83.00   101.0  187.     0.0   1    0    0   0.0   0.0   0.0  F          2         1
```

Figure 2-20. Sample Sorted .NC File Output for a Fixed Wing Aircraft

After the spheres have been sorted, they are searched systematically and up to four spheres are selected for interpolation. There may be conditions under which only 1, 2 or 3 spheres are selected for interpolation. These indices are itemized in the detailed output if keyword DIAGNOSTICS is enabled. The search procedure is done in stages, with the initial search identifying those cases where the physical parameters are matched identically and no interpolation is required. Within the sorted list of available spheres, interpolation is performed using criteria given in Table 2-9.

Table 2-9. Acoustic Source Search Priority and Criteria for Fixed Wing Aircraft

Parameter	Criteria
1) Vehicle Type	Must match, no interpolation
2) Acoustic File (broadband, narrowband or pure tone with phase)	Must match, no interpolation
3) Sphere Location (X,Y,Z)	Must match, no interpolation
4) Aircraft Configuration (Clean, Flaps, Flaps + Gear, Run-Up)	Must match, no interpolation
5) Power Units	Must match, no interpolation
6) Thrust Vector Angle	Linear interpolation, dTVA deg max
7) Power Setting	No Limit, Interpolation permitted for INTERPOLATIONSTATE = 1 Interpolation NOT permitted for INTERPOLATIONSTATE = 0

The search routine systematically narrows down the search range to a smaller subset of sequentially available spheres for vehicle type, acoustic file type (broadband, narrowband or pure tone,) sphere location, Aircraft Configuration, and Power Units (Table 2-9, items 1-5). If any of these three critical items are not matched identically with at least one of the available spheres, program execution is halted and an error message is reported to the user.

By the completion of this portion of the search algorithm a sequential set of inclusive indices have been identified, from which the four (or fewer) interpolation spheres will be chosen. Interpolation limits have been established as parameters for cases where source sphere conditions are too distant for valid interpolation (Table 2-10). In the event that a full set of spheres spanning the desired conditions is not available, then the closest sphere condition will be selected, with power matching taking priority over thrust vector angle matching.

Table 2-10. Physical Parameter Interpolation Limits for Fixed Wing Aircraft

Parameter	Limit
Thrust Vector Angle	20 degrees (dTVA)
Power Setting	No Limit when Interpolation Valid

The outcome of the search routine is the identification of up to four sound spheres. Each sphere has assigned to it (based on information in the NC file) an INTERPOLATIONSTATE parameter, where 0 means no interpolation permitted and 1 means interpolation is permitted. These four spheres will then be linearly interpolated if so indicated, in decibels based first on power setting and second on thrust vector angle. Figure 2-20 illustrates the interpolation procedure graphically.

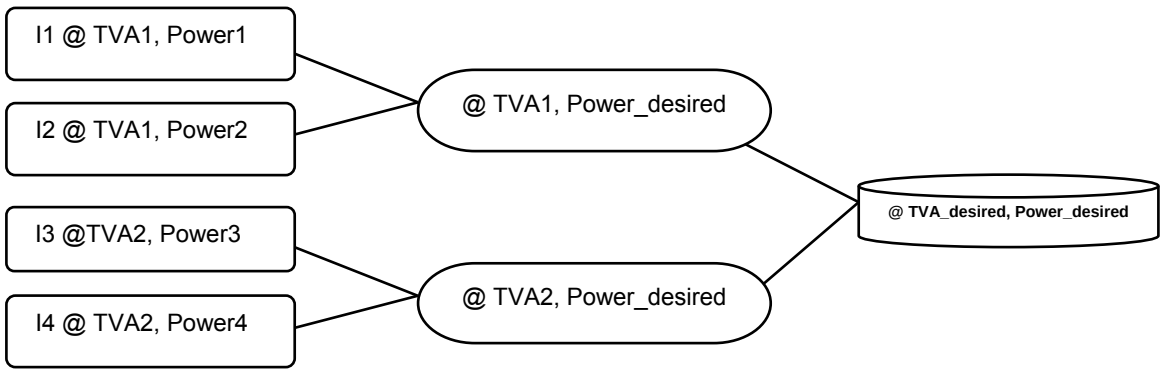

Figure 2-21. Interpolation Procedure for Fixed Wing Aircraft

Indices I1, I2, I3 and I4, as shown in Figure 2-21, are selected by using the rules given in Table 2-11. The numerical interpolation procedures are an extension of the algorithms contained in prior versions of the acoustic model, namely a linear interpolation on decibels. The dependent variables of the interpolation are thrust vector angle and power setting. The interpolation is done in two passes with the first two sets of two sources interpolated to the desired power setting and then these resultant spheres linearly interpolated to the desired thrust vector angle. This sequence is chosen because flight tests are usually conducted with multiple passes at different power settings for a given thrust vector angle. A summary of the interpolation and source selection rules is given in Table 2-11.

Table 2-11. Interpolation and Source Selection Rules for Fixed Wing Aircraft

- A single dTVA criteria will be applied across all operation types.
- Power selections occur before Thrust Vector Angle selections.
- The INTERPOLATIONSTATE criteria will only be used to guide interpolation applicability.
- I1,I2 will span Power_desired or match it exactly within the INTERPOLATIONSTATE criteria; otherwise, the closest available Power to Power_desired will be selected.
- I3,I4 will span Power_desired or match it exactly within the INTERPOLATIONSTATE criteria; otherwise, the closest available Power to Power_desired will be selected.
- I1,I2 will be at the same TVAng1.
- I3,I4 will be at the same TVAng2.
- TVAng1 will be less than or equal toTVA_desired.
- TVAng2 will be greater than TVA_desired.
- In cases where the Power Units are not available, execution will halt.
- In cases where the Aircraft Configuration (Clean, Flaps, Flaps + Gear, Run-Up) are not available, execution will halt.

2.5.2 Relating NOISEMAP and AAM Multiple Operations Mode for Fixed Wing Aircraft

In certain situations, it may be necessary to understand what BASEOPS provides as text input to AAM for running AAM in multiple operations mode. This section will provide the reader a description of the relationship for a typical NOISEMAP analysis.

2.5.2.1 NOISEMAP .OPS File

Running BASEOPS with NOISEMAP requires NOISEMAP be provided an .OPS file which includes a description of the flight profile. Since AAM provides added noise modeling capabilities, this profile description has been modified. The text block in Figure 2-22 provides an example flight profile for use with NOISEMAP. The FLIGHTPROF .OPS file keyword signifies that this profile will be calculated by NOISEMAP. Table 2-12 details the contents of the keyword block.

```
FLIGHTPROF         1
F18A2     TRANSIENT FM04501                                   % NC
04A2               0         0    0.4625        0.     0.011         1        10
          TACAN Arrival to Runway 04
                   0        67       88.  PARALLEL       135          FM0450100
                4557       367       88.  PARALLEL       140          FM0450100
               10848       683       88.  PARALLEL       140          FM0450100
               17139      1017       86.  PARALLEL       140          FM0450101
               28389      1017       87.  PARALLEL       140          FM0450102
               45042      1017       87.  PARALLEL       140          FM0450102
               75439      2217       86.  PARALLEL       140          FM0450101
               86884      2817       86.  PARALLEL       250          FM0450101
              152281     10017       81.  VARIABLE       250          FM0450103
              249121     18017       81.  VARIABLE       300          FM0450103
```

Figure 2-22. Sample NOISEMAP .OPS File FLIGHTPROF Keyword Segment

Table 2-12. NOISEMAP FLIGHTPROF Keyword Format

Line	Column	Format	Description
1	1-10	A10	FLIGHTPROF keyword
	11-20	I10	Number of unique flight profiles
2	1-10	A10	Flight Profile Identification
	11-20	A10	Aircraft Category
	21-27	A7	Aircraft ID code
	61-70	A10	Power Units
3	1-10	A10	Flight Track ID
	11-20	F10	Takeoff displacement (ft)
	21-30	F10	Landing Displacement (ft)
	31-40	F10	Number of daytime events
	41-50	F10	Number of evening events
	51-60	I10	Number of comment lines
	61-70	I10	Number of profile segments
4	1-80	A80	Comment Line
5	1-10	F10	Cumulative flight track distance
	11-20	F10	Altitude in (ft, MSL)
	21-30	F10	Power setting given in appropriate units
	31-40	A10	Interpolation type
	41-50	F10	Airspeed (kts)
	51-60	A10	Noise source ID code

2.5.2.2 Changes Required for AAM .OPS Input

New features in AAM require additional columns of data for incorporation of trim angles yaw, pitch, and roll as well as thrust vector angle and aircraft configuration state. The interpolation and extrapolation behavior of AAM between two sources of the same vehicle has also been given consideration in the new model. The interpolation behavior of AAM routines has been described in Section 2.5.1.2. This section describes the rationale behind the AAM process.

Instead of using NOISEMAP logic, improved interpolation and extrapolation restrictions have been incorporated into AAM. For instance, extrapolation of the acoustic data in a noise sphere in AAM to a higher or lower power setting is not allowed. In NOISEMAP, however, extrapolations are allowed to a maximum change in the single-event noise metric (e.g., SEL) of 5 dB with scaling based on power setting. Since AAM is working from three-dimensional spectral noise sources, a simple scaling of an integrated metric such as SEL is no longer possible, since it would depend a priori on a particular receptor location and corresponding vehicle directivity.

Interpolations in NOISEMAP are structured by database-defined interpolation types including VARIABLE, PARALLEL, and FIXED. A VARIABLE interpolation means interpolation is allowed between two vehicle power states when the user inputs a power setting between two data points in the noise source file. The term FIXED implies this profile segment must use the data supplied by the noise source file as is without any interpolation. Afterburner noise sources, for example, generally are of a FIXED interpolation type since noise characteristics of this power condition are drastically different than other, more subtle noise states.

PARALLEL interpolation is generally reserved for dealing with dirty aircraft configurations such as deployed gear and flaps on approaches. In essence, PARALLEL interpolation is actually an extrapolation[6]. Consider the noise from a dirty configuration compared to a clean configuration

(i.e., gear and flaps fully retracted) at a given power level for a certain aircraft. Assume aerodynamic noise from the gears and flaps is significant and the dirty data point on the SEL versus power graph will fall directly above the clean data point. PARALLEL interpolation means the slope of the clean data set may be used to extrapolate the dirty data point to a higher or lower power setting up to a maximum change in SEL of 5 dB. The term PARALLEL refers to drawing a line through the dirty data point parallel to the imaginary line between the clean data set as the basis for extrapolating the dirty data point.

For an AAM multiple .OPS input deck, the user will define the aircraft configuration state rather than give interpolation rules such as VARIABLE or PARALLEL interpolation. These configuration states are "clean," "flaps," "flaps + gear," and "Static Run-Up." Instead of spelling these out in the input deck, however, the states will be signified by integers as specified in Table 2-13.

Table 2-13. Aircraft Configuration Types and Integer Codes for AAM .OPS File

Integer Code	Aircraft Configuration Type
0	Clean
1	Flaps
2	Flaps + Gear
3	Static Run-Up

These configuration types will be used in conjunction with meta-data contained in the AAM noise sphere source file in order to properly handle interpolation. As mentioned in Section 2.5.1.2, each sphere contains an INTERPOLATIONSTATE parameter, which governs whether it may be interpolated with a noise sphere of a neighboring power setting. If desired, the VARIABLE and PARALLEL interpolation schemes may be implemented in AAM merely by utilizing a suite of noise spheres, which apply the interpolation rules defined in Section 2.5.1.2. The noise interpolation type FIXED in NOISEMAP may be affected by selecting an operating state consistent with a noise sphere with INTERPOLATIONSTATE parameter equal to 0. Additional information about the noise interpolation state parameter may be found in Section 4.1.3 under the keyword NCFILE.

Figure 2-23 is an example of the text input deck for AAM created from the .OPS file presented in Figure 2-22. The .OPS file keyword FIXEDWINGPROF triggers calculation of this particular profile by AAM instead of NOISEMAP. Section 3.5.2 describes in full detail the contents of the FIXEDWINGPROF keyword.

```
FIXEDWINGPROF      1
F18A2     FIXEDWING F18A_                                    %NC
04A2               0         0    0.4625        0.     0.011         1        10
          TACAN Arrival to Runway 04
                   0        90        88          2       135         0         0         0         0
                4557       540        88          2       140         0         0         0         0
               10848      1040        88          2       140         0         0         0         0
               17139      1040        86          0       140         0         0         0         0
               28389      1540        87          0       300         0         0         0         0
               45042      1540        87          0       300         0         0         0         0
               75439      2540        86          0       300         0         0         0         0
               86884      2540        86          0       300         0         0         0         0
              152281     10040        81          0       300         0         0         0         0
              249121     10040        81          0       300         0         0         0         0
```

Figure 2-23. Keyword Block Describing a Flight Profile for Use with NOISEMAP

2.5.3 Rotorcraft Longitudinal Maneuvering Extension

A Quasi-Static Acoustic Mapping (Q-SAM)[54,55] method that takes into account the quasi-static performance states of a conventional helicoptor rotorcraft has been implemented. This method allows one to include the acoustic effects of moderate longitudinal acceleration and deceleration in acoustic predictions. The acoustical equivalence is based on the non-dimensional modeling that can be represented in the first order as:

$$\gamma_{eff} = \gamma + \frac{\dot{v}}{g} \tag{12}$$

where:

γ_{eff} is the effective flight path angle (radians)

γ is the physical flight path angle (radians)

$\frac{\dot{v}}{g}$ is the longitudinal acceleration (relative to gravity).

For small accelerations (less than 0.1 g), there is a direct equivalence between acceleration and climb angle. For example, a 0.1 g acceleration along the flight path corresponds to a 0.1 radians (5.7 degrees) climb angle. The selection of the source data to represent the accelerating flight proceeds by utilizing the new effective flight path angle.

The physical link between the acceleration and flight path angle is via the rotor tip-path plane angle. To first order, the tip path plane operating conditions during slowly accelerating flight are nearly identical to an equivalent steady flight condition at the effective flight path angle. The orientation of the tip-path plane relative to the horizon between these two equivalent conditions differs by the effective flight path angle. The QSAM methodology[54,55] indicates that the orientation of the tip-path plane relative to the horizon is more nose-up during a deceleration maneuver. This capability is enabled by using the QSAM1 keyword. This triggers the model to select and rotate the helicoptor source characteristics using the effective flight path angle, γ_{eff} (see Eq. 12), for non-zero longitudinal flight.

2.5.4 Fixed Wing Altitude Thrust Correction

The reference noise data input to AAM is normalized to sea level conditions. When aircraft descend above 1,000 feet (ft) above Mean Sea Level (MSL), a correction is applied to correct the reference noise data. The correction effectively decreases the reference noise data by 2 dB per 10,000 ft. The correction assumes that noise output is reduced as effective thrust decreases and effective thrust decreases with altitude.[61] The formula for the adjustment is

$$\text{Altitude thrust adjustment} = 10^{[.00002(1000.-Z)]}$$

where Z is the aircraft altitude in ft MSL.

2.5.5 Multiple Source Treatment

AAM is capable of analyzing multiple broadband, narrow band, and pure-tone sources used in combination to define the full noise emission for one vehicle. For a given noise source, the arrival time is calculated based on a straight line propagation path from the sound sphere center to the

receiver using the local speed of sound at the vehicle. For computational efficiency, the vehicle center is used for broadband and narrow band arrival time since phase is not a concern with broadband (incoherent) noise signals. This imparts the assumption that the distance between multiple broadband sound spheres is small compared with the propagation path length. For pure-tone (coherent noise source) propagation the phasing between multiple spheres and any slight difference in propagation path length is critical.

In addition, there are potential phasing differences from one source sphere and trajectory point to another which must be considered. The model sequences the source signals in terms of absolute phase. The source spheres are referenced from the first time point in the flight trajectory. This sequencing is necessary to ensure proper phase alignment between multiple source spheres as required by the varying operational conditions. The resultant phase of a given signal at the receiver point is a sum of the original defined source sphere phase plus the phase change between the beginning of the flight track and the vehicle flight track location (time) from which the pure-tone sphere is propagated. Any phase changes due to different propagation paths from the pure-tone sphere centers to the receiver location are handled by the propagation module. For bookkeeping purposes and summation (incoherently) with broadband noise, the arrival time is considered to be the absolute time at which a signal travels from the vehicle origin to the receiver location. The coherent signal addition is performed using the fully synchronized phase from the start of the flight track in order to capture the constructive/destructive interference patterns for each pure-tone frequency.

A pure-tone source emission may be represented by

$$p(t) = A_1 e^{i(\omega_n t + \theta_1)} + \ldots + A_n e^{i(\omega_n t + \theta_n)} \qquad (13)$$

where $p(t)$ is the instantaneous pressure at time t. Each discrete frequency may be represented by A_n, ω_n, *and* θ_n : amplitude, frequency and phase, respectively.

As the signal propagates through the atmosphere its amplitude undergoes changes due to spherical spreading, atmospheric absorption, and intervening terrain and ground reflections. The phase is also transformed by the nature of the ground reflection. The signals may be combined by considering the real and imaginary components and multiplying the pressure with its complex conjugate.

$$|p|^2 = [\mathrm{Re}\{p\}]^2 + [\mathrm{Im}\{p\}]^2 \qquad (14)$$

This manner of absolute time and absolute phase tracking was implemented in order to eliminate the need for the iterative schemes found in early versions of the flight track module. This binning and interpolation approach also enabled the proper physical treatment of pure tone and narrow band sound spheres by including phase. At present, the curved ray module, RNMwea, can calculate the effect of curved rays for broadband or narrow band sources. A technical description of this may be found in Section 2.2.3.

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3.0 Advanced Acoustic Model User's Guide

3.1 Overview

The calculation of aircraft noise requires the complete specification of the aircraft flight track, the orientation of the vehicle on the flight track, the vehicle operational parameters along the track, the location of the listener positions, and the type and number of aircraft assigned to each of the flight tracks. A single flight track is constructed from a series of connecting line segments, specified as straight or curved segments (Figure 3-1). As input to the model the user specifies:

- The beginning and ending point of each line segment in an earth-fixed coordinate system.
- The height of the track above the reference ground level.
- The turn radius and turn angle if the segment is curved.
- The airspeed.
- The vehicle orientation (roll, angle of attack, and yaw).
- The nacelle tilt angle for rotary wing aircraft.
- The engine operating state (thrust and vector angle) for fixed wing aircraft.
- Location of the receiver positions (grid or individual points of interest).

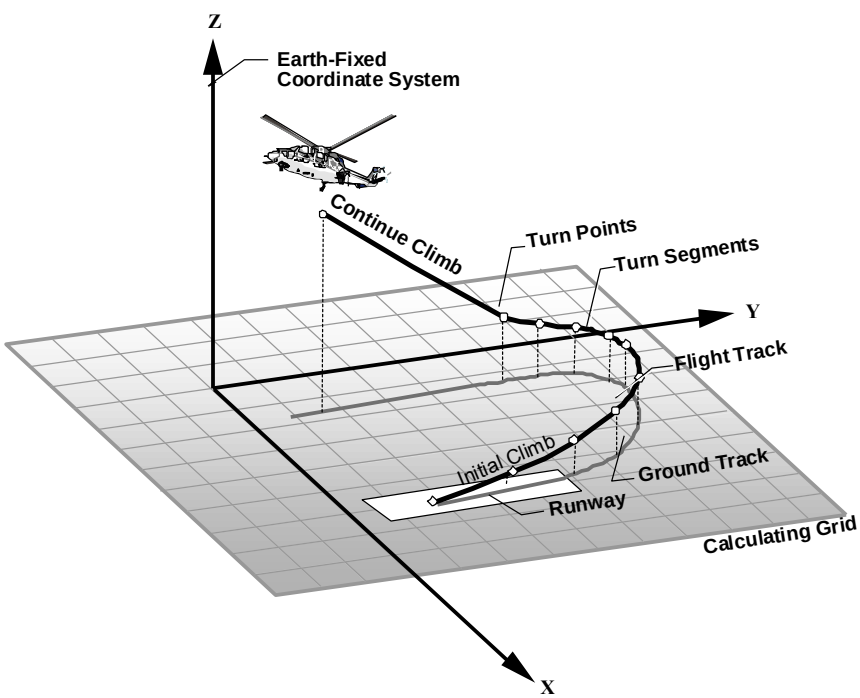

Figure 3-1. Example: Sample Flight Track

The output is dependent on whether the user chooses a grid of receiver positions or specific points of interests. Reference frame and angle definitions and geometric illustrations may be found in Chapter 2.

The acoustic model reads two ASCII input file formats: a single track format and a multiple track format. The single track format is designed for research purposes where the user is interested in calculating the noise exposure footprint for a single operation. The multiple track format is used for predicting the noise contours at a airport or vertiport where there are often multiple daily operations assigned to departure and arrival flight tracks. If the user chooses the single track file format, the noise model will report noise metrics appropriate for a single aircraft noise event. Otherwise, for a multiple track file format, the noise model outputs cumulative noise metrics which integrate the individual aircraft noise events over the specified multiple operations. Table 3-1 provides a summary of the different types of output. All of the graphical output is in the form of ASCII and binary grid files that are ready for importing into Tecplot [27] and NMPlot,[16] respectively. Both of these computer programs may be used to graphically display the noise predictions.

This chapter presents the procedure for entering flight track and operation data into the noise model. The first two sections review terminology and geometric definitions used throughout this document and the definition of the noise metrics. The remaining sections contain step-by-step instructions on entering data into the model and running the program.

Table 3-1. Summary of AAM Output

Input File	Type of Receiver	Description of Output
Single Track Format	GRAPHICAL OUTPUT	
	Grid of Receivers	Noise Footprints At Each Grid Point – SPL, SPL(A), PNL, PNLT
	Grid of Receivers	Noise Contours - SEL, SEL(C), SEL(A), L_{max}(A), EPNL, NA
	Points of Interest	Time History Plot - Overall SPL, SPL(A), PNLT, DPRIME
	TABULATED OUTPUT	
	Points of Interest	Time History Tabulated - L_{max}(A), SEL, SEL(C), SEL(A), EPNL
	Points of Interest	Table of Levels - Overall SPL, SPL(C), SPL(A), PNL, PNLT
Multiple Track Format	GRAPHICAL OUTPUT	
	Grid of Receivers	Noise Exposure Contours - DNL, CNEL, NEF, WECPNL, NA
	Points of Interest	Time History Plot - Overall SPL, SPL(A), PNLT
	TABULATED OUTPUT	
	Points of Interest	Ranked Events - SEL(A), L_{max}(A), R_{min}
	Points of Interest	Table of Levels - DNL, CNEL, L_{eq}, L_{eq}(C), L_{eq}(A), L_{max}(A), NA

3.2 System and Installation

The software distribution is in the form of a self-extracting Windows executable which will automatically uncompress the executable modules, the acoustic source data and sample files. Table 3-2 shows a listing of the files contained on the distribution disk. Not shown in this table are the installation program, the sample input files, and the acoustic source data.

Table 3-2. Software Distribution for a PC Running Microsoft Windows

File Name	Description
3DVISUALIZER.EXE	Reads in elevation data and AAM output .TIG files, and allows for 3D visualization of the flight trajectory, as well as the noise data overlayed on an elevation data set. 3DVISUALIZER can also be used to output bitmaps, which can then be turned into video files.
AAM.EXE	Advanced Acoustic Model for prediction of environmental noise for fixed and rotary wing aircraft.
ART.EXE	Acoustic Repropagation Technique program, which takes both the time history data generated by AAM and microphone data and uses these data sets to generate sound hemispheres.
BACKTIG.EXE	Inserts specified background spectral data into a .TIG file.
BUILDIMP.EXE	Reads an XYZ ASCII impedance file and creates an NMBGF-format impedance file.
BULLWINK.EXE	Creates a broadband, narrow band or pure tone sound sphere based on the user input.
DEDOPPLERIZER.EXE	Reads in microphone data and removes Doppler effects.
ELV2PLT.EXE	Reads in a NMBGF-format .ELV or .IMP file and creates a Tecplot .PLT file.
ELVBUILDER.EXE	Utility for the creation of elevation and impedance files.
FLATTENELV.EXE	Reads in an NMBGF-format .ELV file and flattens the elevation at the existing grid points.
IMPCHANGER.EXE	Reads in an NMBGF-format .IMP file and creates a new .IMP file with a user-specified flow resistivity with the same dimensions and grid points.
NB2TIG.EXE	Reads in a narrow band background spectra and outputs a .TIG file.
NCDUMP.EXE	NetCDF utility used to display the contents of a NetCDF file.
NETCDF.DLL	Dynamic link library used by NetCDF software to read and write the sound sphere acoustic data.
PLT2ELV.EXE	Reads in Tecplot-format impedance or elevation data and creates an NMBFG-format .ELV or .IMP file.
POI2MIC.EXE	Reads in an AAM-generated .POI file and outputs microphone input data files for each POI.
PULLTIG.EXE	Creates an output Tecplot contour file from an input .TIG file at a user-specified point along the flight trajectory.
RAZ2PLT.EXE	Reads in a user-specified .RAZ atmospheric data file and outputs a Tecplot file.
RAZSUBTRACT.EXE	Reads in two .RAZ files and creates a Tecplot .POI file of the difference between them.
RNMWEA.EXE	Reads in atmospheric data and creates an .RAZ file suitable for use with AAM.
SPHERE.EXE	Reads a sound sphere NetCDF file and writes a text file that is used by Tecplot to display a 3-dimensional image of the sound sphere.
TH2MIC.EXE	Takes a time history input file created by AAM and outputs a set of microphone data files.
TRJRESAMPLER.EXE	Resamples a flight trajectory output by AAM to a user-specified time spacing.

Table 3-3 lists the system requirements for AAM, ART, and NMPlot.

Table 3-3. System Requirements

Category	Requirement
Hardware	32-bit Pentium II or better microprocessor, 300 MHz or faster VGA or higher resolution video display adapter Hard disk with 1.8 gigabytes (GB) minimum free space CD-ROM drive
Memory	512 MB recommended minimum
Software	Windows 95 or higher, Windows 2000, Windows NT, Windows XP, Windows Vista, or Windows 7.

To install AAM, copy the INST-AAM.exe into the directory where you would like the software to be installed. For the purposes of explanation this will be c:\AAM. From explorer, double-click on the INST-AAM.EXE file to unpack the AAM. Alternatively, you may type INST-AAM.EXE from a Windows command prompt Alternatively, from the Run option under the Start menu button, browse and select INST-AAM.EXE. This will unpack a series of executables, noise source spheres, and sample files. The standard installation process for AAM unpacks distribution fixed and rotary wing NC source files into a single directory. The user may elect to separate rotary wing and fixed wing acoustic data into separate directories. AAM will support such directories.

Once the INSTALL program is completed, you must make the following two changes to your AUTOEXEC.BAT file or run from the command line before executing AAM:

SET ROTOR_NOISE=C:\AAM\NCFILES

SET FWING_NOISE=C:\AAM\NCFILES

PATH=%PATH%;C:\AAM\BIN

If the software or source data.NC files were installed into a directory other than C:\AAM, substitute that directory name in the additions above. If you make these changes to your AUTOEXEC.BAT file, you must reboot your computer or rerun AUTOEXEC.BAT to activate them. Alternately, one can set the path and environmental variables through Windows.

- Step 1 – Right click on My Computer and click on the Advanced tab under system properties.
- Step 2 – Click on the Environmental Variable button located on the bottom of the tab.
- Step 3 – Go to System Variables and click on New.
- Step 4 – Add ROTOR_NOISE as the Variable Name and for the Variable Value enter C:\AAM\ncfiles (or the path to the sound spheres if you installed to any directory other than the default installation). Click OK.
- Step 5 – Repeat steps 1-3.
- Step 6 – Add FWING_NOISE as the variable noise, and for the variable value enter C:\AAM\ncfiles (or the path to the sound spheres if you installed to any directory other than the default installation). Click OK.
- Step 7 – Search for the system variable "path" and select Edit; scroll to the end of the Variable Value and add C:\AAM\bin (or add the path to the AAM executable if you installed to any directory other than the default installation). Note: semi-colon (;) delimiters are required in between directories.

For users of computers with the Vista operating system, click the Start button and type Accounts in the 'Start Search' box. Click 'User Accounts' under 'Programs'. In the User Accounts dialog box, click 'Change my environment variables' under Tasks. Add ROTOR_NOISE as an environment variable with the associated path noted above. Also, add 'path' as an environment variable in the location of the AAM executable followed by %path% for its value. For example, if aam.exe is in c:\noisemap\aam, then type c:\noisemap\aam;%path% for the value.

3.3 Noise Metrics

Various federal agencies involved in environmental aircraft noise studies have agreed on common metrics for environmental documents, and both the Department of Defense and the Federal Aviation Administration have specified those which should be used for federal aviation noise assessments.

3.3.1 Maximum Sound Level (L_{max})

The highest A-weighted sound level measured during a single event in which the sound level changes value as time goes on (e.g., an aircraft overflight) is called the maximum A-weighted sound level or maximum sound level. It is usually abbreviated L_{max} or L_{amax}.

3.3.2 Sound Exposure Level (SEL)

Individual time-varying noise events have two main characteristics—a sound level which changes throughout the event, and a period of time during which the event is heard. Although the maximum sound level, described above, provides some measure of the intrusiveness of the event, it alone does not completely describe the total event. The period of time during which the sound is heard is also significant. The Sound Exposure Level (SEL) combines both of these characteristics into a single metric.

SEL is a logarithmic measure of the total acoustic energy transmitted to the listener during the event. Mathematically, it represents the sound level of the constant sound that would, in one second, generate the same acoustic energy as did the actual time-varying noise event. Since aircraft overflights usually last longer than one second, the SEL of an overflight is usually greater than the maximum sound level of the overflight.

Note that Sound Exposure Level is a composite metric, which represents both the intensity of a sound and its duration. It does not directly represent the sound level heard at any given time, but rather provides a measure of the net impact of the entire acoustic event. It has been well established in the scientific community that SEL measures this impact much more reliably than just the maximum sound level when considering human response.

3.3.3 Day-Night Average Sound Level (DNL)

Time-average sound levels a measure of the average sound energy during the measurement period. For the evaluation of community noise effects, and particularly aircraft noise effects, the Day-Night Average Sound Level (DNL or L_{dn}) is used. DNL averages sound levels at a location over a complete 24-hour period, with a 10 dB adjustment added to those noise events which take place between 10:00 p.m. and 7:00 a.m. (local time). This 10 dB "penalty" represents the added intrusiveness of sounds which occur during normal sleeping hours, both because of the increased sensitivity to noise during those hours and because ambient sound levels during nighttime are typically about 10 dB lower than during daytime hours. Ignoring the 10 dB nighttime adjustment for the moment, DNL may be thought of as the constant A-weighted sound level over a 24-hour period which contains the same total sound energy as the actual 24-hour time history.

DNL provides a single measure of overall noise impact, but does not provide specific information on the number of noise events or the individual sound levels which occur during the day, for example, very few noisy events, or a large number of quieter events.

3.3.4 Community Noise Equivalent Level (CNEL)

In the State of California, the standard for the evaluation of community noise effects from aircraft is the Community Noise Equivalent Level (CNEL). The definition of CNEL is similar to DNL except for the following two components: (1) the daytime period is defined from 7:00 a.m. to 7:00 p.m., and (2) an evening period is introduced and defined as from 7:00 p.m. to 10:00 p.m., with a five decibel adjustment added to those noise events which occur during that period. The nighttime adjustment of +10 dB is identical to that of DNL.

3.3.5 Perceived Noise Level (PNL)

The Perceived Noise Level (PNL) is a rating of the "noisiness" of sound from an aircraft as opposed to the "loudness" of that sound. It is a weighted summation of the sound pressure levels in the 24 one-third octave bands centered between 50 Hz and 10 KHz. Developed by Kryter[57] specifically for fixed wing jet aircraft flyover noise, a discussion on the PNL is found in 14 CFR Part 36, Appendix B.[58]

3.3.6 Tone-Corrected Perceived Noise Level (PNLT)

The Tone-corrected Perceived Noise Level (PNLT) is the sound pressure level obtained by adding to the perceived noise level an adjustment which accounts for tonal components in the vehicle acoustic spectrum.

3.3.7 Effective Perceived Noise Level (EPNL)

EPNL is a metric which takes into account duration of the noise event based on a tone-corrected PNLT time history. A duration correction is based on the minimum of the event time within 10 dB of the maximum PLNT or the time when 90 dB PLNT is exceeded.[58]

3.3.8 Weighted Equivalent Continuous Perceived Noise Level (WECPNL)

WECPNL characterizes flyover and run-up noise events with EPNL and PNLT, respectively. WECPNL, like CNEL, averages sound levels at a location over a complete 24-hour period, with a 5 dB adjustment added to those noise events which take place between 7:00 p.m. and 10:00 p.m. and a 10 dB adjustment added to those noise events which take place between 10:00 p.m. and 7:00 a.m. the following morning. This 5 dB and 10 dB "penalty" represents the added intrusiveness of sounds which occur during the evening and nighttime, both because of the increased sensitivity to noise during those hours and because ambient sound levels during evening and nighttime are typically about 5 dB and 10 dB, respectively, lower than during daytime hours.

3.3.9 D-Prime Audibility (DPRIME)

The D-prime metric describes the auditory detectability index d' based on one-third octave band target and background spectra, taking into account the normal equal-loudness threshold of hearing.[59,60] Two parameters are derived: D-prime (referred to in the output files as DPRMX), which is the maximum value of d' across any of the one-third octave bands, and D-prime cumulative (referred to in the output files as DPR), which is a pressure integration across the individual bands.

3.3.10 Number-of-events Above (NA)

Number-of-events Above (NA) presents the number-of-events per day where the sound level in a specified metric meets or exceeds a user-specified threshold.

3.3.11 Time Above (TA) a Specified Level (L)

The Time Above (TA) metric is a measure of the total time that the A-weighted aircraft noise level is at or above a defined sound level threshold. Combined with the selected threshold level (L), the TA metric is symbolized as TAL. TA is not a sound level, but rather a time expressed in minutes. TA values can be calculated over a full 24-hour annual average day, the 15-hour daytime and 9-hour nighttime periods, a school day, or any other time period of interest, provided there is operational data to define the time period of interest.

TA has application for describing the noise environment in schools, particularly when comparing the classroom or other noise sensitive environments for different operational scenarios. TA can be portrayed by means of noise contours on a map similar to the common DNL contours.

The TA metric is a useful descriptor of the noise impact of an individual event or for many events occurring over a certain time period. When computed for a full day, the TA can be compared alongside the DNL in order to determine the sound levels and total duration of events that contribute to the DNL. TA analysis is usually conducted along with NA analysis so the results show not only how many events occur above the selected threshold(s), but also the total duration of those events above those levels for the selected time period.

In the context of AAM, TA is computed for all the operations prescribed in the input file. In single event mode the TA metric output at either a point of interest or a set of grid points reflects the time (in minutes) for which the specified threshold was met or exceeded. In multiple OPS mode the aggregated time for all operations is computed.

3.4 Input File Description

A major consideration in the development of AAM is the input file format. RNM, the legacy code from which AAM evolved was developed for both aeroacoustic research purposes, and predicting community noise. RNM was developed with two primary modes of analysis: (1) single operation analysis (research mode), and (2) multiple operations analysis (community noise model). This dual use functionality has been retained in AAM. The keyword-controlled file format is simple to use for research applications involving a single flight track. It is also capable of accepting operational data to model the noise environment at airports involving multiple tracks with different aircraft operations assigned to each track. Section 3.4.1 defines the single track format and Section 3.4.2 defines the multiple track format.

One application of AAM is to identify low noise takeoff and landing profiles by creating and interpreting detailed information on the noise footprint. The single track mode may also be used to create three dimensional sound simulation videos in order for the viewer to gain a better understanding of the sound propagation, especially over varying terrain. A sample .AVI video file created using rotary wing propagation is included with the software distribution package. Additional applications are the development of noise abatement profiles or the comparison between noise footprints using sound spheres created using analytical models (CFD), field measurements, or wind tunnel measurements.

The prediction of community noise impact contours requires AAM to simulate all noise-generating activities that result from annual flight operations. The multiple-flight track format is consistent with that used by NOISEMAP[6]. The multiple track format requires a more detailed definition of the airfield than the single track version, but has the advantage that its form and structure are

consistent with the data currently logged and collected by the flight crews and airport/base personnel.

The structure of the input files is based on a system of keywords; each keyword signifies the type of data that is entered into the noise model. Data input and output is made by a combination of dimensional and dimensionless variables. British Standard Units (BSU) are used throughout the program.

Program execution is a single pass acoustic simulation. It obtains its analysis directions from an ASCII input file. This file has a structured keyword driven format. Keywords control both the computations and the data it utilizes for analysis. These keywords and the associated blocks of data may be freely inserted into the input file. Depending on the level of analysis (single flight track or multiple operations), input may consist of a single .INP file or a single .RUN file with an associated operations (.OPS) file. The latter mode has been designed to be compatible with analysis tools presently adopted by the Department of Defense for analyzing community noise impact due to fixed wing aircraft operations.[6,51]

When the input file is read, certain assumptions are made about the data. These assumptions are as follows:

1. All lowercase characters are interpreted as uppercase characters;
2. All length dimensions are in units of feet;
3. Altitude is in units of feet, and AGL or MSL depends on the presence of keywords;
4. All speeds are in units of knots; and
5. All angles are in units of degrees.

AAM has error checking features that identify some common errors.

Tables in the following sections describe each keyword block. The expected line number, relative to the keyword defined as line (1) is given. Keywords themselves should be left-justified and begin in column one (1). All keywords should be in all capital letters. The format field is given in FORTRAN notation: A, I, and F. The letter A appearing under the format column signifies a character input, while the letter I signifies an integer value. For example, A10 represents a data field that may be 10 characters long. I10 represents an integer data field that may be 10 elements long. All text strings must be left justified in their respective fields and must be capitalized where noted. Numeric inputs may appear anywhere in their allocated columns. Filenames and paths up to 256 characters in length are allowed. Spaces are not permitted in filenames or pathnames.

3.4.1 Single Track Format

AAM recognizes the .INP extension as an ASCII file containing the specification for a single flight track. Contained in this file are keywords that define the vehicle orientation (roll, angle of attack, and yaw) and operational state (airspeed, flight path angle engine operating state, thrust vector angle, and nacelle tilt angle), the flight track segments, the size and dimension of the grid for which noise calculations are to be made, the location of points of interest, and the type of output desired. Additional information defining the ground terrain and impedance and any special output files are contained in the .INP file. The data required by each keyword may be given in free formats, comma- or space-delineated.

There are two different types of keywords: keywords that are used to enter data into the model and keywords that control computational analysis and reporting features. Some commonly used data input and computational keywords are introduced here.

ART - This signals the model to create a detailed output time history (.TH) file for use by the sphere assembly program, ART and the DeDopplerizer program for creation of stationary sources.

ATMOS - Specifies the atmospheric profile (humidity, temperature and pressure as a function of geometric altitude). The ATMOS keyword triggers the model to consider atmosphere effects on straight ray sound propagation.

AUDIB - Triggers the creation of a narrow band output .TIG files for audibility analysis.

COMPUTEGRD - Outputs one of the following noise metrics to a .GRD file: unweighted SEL, A-weighted SEL, C-weighted SEL, or maximum A-weighted sound level. A .GRD file is used with NMPlot. To specify which noise metric will be written to the .GRD file, the input file must also include one of the following keywords: SEL, SELA, SELC, or LMAXA. Otherwise, by default a grid file will contain A-weighted SELs. When the DPRIME keyword is enabled COMPUTEGRD will also output the audibility metric D-prime to the .GRD file.

COMPUTEPLT - Outputs the unweighted SEL, the A-weighted SEL, the C-weighted SEL, the A-weighted maximum sound level, and the EPNL on a grid of equally spaced points. The results are written in Tecplot format to a file with a .PLT extension.

COMPUTEPOI - Outputs the sound levels at specific points of interest. The input file must contain a POI keyword, which describes the location for the points of interest. A time history of the overall SPL, the A-weighted SPL, and the PNLT are written in Tecplot format to an ASCII file with a .POI extension.

DIAGNOSTICS - Outputs an extensive number of internal diagnostic messages.

NO REPORT - Suppresses the default output messages.

ONE TRACK - Signals that the user will specify the flight trajectory in detail: the X, Y, and Z coordinates in feet relative to the earth-fixed coordinate system, the turn angle in degrees, the airspeed in knots, the angle of attack, the roll angle, the yaw angle, and the nacelle tilt angle in degrees.

POI - Specifies the location (X, Y, and Z in the earth-fixed coordinate system) for points of interest for which the time history or detailed acoustic signal (frequency, amplitude, and phase) are calculated and output.

REM - Marks a comment (remark) line. Information on these lines is ignored.

SETUP PARA - Specifies the grid dimensions, the aircraft name (corresponding to the 5-character .NC filename), the vehicle source locations, acoustic type (broadband or pure tone/phase), and several other global parameters.

SPECTRUM - When analyzing pure-tone sound spheres the SPECTRUM keyword creates a Tecplot output file containing the raw pure tone individual and summed un-weighted dB output. Each source frequency and phase is independently propagated and treated as a separate zone in the Tecplot file and may be post processed in order to reconstitute pressure time history signals.

TERRAIN - When the analysis is to include varying terrain or varying acoustic ground impedance the TERRAIN keyword is used.

TIMETRAJ - Used when the ONE TRACK specification includes local time in seconds after midnight at the beginning of each trajectory point input line.

VIDEO - Triggers creation of one-third octave band time history data (.TIG file) at each grid point for post processing into sound animations with 3DVisualizer.

WEATHER - Specifies an external weather (.RAZ) file from the pre-processor RNMwea. At present, this option may only be used over uniform flat terrain for broadband or narrow band spheres in single track mode.

3.4.1.1 Geometric Study Setup

The geographical area over which the noise calculations are to be computed must be defined. An earth-fixed Cartesian coordinate system is used to provide complete spatial definition of the flight track and the receiver positions. The user has the option of working either in a local coordinate system or UTM coordinates. The workspace is in the form of a horizontal grid described in terms of its lower left and upper right hand corners. These corners designate a rectangular grid space within which the noise levels will be calculated. The user must also choose the grid spacing in the X and Y directions. A fine grid might have a spacing of a hundred feet while a course grid spacing could be a thousand feet. Certain restrictions are imposed by the model to avoid potential problems with the contouring programs. Following is a list of these restrictions:

- The number of grid points in both the X and Y directions, must be greater than or equal to 5.
- The total number of grid points must fit in the available machine memory.

If these criteria are not satisfied, the computational module will either modify the grid domain or terminate the program depending on the cause of the error. In either instance, the program will notify the user if a problem develops.

The three-dimensional flight track trajectory must be defined. A flight trajectory may be composed of straight line and circular segments. At each turn point the user must define a flight path angle, engine operating state parameters, nacelle tilt angle, and the airspeed. The flight conditions associated with the available source characteristics should be considered when defining the vehicle flight path and operating state. The model will automatically sort the available noise spheres and create tables similar to those presented for rotary wing (Table 3-4a), and fixed wing (Table 3-4b) aircraft operations.

Often, the conditions specified at a turn point will not exactly correspond to the conditions found in the acoustic data set. AAM has implemented a procedure for choosing the best available sound sphere for a given flight condition. Section 2.5.1 contains the details of the sound sphere selection and interpolation process for both rotary wing and fixed wing vehicles. AAM maintains a record of the sound spheres used in the calculations and tabulates the information near the bottom of the output file.

Table 3-4a. Sample of Rotorcraft Source Data Flight Conditions (CH-146)

Sphere Index Number	Flight Path Angle (Degrees)	Pylon Angle (Degrees)	Airspeed (Knots)	Rate of Ascent or Descent (Feet per Minute)
189	-12.0	90.0	58	-1224.6
188	-11.00	90.0	80	-1547.7
179	-6.00	90.0	62	-658.5
171	-6.00	90.0	104	-1101.3
181	-5.00	90.0	58	-513.9
175	-5.00	90.0	84	-737.6
173	-5.00	90.0	107	-947.5
183	-4.00	90.0	44	-311.1
120	0.00	90.0	78	0.0
105	0.00	90.0	98	0.0
101	0.00	90.0	99	0.0
170	0.00	90.0	100	0.0
104	0.00	90.0	102	0.0
194	0.00	90.0	102	0.0
117	0.00	90.0	119	0.0
121	0.00	90.0	120	0.0
122	0.00	90.0	126	0.0
118	0.00	90.0	126	0.0
110	0.00	90.0	127	0.0
106	1.00	90.0	81	143.7
114	1.00	90.0	98	173.2
124	1.00	90.0	111	196.6
112	1.00	90.0	128	227.0
222	1.00	90.0	129	227.8
152	3.00	90.0	83	440.3
130	4.00	90.0	78	552.5
128	4.00	90.0	82	577.6
154	4.00	90.0	88	620.9
126	5.00	90.0	80	709.7
180	9.00	90.0	73	1156.1
176	9.00	90.0	94	1486.7
178	9.00	90.0	96	1518.1
182	10.00	90.0	67	1172.9
174	10.00	90.0	76	1328.2
166	11.00	90.0	62	1201.0
184	11.00	90.0	98	1886.8
172	12.00	90.0	74	1567.0
160	15.00	90.0	60	1567.4
158	15.00	90.0	61	1596.7

Table 3-4b. Sample of Fixed Wing Source Data Flight Conditions (AV-8B)

Run Number	Thrust Vector Angle Deg.	Power	Speed Knots	Climb Rate ft/min	Vehicle Config.
108	0	73	252	0	0
105	0	80	219	0	0
952	0	99.3	404	0	0
135	0	111	391	0	0
107	25	73	230	0	0
109	40	75	205	0	0
111	60	91	164	0	0
239	72	105	162	0	0
121	83	101	187	0	2

Notes: Aircraft Config — 0 = clean, 1 = flaps, 2=flaps + gear, 3 = Static Run-Up
Interpolation State — 0 = No interpolation, 1 = Interpolation Permitted

Figure 3-2 presents a sample input file that corresponds to the hypothetical flight track drawn in Figure 3-3. Specific keyword data input formats are defined in detail in Section 3.5.1.3. The first four keywords shown in this example are used to direct the computational control and reporting features of the model. These keywords will cause the model to:

- Display diagnostic messages.
- Calculate the time history and integrated metrics at points of interest.
- Calculate the noise contours on the computational grid.

The sample workspace measures 10,000 feet by 10,000 feet and the spacing between the grid points is 200 feet in the X and Y directions. The reference ground elevation is at 500 feet above mean sea level and the grid lies five feet above ground level. Terrain is not utilized in this example. The type of vehicle is a CH-146 helicopter. The vehicle will be modeled using a single broadband sound sphere located at the center of the vehicle.

The flight track has seven turn points or equivalently six segments. In Figure 3-3 the turn points are labeled A through G. Four of the segments are straight line segments (AB, BC, DE, and FG), and two of the segments are turns (CD and EF). The starting point for the track is at point A where X = 1000 feet, Y= −9000 feet, and Z= 1000 feet AGL. The track proceeds in the positive Y direction, while the airspeed decreases from 100 knots to 90 knots. Segment AB and part of BC extend beyond the boundaries of the workspace. This is perfectly acceptable provided the track and workspace use a common earth-fixed coordinate system and no topography. A right-hand turn begins at point C with a radius of 1000 feet and a change in heading angle of 270 degrees. Following the turn is a straight line segment (DE) which joins a second turn, having the same conditions as before. The final line segment decreases from 1000 feet to 600 feet AGL. When the calculations are completed the model will have used interpolations between sphere numbers 001, 010, and 027. Table 3-4a describes the conditions. Section 2.5.1 describes the interpolation procedure.

When designing a flight track with a circular segment, one should begin and end curves with straight segments. A flight track may never begin nor end with a curved segment.

3.4.1.2 Single Track Command Line Execution

Once an input file is available for processing, AAM can be run from the command prompt. To run the program type "AAM" followed by the name of the input file.

On an Intel-based platform, AAM expects the input file (filename.INP) to be located in the current working directory and the NetCDF files to be located in the directory specified by the ROTOR_NOISE, and FWING_NOISE environment variables.

On a UNIX platform, AAM expects the following files to be located in the same directory as the executable:

- filename.INP - input file for a single operation.
- filename.NC - files containing the raw acoustic data.

If the operating system is Windows the file NetCDF.DLL is required. This file is a dynamic link library and should be located where other dynamic link libraries are stored and used by the operating system. For example, under Windows XP the directory frequently used for dynamic link libraries is c:\windows\system32.

```
REM456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
REM       ^         ^         ^         ^         ^         ^         ^         ^         ^
REM       11-20     21-30     31-40     41-50     51-60     61-70     71-80     81-90     91-100
DIAGNOSTICS
COMPUTEPOI
COMPUTEPLT
COMPUTEGRD
SETUP PARA
       200       200       500
     -5000     -5000         5
      5000      5000
        60     30000    100000
ch146
1
      0.00      0.00      0.00
0
0
REM  X(ft)     Y(ft)     Z(ft) Turn(deg)   Rad(ft)  Spd(kts)  Yaw(deg)  AOA(deg) Roll(deg) Nacl(deg)
REM                                                            +L turn            +L down
ONE TRACK
Pretzel Track
7
   1000.00  -9000.00   1000.00      0.00      0.00    100.00      0.00      0.00      0.00     90.00
   1000.00  -8000.00   1000.00      0.00      0.00     90.00      0.00      0.00      0.00     90.00
   1000.00   2000.00   1000.00    270.00   1000.00     90.00      0.00      0.00      0.00     90.00
   2000.00   1000.00   1000.00      0.00   1000.00     90.00      0.00      0.00      0.00     90.00
  -2000.00   1000.00   1000.00    270.00   1000.00     90.00      0.00      0.00      0.00     90.00
  -1000.00   2000.00   1000.00      0.00      0.00     50.00      0.00      0.00      0.00     90.00
  -1000.00  -2000.00    600.00      0.00      0.00     50.00      0.00      0.00      0.00     90.00
POI
2
mic 1          0.00      0.00      0.00
mic 2          0.00  -1000.00      5.00
END
```

Figure 3-2. Sample Input File for a Single Flight Track

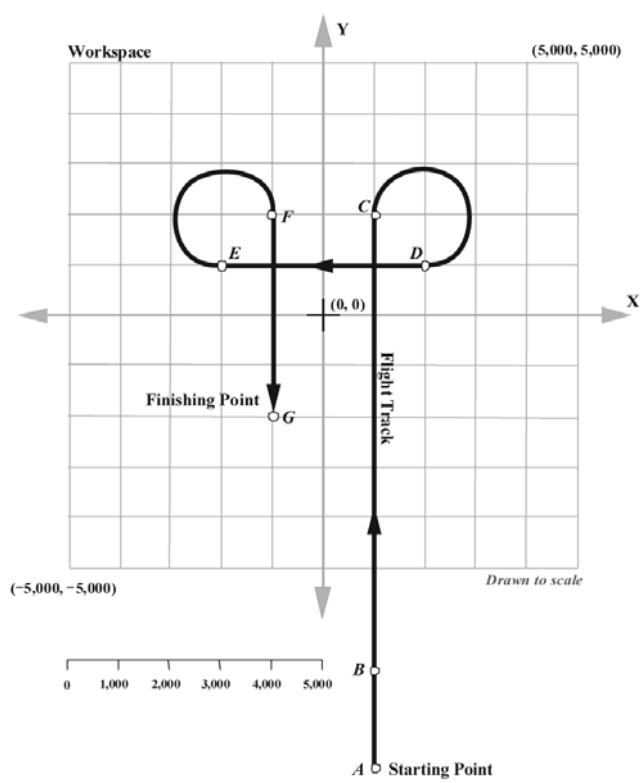

Figure 3-3. Sample Flight Track

3.4.1.3 Single Track Input File (.INP) Description

AAM recognizes the .INP extension as an ASCII text file that describes the flight operations for a single aircraft operating on a single flight track. This section describes the single track format keywords. Keywords perform two functions: they control the program analysis function and they provide input data to the model. Some do both. A keyword summary is given in Table 3-5. The remainder of this section contains an alphabetical keyword listing followed by a description of its usage and a table showing the required data structure.

Figure 3-4 shows a sample .INP file. At the top of the file are the keywords DIAGNOSTICS, COMPUTEPOI, and COMPUTEPLT. These keywords activate computational and reporting features in the noise model. The next keywords are SETUP PARA, ONE TRACK, and POI. Their purpose is to enter data into the noise model.

Table 3-5. Single Track Input File Keyword Summary

Keyword	Analysis Control	Data Input	Description
ABSANGLES	•	•	Bypass coordinate rotation and use user input directly.
ALL MESSAGES	•		Signals output extremely of detailed intermediate calculation results.
ART	•		Signals output of a time history .TH file with an omnidirectional source
ATMOS	•	•	Use the user defined profile instead of the default US 1976 atmosphere.
AUDIB		•	Triggers output of a detailed .TIG time history file.
BACKGROUND		•	Specify the spectral background levels.
CALCALL			Forces calculation of 100% of operations.
COMPUTEGRD	•	•	Signals creation of a grid file for NMPlot (default = A-weighted SEL).
COMPUTEPLT	•		Signals creation of a grid file for Tecplot.
COMPUTEPOI	•		Signals detailed output at a Point of Interest..
DBDOWN10	•		Forces metric calculations to only use points within 10 dB of the maximum level.
DIAGNOSTICS	•		Signals creation of extensive diagnostic calculation messages.
DPRIME	•		Calculate audibility detectability index *d.'*
DPRIMEMAX	•		Outputs single longest one-third octave band value of the auditory index.
END (1)	•		Marks the end of the file. Data beyond the END is not read.
EULER	•		Overrides automatic Euler angle selection process and allows user to specify mode of calculation (on/off) .
HOTSPOT	•	•	Signals AAM to create spectral output on a radial mesh.
MAST TILT		•	Constant tilt angle uniformly added to source (.NC) orientation (+angle, nose up)(2).
NCSPEC	•	•	User defined source file selections for each trajectory point.
NO REPORT	•		Suppresses the echo of input data in the output file.
ONE TRACK	•	•	Flight trajectory input for analysis.
POI	•	•	Point of Interest detailed analysis will be performed.
QSAM1		•	Longitudinal acceleration/flight path angle equivalence will be used(2).
REM		•	Marks a comment line. Remainder of the line is not read or used.
SETUP PARA (1)	•	•	Required input parameters.
SPECTRUM	•		Signals detailed mixed pure tone/broadband spectral time history (.TH) output.
TERRAIN	•	•	Signals analysis of sound propagation over varying terrain. Ground elevations and impedance will be included in the propagation.
TIMESPACING	•	•	Maximum Δt between trajectory points.
TIMETRAJ		•	Used when synchronized flight trajectory is input.
USERBAND	•	•	Only user specified one-third octave bands used in the metric calculations.
VIDEO	•	•	Create time history files for each grid point for sound animation.
WEATHER	•	•	Signals curved ray calculations.

Notes: (1) These are required keywords.
(2) Only valid for rotary wing operations.

```
REM456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
REM       ^         ^         ^         ^         ^         ^         ^         ^         ^         ^
REM       11-20     21-30     31-40     41-50     51-60     61-70     71-80     81-90     91-100
DIAGNOSTICS
COMPUTEPOI
COMPUTEGRD
COMPUTEPLT
TIMESPACING
10.0
SETUP PARA
       500       500         0
     -1000     -1000         5
      1000      1000
      1000    100000       200     0.0
AV8B_
1
      0.00      0.00      0.00
0
0
FIXEDWINGAC
REM     X(ft)       Y(ft)     Z(ft) Turn(deg) Rad(ft)  Spd(kts) Yaw(deg) AOA(deg) Roll(deg)  Power  T Vector
Config
REM                                                                +L turn            +L down             Angle
State
ONE TRACK
Run 001
2
 -10000.0          0.0        1000.     0.00    0.00   15.00    0.00     0.00      0.00     3000.0    0.00
0
  10000.0          0.0        1000.     0.00    0.00   15.00    0.00     0.00      0.00     3000.0    0.00
0
POI
3
P0k      0.    0.0      4.
P1k      0. 1000.0      4.
P2k      0. 2000.0      4.
END
```

Figure 3-4. Sample .INP File

Keyword **ABSANGLES**

When the **ABSANGLES** function is enabled, the geometry module bypasses any coordinate rotation and directly utilizes the user input earth-based coordinate system source orientation. This keyword is only permitted when modeling vehicles with one source.

Keyword **ALL MESSAGES**

ALL MESSAGES signals AAM to create extremely verbose output at each step of the acoustic calculation process. This keyword should be used with caution, perhaps only with a few points of interest in order to keep output file sizes manageable. The additional output is sent to the regular text output run listing file.

Keyword **ART**

ART signifies that the output will be used by ART to generate a sound sphere. This triggers creation of a .TH file which contains ASCII information about the propagation physics and specific vehicle geometric positioning with respect to the receiver points. The output will be generated for each point of interest. These points should correspond to the microphone measurement locations. The flight trajectory should correspond to the actual flight path flown by the vehicle during the acoustic measurement. The desired spectral format—one-third octave band, (TOFORMAT) or narrow band (NBFORMAT)—must be identified along with the band numbers or frequencies of interest. The source location of the sphere center and the spectral type must match those parameters in the SETUP PARA keyword section.

Table 3-6. ART Keyword Format

Line	Position	Max Length	Description
1	1	3	Keyword for .TH file.
2	1	8	TOFORMAT or NBFORMAT.
3	1	4	Number of bands or frequencies.
4	any	any	Listing of standard one-third octave band number for TOFORMAT or listing of narrow center band frequencies (Hz).
5	1	8	Sphere radius (ft).
6	1	10	STATIONARY or MOVING to signify source type.

Notes: (1) Line 4 may be repeated as often as necessary to list all the data points specified on line 3.
(2) Line 5 is optional. If omitted, MOVING is assumed.
(3) Line 6 is optional. If omitted, 100ft sphere radius is assumed.

The STATIONARY or MOVING keyword indicates whether the omnidirectional sphere will be representative of a stationary source or moving source. If STATIONARY is chosen, then the acoustic model will compute the Doppler frequency shifts for the .TH file for use with the DeDopplerizer code.

When using the ART keyword, AAM will automatically create (if it does not already exist) a 200 dB, omnidirectional source sphere containing the spectral characteristics set by the user. It will use a sphere radius of 100 ft if none has been specified by the user. This file will be called OMNI_200.NC. If this file already exists but does not contain the same spectral content, then it will be automatically replaced, and a warning message will be generated to the output file.

Keyword **ATMOS**

ATMOS specifies the atmospheric profile. It may be used only for straight ray propagation analysis, and is incompatible with the WEATHER keyword. If this keyword is not included in the input file, the acoustic module will use as default the United States Standard Atmosphere, 1976, with 70% relative humidity as described in Chapter 2. The user may enter a maximum of 32 points to describe the atmosphere. The altitude for each point corresponds to the geometric altitude above the mean sea level. The altitude profile must extend above the highest point on the flight track; otherwise extrapolation will occur, using the highest altitude data entered. The altitude profile must be entered in monotonically increasing order beginning with the lowest altitude. The user may choose the units for altitude, temperature, and pressure by using the system of keywords shown in Table 3-7.

Table 3-7. ATMOS Keyword Format

Line	Position	Max Length	Description
1	1	A5	Keyword for atmospheric profile.
2	1	I10	Number of points describing atmosphere (32 max).
3	1 2 3	A5 A1 A3	Units for atmospheric altitude (FEET or METER). Units for temperature Fahrenheit or Centigrade (F or C). Units for pressure pounds per square inch, kilo Pascal, or milli Bar (PSI, KPA, or MB).
4	1 2 3 4	I10 I10 I10 I10	Altitude in specified units above mean sea level. Temperature in specified units. Pressure in specified units. Relative humidity in percent.

Note: Line 4 should be repeated to satisfy the number of points describing the atmospheric profile.

Keyword **AUDIB**

AUDIB triggers output at each grid or point of interest a detailed .TIG file for use by the audibility post-processor. This keyword must be used in conjunction with the COMPUTEPOI keyword in order to generate output. The user must specify the narrow band spacing of the .NC files in use along with the output .TIG filename as shown in Table 3-8. The bandwidth parameter on line 2 represents the data contained in the source .NC file. When using narrow band noise spheres in the analysis the .NC file bandwidth in Hz is specified. .NC files contain information about the specific centerband frequencies in use. However, for computational efficiency a user may create and use in .NC files that are sparsely populated and only contain certain important narrow bands (for example, those with main and tail rotor fundamentals and harmonics). Subsequent analyses require this information so it is merely passed from the input file directly into the output .TIG file. The VIDEO keyword is incompatible with AUDIB keyword.

Table 3-8. AUDIB Keyword Format

Line	Position	Max Length	Description
1	1	A5	Keyword for audibility .TIG file.
2	1 2	F38 A256	Narrow band analysis bandwidth (Hz) as used in the .NC files. Output .TIG path and filename including .TIG file extension.

Notes: (1) Filenames and paths may NOT contain spaces.
(2) If one-third octave band source data is in use, this parameter should be entered as 0.

Keyword BACKGROUND

BACKGROUND is used to specify the background spectra in one-third octave band or narrow band mode for inclusion in the .TIG file and for use by the DPRIME metric for calculation of the auditory detectability index. The background is specified in a file whose path and name is identified in the BACKGROUND keyword section (Table 3-9).

Table 3-9. BACKGROUND Keyword Format

Line	Position	Max Length	Description
1	1	A10	BACKGROUND keyword.
2	1	A256	Background path and filename.

Several sample background files are included with the software distribution. The format of the background .BAK file is consistent with the narrow band data file microphone format used by ART. Changed from earlier versions of RNM (Version 5 or earlier), AAM now requires three header lines at the top of the file (Figure 3-5). Sample files represent the Standard U.S. Army one-third octave band spectral distributions for Low, Medium and High ambient levels: ArmyLow.BAK, ArmyMed.BAK and ArmyHig.BAK, respectively. A fourth sample file, Quiet.BAK is a 20 dB flat ambient spectra across all frequency bands. Additional backgrounds may be defined by the user. A sample background file is given in Figure 3-5; the format of the background file is given in Table 3-10.

```
US Army Standard Low Background One-Third Octave Spectra


31
10  11  12  13  14  15  16  17  ...
400 400 400 400 400 400 400 400 ...
```

Figure 3-5. Sample Background Spectra

Table 3-10. Background Spectra File Structure

Line	Position	Max Length	Description
1-3	1-255	A255	Background description.
4	1	I3	Number of frequencies.
5	1	any	Frequency band indices (must match AAM output); use integer for one-third octave bands or real for narrow band data.
6	1	any	Ambient spectral level in centibels for each frequency in line 3.

Note: Lines 5 and 6 should be repeated to satisfy the number of frequencies and spectral data.

Keyword **CALCALL**

CALCALL triggers calculation and output of 100% of the operations in its acoustic analysis. Ordinarily, the track proximity to the point in question is compared with the acoustic proximity criteria (see keyword SETUP PARA) for analysis. When using the CALCALL keyword, this checking is skipped and all tracks are analyzed regardless of the proximity criteria.

Keyword **COMPUTEGRD**

COMPUTEGRD signals to create an output GRD file in NMBGF[15] format. Possible output metrics (and their respective keywords) are created by including one or more of the following in the input deck.

- (SEL) Sound Exposure Level.
- (SELA) A-weighted Sound Exposure Level.
- (SELC) C-weighted Sound Exposure Level.
- (LMAXA) Maximum A-weighted Level.
- (EPNL) Effective Perceived Noise Level.
- (DNL) Day-Night Average Sound Level.
- (CNEL) Community Noise Equivalent Level.
- (NEF) Noise Exposure Forecast.
- (WECPNL) Weighted Equivalent Continuous Perceived Noise Level.
- (DPRIME) Auditory Detectability Index.
- (DPRIMEMAX) Value of highest band for DPRIME calculation.
- (TA*nnn*) Time Above threshold *nnn* dBA, minutes.

If none of the above metrics are specified, the default A-weighted sound exposure level will be used. See Table 3-11 for the format. The grid extent and spacing are defined and input via the SETUP PARA keyword.

Table 3-11. COMPUTEGRD Keyword Format

Line	Position	Max Length	Description
1	1	A10	COMPUTEGRD keyword for NMBGF output grid.
2	1	A9	Metric to be used in GRD file (SEL, SELA, SELC, LMAXA, EPNL, DNL, CNEL, NEF, WECPNL, DPRIME, DPRIMEMAX, TA*nnn*).

Notes: (1) If a metric is not included, SELA will be used.
(2) Line 2 may be repeated as many times as required to include all the desired metrics, one per line.

Keyword **COMPUTEPLT**

COMPUTEPLT signals the creation of Tecplot[27] format output file containing a grid of equally spaced points. The A-weighted SEL, the C-weighted SEL, the A-weighted maximum sound level and the EPNL are output at each grid point in the earth-fixed coordinate system. The output file will be the same as the input filename prefix with the .PLT extension. A maximum of 256 characters are permitted. Filenames and paths may not contain spaces. An ASCII format Tecplot as shown in Figure 3-6 will be created.

```
TITLE = "Integrated Noise Metrics"
VARIABLES =  X       Y     SEL_unweighted  SEL_A-weighted  SEL_C-weighted  Lmax_A-weighted  EPNL
ZONE I=    11 J=    61
           -50.    -30.       111.49          111.49          111.49          111.24          101.01
           -40.    -30.       111.51          111.51          111.51          111.24          101.02
           -30.    -30.       111.50          111.50          111.50          111.21          101.06
           -20.    -30.       111.47          111.47          111.47          111.15          101.09
           -10.    -30.       111.44          111.44          111.44          111.23          100.87
             0.    -30.       111.43          111.43          111.43          111.23          100.82
            10.    -30.       111.44          111.44          111.44          111.23          100.88
            20.    -30.       111.46          111.46          111.46          111.15          101.08
            30.    -30.       111.48          111.48          111.48          111.21          101.02
```

Figure 3-6. Portion of a .PLT File

Keyword **COMPUTEPOI**

COMPUTEPOI triggers the creation of a detailed time history Tecplot format ASCII file as well as a series of sound rankings at points of interest for multiple flight track analyses. Contained within the main text output file will be an ASCII ART table of the time history at each point of interest. In addition, a Tecplot file will be created with the input filename prefix and the .POI extension. This file will be in ASCII format and will contain the aforementioned time history metrics for each point of interest, sequenced in the same manner as the .INP file. Point of interest locations are entered using the POI keyword.

Keyword **DBDOWN10**

DBDOWN10 forces all integrated metric calculations to only include points within 10 dB of the maximum level. The default without this keyword is to include all frequencies in the source data in the metric summations. Only if keyword SPECTRUM is used may the particular spectral bands in the summation be varied.

Keyword **DIAGNOSTICS**

DIAGNOSTICS triggers a very exhaustive set of intermediate calculations and output messages to the main ASCII text output file. Care must be taken to ensure sufficient disk space exists for the ASCII text output file or program execution will halt.

Keyword **DPRIME**

DPRIME signals the output of D-PRIME audibility detectability index d' to the time history and grid output files.

Keyword DPRIMEMAX

DPRIMEMAX signals the output of single longest one-third octave band value of the auditory index to the time history and grid output files.

Keyword **END**

END signals the end of the input deck. Any data contained on lines beyond the END marker are neither read nor processed.

Keyword **EULER**

EULER allows the user to control the geometric calculation of the Euler angles. The default setting when the EULER keyword is not present is to automatically switch as needed between the first order solution and the iterative solution. The user may override this by specifying ON or OFF on the line below the EULER keyword. ON forces AAM to use the iterative solution algorithms, and OFF forces the use of the first order solution. OFF will yield the geometric calculations as performed by RNM4 and earlier. Section 2.4.1 describes the automatic Euler angle solver criteria.

Keyword **HOTSPOT**

HOTSPOT triggers acoustic calculations to be performed in single point mode. The capability to generate detection ranges for one or several azimuths relative to a vehicle is provided for with the HOTSPOT keyword. A flight track of one point oriented at the user-specified location, orientation, altitude, and flight condition is used to generate an output signal at automatically placed points of interest. The points of interest are organized on a radial grid pattern on the ground with the radial and azimuthal spacing defined by the user (Figure 3-7). The format of the keyboard inputs are provided in Table 3-12. The HOTSPOT keyword generates an .HS file. The receiver points are listed toward the right side of the .HS file. The vehicle is oriented in 3D using the two trajectory points and the roll/pitch/yaw as specified on input. Only the first time step along the trajectory is modeled, and the propagation from that first point to each receptor point is performed. The second trajectory point is merely to orient the vehicle. The .HS file looks the same as a .TIG file and can be read by AudibRNM. An example .TIG file is shown in Figure 3-8.

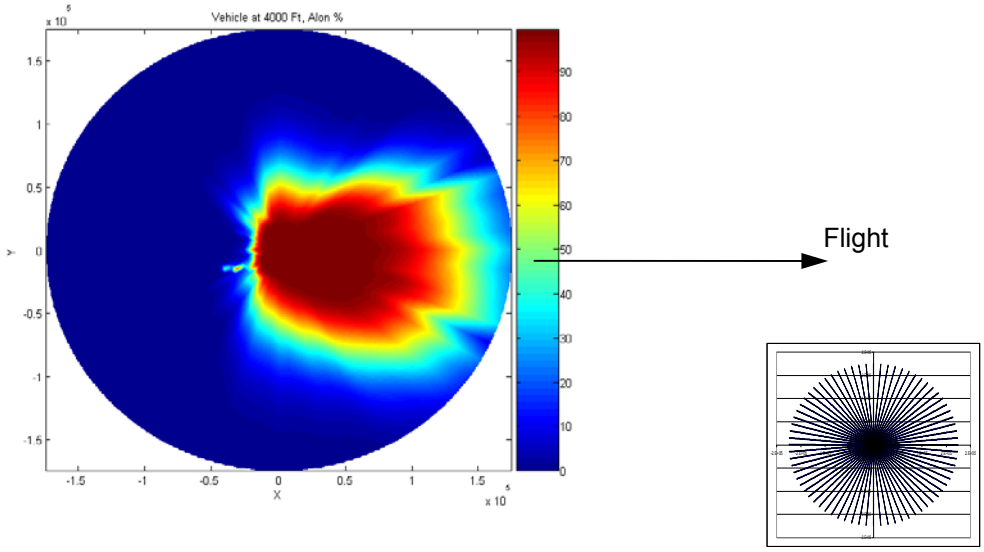

Figure 3-7. Radial Grid Pattern Display

Table 3-12. HOTSPOT Keyword Format

Line	Position	Max Length	Description
1	1	A8	HOTSPOT keyword for POI analysis.
2	1	A256	Hotspot.HS output filename and path.
3	1	A80	Descriptor for source location and condition.
4	1	I 10	Number of points--must be 2.
5	1	F38	X-coordinate turn point for flight segment (ft).
	2	F38	Y-coordinate turn point for flight segment (ft).
	3	F38	Z-coordinate turn point for flight segment (ft, AGL).
	4	F38	Segment turn angle (degrees) (+ right turn).
	5	F38	Segment turn radius (ft).
	6	F38	Segment speed (knots).
	7	F38	Segment yaw angle (degrees, positive nose left).
	8	F38	Segment angle of attack (degrees, positive nose up).
	9	F38	Segment roll angle (degrees, positive port wing down).
	10	F38	Segment nacelle angle (degrees, positive up).
6	1	F38	X-coordinate turn point for flight segment (ft).
	2	F38	Y-coordinate turn point for flight segment (ft).
	3	F38	Z-coordinate turn point for flight segment (ft, AGL).
	4	F38	Segment turn angle (degrees) (+ right turn).
	5	F38	Segment turn radius (ft).
	6	F38	Segment speed (knots).
	7	F38	Segment yaw angle (degrees, positive nose left).
	8	F38	Segment angle of attack (degrees, positive nose up).
	9	F38	Segment roll angle (degrees, positive port wing down).
	10	F38	Segment nacelle angle (degrees, positive up).
7	1	F38	X-coordinate turn point for flight segment (ft).
	2	F38	Y-coordinate turn point for flight segment (ft).
	3	F38	Z-coordinate turn point for flight segment (ft, AGL).
	4	F38	Segment turn angle (degrees) (+ right turn).
	5	F38	Segment turn radius (ft).
	6	F38	Segment speed (knots).
	7	F38	Segment yaw angle (degrees, positive nose left).
	8	F38	Segment angle of attack (degrees, positive nose up).
	9	F38	Segment roll angle (degrees, positive port side down).
	10	F38	Thrust setting (units consistent with .NC file).
	11	F38	Thrust vector angle (degrees).
8	1	F38	X-coordinate turn point for flight segment (ft).
	2	F38	Y-coordinate turn point for flight segment (ft).
	3	F38	Z-coordinate turn point for flight segment (ft, AGL).
	4	F38	Segment turn angle (degrees) (+ right turn).
	5	F38	Segment turn radius (ft).
	6	F38	Segment speed (knots).
	7	F38	Segment yaw angle (degrees, positive nose left).
	8	F38	Segment angle of attack (degrees, positive nose up).
	9	F38	Segment roll angle (degrees, positive port side down).
	10	F38	Thrust setting (units consistent with .NC file).
	11	F38	Thrust vector angle (degrees).
9	1	F38	Max ground distance (ft).
	2	F38	Incremental spacing (ft).
	3	F38	Receiver height (AGL).
10	1	F38	POI receptor mesh start heading (degrees).
	2	F38	POI receptor mesh ending heading (degrees).
	3	F38	POI receptor mesh spacing (Δ-heading) (degrees).
11	1	F38	POI receptor mesh spacing (Δ-elevation) (degrees).

Notes: (1) Line 5 is the vehicle location and operating condition.
(2) Line 6 is the point to which the vehicle is heading.
(3) The larger of line 9 will be implemented.
(4) Filename and path may NOT contain spaces.
(5) No adjustments are made to the POI receptor mesh incremental heading (line 10).
(6) Lines 7 or 8 are required for fixed wing aircraft.
(7) Lines 5 or 6 are required for rotary wing aircraft.

Keyword **MAST TILT**

MAST TILT allows the user to define a fixed mast tilt angle that will be applied uniformly to the source (.NC) orientation. Positive mast tilt angle is a nose-up rotation of the source sphere. When using the ABSANGLES keyword, the specified mast tilt angle will be added to the user input angle-of-attack data provided in the ONE TRACK keyword section. This keyword is applicable only to rotary wing operations.

Keyword **NCSPEC**

NCSPEC is used when the exact source .NC file is to be specified for each trajectory point. The root path and 5-character vehicle ID is defined by the user and the 3-digit run number is read for each trajectory point specified in the ONE TRACK keyword section. The path specified in this keyword section overrides the ROTOR.NOISE and FWING.NOISE set parameters.

Table 3-13. NCSPEC Keyword Format

Line	Position	Max Length	Description
1	1-6	A6	NCSPEC keyword for POI analysis.
2	1-256	A256	Path and 5-digit vehicle ID.

Keyword **NOALTCORR**

NOALTCORR disables the thrust connection with aircraft flight altitude (MSL) as described in Section 2.5.4. This keyword is applicable only to fixed wing operations.

Keyword **NO REPORT**

NO REPORT suppresses the normal summary output containing the echo of the input file, setup parameters, flight track, and points of interest in the ASCII output file.

Keyword **ONE TRACK**

ONE TRACK specifies the flight trajectory as described in Section 2.3. If local time in seconds after midnight are input, the TIMETRAJ keyword must appear above the ONE TRACK keyword. A flight track is composed of straight line and circular segments. Points denoting the beginning and ending of a line segment are called turn points. ONE TRACK requires complete specification of the flight parameters at each turn point. Specified at each turn point are the X, Y, and Z coordinates in units of feet, turn angle and turn radius in feet, the speed in knots, yaw angle, angle of attack, roll angle and nacelle tilt angle. All angles are specified in units of degrees. Figures 2-8, 2-9, 2-10, 2-12, and 2-15 show the geometric definition. A circular segment is specified by a turn angle and turn radius. Use a positive turn angle for a right-hand turn and a negative turn angle for a left-hand turn. Details of the keyword input structure are given in Table 3-14. See the TIMETRAJ keyword section for further explanation of how the model handles the time simulation. See the NCSPEC keyword for manually specifying source data files.

Table 3-14. ONE TRACK Keyword Format

Line	Position	Max Length	Description
1	1	A9	ONE TRACK keyword for a single track.
2	1	A20	Flight track identification.
3	1	F38	Number of flight track segments (500 max).
4	1	F38	X-coordinate/turn point for flight segment (ft).
	2	F38	Y-coordinate/turn point for flight segment (ft).
	3	F38	Z-coordinate/turn point for flight segment (ft).
	4	F38	Segment turn angle (degrees) (+ right turn).
	5	F38	Segment turn radius (ft).
	6	F38	Segment speed (knots).
	7	F38	Segment yaw angle (degrees, positive nose left).
	8	F38	Segment angle of attack (degrees, positive nose up).
	9	F38	Segment roll angle (degrees, positive port wing down).
	10	F38	Segment nacelle angle (degrees, positive up).
	11	I43	Source data 3-digit run number.
5	1	F38	Time, seconds after midnight.
	2	F38	X-coordinate/turn point for flight segment (ft).
	3	F38	Y-coordinate/turn point for flight segment (ft).
	4	F38	Z-coordinate/turn point for flight segment (ft).
	5	F38	Segment turn angle (degrees).
	6	F38	Segment turn radius (ft).
	7	F38	Segment speed (knots).
	8	F38	Segment yaw angle (degrees, positive nose left).
	9	F38	Segment angle of attack (degrees, positive nose up).
	10	F38	Segment roll angle (degrees, positive port wing down).
	11	F38	Segment nacelle angle (degrees, positive up).
	12	I3	Source data 3-digit run number.
6	1	F38	X-coordinate/turn point for flight segment (ft).
	2	F38	Y-coordinate/turn point for flight segment (ft).
	3	F38	Z-coordinate/turn point for flight segment (ft).
	4	F38	Segment turn angle (degrees) (+ right turn).
	5	F38	Segment turn radius(ft).
	6	F38	Segment speed (knots).
	7	F38	Segment yaw angle (degrees, positive nose left).
	8	F38	Segment angle of attack (degrees, positive nose up).
	9	F38	Segment roll angle (degrees, positive port side down).
	10	F38	Thrust setting (units consistent with .NC file).
	11	F38	Thrust vector angle (degrees)
	12	I1	Aircraft configuration state
	13	I3	Source data 3-digit run number
7	1	F38	Time, seconds after midnight
	2	F38	X-coordinate/turn point for flight segment (ft)
	3	F38	Y-coordinate/turn point for flight segment (ft)
	4	F38	Z-coordinate/turn point for flight segment (ft)
	5	F38	Segment turn angle (degrees) (+ right turn)
	6	F38	Segment turn radius(ft)
	7	F38	Segment speed (knots)
	8	F38	Segment yaw angle (degrees, positive nose left)
	9	F38	Segment angle of attack (degrees, positive nose up)
	10	F38	Segment roll angle (degrees, positive port side down).
	11	F38	Thrust setting (units consistent with .NC file)
	12	F38	Thrust vector angle (degrees)
	13	I1	Aircraft configuration state
	14	I3	Source data 3-digit run number

Notes: (1) Line 4, 5, 6, or 7 should be repeated to satisfy the number of flight track segments.
(2) Line 5 should be used instead of line 4 when the TIMETRAJ keyword is in use for rotary wing aircraft.
(3) Line 7 should be used instead of line 6 when the TIMETRAJ keyword is in use for fixed wing aircraft.
(4) The TIMETRAJ keyword must appear before ONE TRACK when using line 5 or 7.
(5) The NCSPEC keyword must be enabled to specify the source data 3-digit run number.
(6) When turn angle = 0, segment is straight.
(7) The aircraft configuration state parameter; 0 = clean, 1 = flaps, 2 = flaps + gear, 3 = Static Run-Up.
(8) When using the TERRAIN keyword Z-coordinate should be input as MSL (ft), otherwise Z-coordinate should be input as (AGL (ft), with the ground altitude defined by the airport reference height.

Keyword **POI**

POI specifies the X, Y, and Z location for points of interest in the (X,Y) earth-fixed coordinate system for which the time-history and spectral propagation output are to be generated. X and Y values are defined in the grid coordinate specified under the SETUP PARA keyword. The Z location is input relative to the reference ground level. The local ground altitude will be that defined in the ground elevation (.ELV) file when operating in Terrain mode.

Output will contain, for each point of interest, a table containing the noise level (unweighted SPL, C-weighted SPL, A-weighted SPL, PNL, PNLT) as a function of time. In a separate summary table, output will contain, for each specific point, the A-weighted maximum sound level, the overall SEL, the C-weighted SEL, the A-weighted SEL, and the EPNL. In a file labeled with the extension.POI, is a Tecplot format time history of the noise event for the unweighted SPL, the A-weighted SPL, and the PNLT. See keywords SPECTRUM and TERRAIN for additional detailed outputs which may be generated at points of interest.

Table 3-15 shows the POI keyword format. The maximum allowable number of points of interest is 100.

Table 3-15. POI Keyword Format

Line	Position	Max Length	Description
1	1	A3	POI keyword for points of interest
2	1	I10	number of points (100 max)
3	1 2 3 4	A10 I10 I10 I10	point identification x-coordinate (ft) y-coordinate (ft) z-coordinate (ft, AGL)

Keyword **QSAM1**

QSAM1 causes the sphere lookup module to consider the equivalence between longitudinal acceleration and flight path angle when selecting and orienting source (.NC) data. See Section 2.5.2 for a technical discussion. No further information is required with the QSAM1 keyword. The QSAM1 keyword is only applicable to rotary wing operations.

Keyword **REM**

REM (short for REMARK) signals the input module to skip over reading this line. It may appear in between other blocks of keywords and data but not in the middle of a keyword data block.

Keyword **SETUP PARA**

SETUP PARA specifies the grid dimensions, the sound source, and several other general input parameters that are required. It can be freely inserted into the input file but is generally inserted at the beginning of the file. Table 3-16 shows the keyword format.

The X and Y values used to specify the grid spacing and the two grid corners are Cartesian coordinates in units of feet. Positive and negative values may be used to define the grid domain provided the lower left and upper right corners are appropriately defined. The location of the flight track and the specific points are specified relative to this coordinate system.

The ground elevation specifies the altitude of the ground relative to the mean sea level. The Z-coordinate altitude for the computational grid is the elevation of the grid above the local ground level. The elevation contained in the .ELV file will be used if keyword TERRAIN is implemented. All points on the grid must be at the same elevation above local ground. Normally the grid elevation is set for 5 feet.

Table 3-16. SETUP PARA Keyword Format

Line	Position	Max Length	Description
1	1	A10	SETUP PARA keyword for setup parameters
2	1 2 3	I10 I10 I10	Grid point spacing in x direction (ft), minimum 100 ft Grid point spacing in y direction (ft) , minimum 100 ft Ground elevation measured relative to the mean sea level (ft)
3	1 2 3	I10 I10 I10	X-coordinate for lower left corner of calculating grid (ft) Y-coordinate for lower left corner of calculating grid (ft) Z-height altitude for the calculating grid above ground level (ft)
4	1 2	I10 I10	X-coordinate for upper right corner of calculating grid (ft) Y-coordinate for upper right corner of calculating grid (ft)
5	1 2 3 4	I10 I10 I10 F10	Spherical loss factor ($\Delta\beta$) Cutoff distance (ft), maximum distance of interest between source and receiver for calculations Flow resistance parameter (CGS Rayls) see Table 3-17 Turbulent decoherence Parameter $(\mathrm{rad}\cdot\mathrm{sec}\cdot\sqrt{\mathrm{ft}})$
6	1	A5	Name of maximum of five characters (example CH146)
7	1	I10	Number of one-third octave sound spheres (10 max)
8	1 2 3	I10 I10 I10	X-coordinate for center of broadband sound sphere (ft) Y-coordinate for center of broadband sound sphere (ft) Z-coordinate for center of broadband sound sphere (ft)
9	1	I10	Number of narrow band sound spheres (10 max)
10	1 2 3	I10 I10 I10	X-coordinate for center of broadband sound sphere (ft) Y-coordinate for center of broadband sound sphere (ft) Z-coordinate for center of broadband sound sphere (ft)
11	1	I10	Number of pure-tone sound spheres (10 max)
12	1 2 3	I10 I10 I10	X-coordinate for center of pure-tone sound sphere (ft) Y-coordinate for center of pure-tone sound sphere (ft) Z-coordinate for center of pure-tone sound sphere (ft)
13	1	A12	Vehicle type (ROTARYWINGAC or FIXEDWINGAC)

Notes: (1) Line 2 (21-30) ground elevation is ignored when in TERRAIN mode.
(2) Line 3 Z-grid height will be added to the ground elevation when in TERRAIN mode.
(3) Line 8 should be repeated to satisfy the number of broadband sound spheres on line 7.
(4) Line 10 should be repeated to satisfy the number of narrow band sound spheres on line 9.
(5) Line 12 should be repeated to satisfy the number of pure-tone sound spheres on line 11.
(6) Line 13 is optional and ROTARYWINGAC will be assumed.
(7) Recommended value of turbulent decoherence Parameter (Line 5) is 0.0004.

There are two proximity checks in the acoustic model, which are used to determine if a particular source-receiver combination is worthy of acoustic analysis. The point of closest approach is determined for an entire flight trajectory relative to a given receiver point. If the slant range to the point of closest approach exceeds the cutoff distance specified in the input check, the entire track will be bypassed for this receiver point. In order to determine which individual trajectory points are analyzed the following relationship is used:

$$R_{\max} = \left[R_{\min}\right]^{\left(\frac{\Delta\beta}{20}\right)} \qquad (15)$$

The $\Delta\beta$ relationship ($\Delta\beta$ /20) is the geometric loss assuming spherical spreading. From this we can establish the maximum to minimum geometric distance ratio within which propagation analysis will occur. R_{min} represents the distance from the point of closest approach to the receiver point. When in multiple track analysis mode the defaults are $\Delta\beta$= 40 dB and cutoff = 30,000 ft. This value of $\Delta\beta$ = 40 dB results in an R_{max} two orders of magnitude greater than the slant range at the point of closest approach. This logic has been implemented in RNM since Version 1.0.

The CALCALL keyword may be used to disable all proximity checking and force acoustic analysis for each trajectory point and receiver point. This can considerably increase computational run time without a discernable impact on the results. However, under certain situations where very low levels or long distances are predicted or where all operational contributions must be tallied, the CALCALL keyword should be used.

The specific flow resistivity per unit thickness is a measurable parameter used to express the ground specific acoustic impedance. Table 3-17 shows typical flow resistance factors for various surfaces. The flow resistivity parameter[38] is a function of the porosity of the material. The units for Rayls are N•sec/m^3 (mks) or dynl•sec/cm^3 (cgs).

Table 3-17. Typical Specific Flow Resistivity Values

Ground Cover	Specific Flow Resistivity (Rayls/m)
Snow Covered Ground	30
Forest Floor	50
Grassy Field	225
Roadside Dirt	650
Packed Sand	1650
Hard Packed Dirt	3000
Exposed Dirt/Rock	6000
Asphalt	30000
Water	1000000

The name of the aircraft is limited to five characters and must be identical to the five character label used to name the NetCDF sound sphere files. AAM assumes a sound sphere file having an eight character base name. Five of the characters are used to denote the aircraft type and three of the characters are reserved for the index number. The file extension is .NC, which signifies a NetCDF file. For each vehicle type there may be up to one thousand (1000) sound spheres numbered 000 to 999.

Each vehicle may be defined by up to 10 broadband, 10 narrow band and 10 pure-tone sound spheres. The center of the sound sphere is defined in terms of the X, Y and Z values in body-fixed coordinates.

Keyword **SPECTRUM**

SPECTRUM signals the creation of an ASCII output file containing the spectral details. This keyword is only available in single track mode if COMPUTEPOI is active and COMPUTEGRD and COMPUTEPLT are inactive. The output file will contain the same prefix as the input file and the .PT or .TH file extension for pure tone and third octave outputs, respectively. A maximum of 256 characters are permitted for filenames and directory paths. This output file is compatible with terrain analysis and will contain, for each source emission along the trajectory, detailed spectral output.

The output file structure and data will depend on the source characteristics. For analyses containing only one-third octave sources the output will be a .TH file as described in Table 3-18. For analyses containing only narrow band sources, the output will be a .NB file as described in Table 3-19. For analyses containing only pure-tone spheres the output will be a .PT file as described in Table 3-20.

The time history (.TH) file is also created when using the ART keyword. This file is read in by ART and the tool is used to de-Dopplerize the microphone signal to aid in the generation of stationary source .NC files.

Table 3-18. SPECTRUM ASCII Time History (.TH) File (Terrain Enabled Broadband)

Label	Description
F1, F2, F3,	Index of the sphere file used for interpolation
Xsource	Source X location
Ysource	Source Y location
Zsource	Source Z location
Tsource	Source time (seconds)
Xrecvr	Receiver X location
Yrecvr	Receiver Y location
ZAGL	Receiver Z location above ground level
Trecvr	Arrival time at receiver (seconds)
#	One-third octave band number
Slev	Source sound level (dB)
Freq NC	Source Frequency (Hz)
Fre Dop	Doppler shifted frequency (Hz)
FreeF	Unweighted free field propagation result for frequency n (no ground or terrain effects)
Weather	Attenuation due to the terrain or weather effects
BBlev	Unweighted overall level at the receiver (dB) for each frequency band
cB01…cB10	Level at the receiver due to each individual source at the vehicle (cB)
Slant	Slant range (ft) source to receiver
Beta	Vehicle heading angle at source trajectory point (degrees, 0° = East, 90° = North)
Gamma	Vehicle climb angle at source trajectory point (degrees from horizontal)
Theta	Sound sphere location for source level (degrees in sphere coordinate system)
ACSpd	Average speed at source trajectory point (knots)
Phi	Sound sphere location for source level (degrees in sphere coordinate system)
Thr	Thrust parameter for the source (units consistent with .NC files)
Thv	Thrust vector angle for the source (degrees) (0° = horizontal, 90 ° = vertical downwards)
Receiv	(Same as BBlev)
Free	Free field unweighted level (dB) summed over all frequencies
Spread	Adjustment due to spherical spreading (dB)
AirAb	Adjustment due to atmospheric absorption (dB) as a function of frequency
gOut	Adjustment due to ground effect (dB) as a function of frequency
Nlc	Nonlinear correction (dB) as a function of frequency
Rec_dB	Overall unweighted level (dB) summed over all frequencies

Notes: (1) This block of data will be repeated for each time step in the flight trajectory.
(2) Thrust, thrust vector angle, and nonlinear correction are only included in the .TH file when the SPECTRUM keyword and FIXEDWINGAC types are enabled.

Table 3-19. SPECTRUM ASCII Time History (.NB) File (Terrain Enabled Narrow Band)

Label	Description
Xsource	Source X location
Ysource	Source Y location
Zsource	Source Z location
Tsource	Source time (seconds)
Xrecvr	Receiver X location
Yrecvr	Receiver Y location
ZAGL	Receiver Z location above ground level
Trecvr	Arrival time at receiver (seconds)
#	Band number
Slev	Source sound level (dB)
Freq NC	Source Frequency (Hz)
Fre Dop	Doppler shifted frequency (Hz)
FreeNB	Unweighted free field propagation result for frequency n (no ground or terrain effects)
Weather	Attenuation due to the terrain or weather effects
NBlev	Unweighted overall level at the receiver (dB) for each frequency band
cB01…cB10	Level at the receiver due to each individual source at the vehicle (cB)
Slant	Slant range (ft) source to receiver
Beta	Vehicle heading angle at source trajectory point (degrees, 0° = East, 90° = North)
Gamma	Vehicle climb angle at source trajectory point (degrees from horizontal)
Theta	Sound sphere location for source level (degrees in sphere coordinate system)
ACSpd	Average speed at source trajectory point
Phi	Sound sphere location for source level (degrees in sphere coordinate system)
Thr	Thrust parameter for the source (units consistent with .NC files)
Thv	Thrust vector angle for the source (degrees) (0° = horizontal, 90 ° = vertical downwards)
Receiv	(Same as BBlev)
Free	Free field unweighted level (dB) summed over all frequencies
Spread	Adjustment due to spherical spreading (dB)
AirAb	Adjustment due to atmospheric absorption (dB) as a function of frequency
gOut	Adjustment due to ground effect (dB) as a function of frequency
Nlc	Nonlinear correction (dB) as a function of frequency
Rec_dB	Overall unweighted level (dB) summed over all frequencies

Notes: (1) This block of data will be repeated for each time step in the flight trajectory.
(2) Thrust, thrust vector angle, and nonlinear correction are only included in the .TH file when the SPECTRUM keyword and FIXEDWINGAC types are enabled.

Table 3-20. SPECTRUM ASCII Time History (.PT) File (Terrain Enabled Pure Tone)

Label	Description
Xsource	Source X location
Ysource	Source Y location
Zsource	Source Z location
Tsource	Source time (seconds)
Xrecvr	Receiver X location
Yrecvr	Receiver Y location
ZAGL	Receiver Z location above ground level
Trecvr	Arrival time at receiver (seconds)
#	Frequency
Slev	Source sound level (dB)
Sph	Source phase (deg)
Freq NC	Source Frequency (Hz)
Fre Dop	Doppler shifted frequency (Hz)
Tot (dB)	Unweighted overall level at the receiver (dB) for each frequency band
Phas	Overall phase at this (#) frequency
cB01…cB10	Level at the receiver due to each individual source at the vehicle (cB)
ph01…ph10	Phase at the receiver due to each individual source at the vehicle (deg)
Slant	Slant range (ft) source to receiver
Beta	Vehicle heading angle at source trajectory point (degrees, 0° = East, 90° = North)
Gamma	Vehicle climb angle at source trajectory point (degrees from horizontal)
Theta	Sound sphere location for source level (degrees in sphere coordinate system)
ACSpd	Average speed at source trajectory point
Phi	Sound sphere location for source level (degrees in sphere coordinate system)
Thr	Thrust parameter for the source (units consistent with .NC files)
Thv	Thrust vector angle for the source (degrees) (0° = horizontal, 90 ° = vertical
Spread	Adjustment due to spherical spreading (dB)
AirAb	Adjustment due to atmospheric absorption (dB) as a function of frequency
gOut	Adjustment due to ground effect (dB) as a function of frequency
Nlc	correction (dB) as a function of frequency
Rec_dB	Overall unweighted level (dB) summed over all frequencies

Notes: (1) This block of data will be repeated for each time step in the flight trajectory.
(2) Thrust, thrust vector angle, and nonlinear correction are only included in the .TH file when the SPECTRUM keyword and FIXEDWINGAC types are enabled.

Keyword **TERRAIN**

TERRAIN Signals analysis considering terrain effects on sound propagation (Table 3-21).

Table 3-21. TERRAIN Keyword Format

Line	Position	Max Length	Description
1	1	A7	TERRAIN keyword for nonuniform ground input
2	1	A256	Elevation filename (.ELV format) and path
3	1	A256	Impedance filename (.IMP format) and path

Notes: (1) Doppler effect on frequency for stationary .NC file source acoustics not included in TERRAIN mode.
(2) Filename and path may NOT contain spaces.

Keyword **TIMESPACING**

TIMESPACING Signals interpolation of the flight track to user-defined time spacing increments based on constant acceleration (Table 3-22).

Table 3-22 TIMESPACING Keyword Format

Line	Position	Max Length	Description
1	1	A11	TIMESPACING keyword to control simulation time increment
2	1	F38	Time increment (seconds)

Keyword **TIMETRAJ**

TIMETRAJ is used when a detailed single event flight track, including absolute time at each point, is input. This keyword's function is to facilitate comparison with measured signals or aid in the synchronization of multiple events. The time is defined in seconds after midnight. Since AAM is a simulation tool which accounts for sound travel time, the resultant output signals at the receivers will also be synchronized in the same timeframe. At present AAM does not track dates or handle operations flying over midnight. Nor does the local time of day enter into the Day/Evening/Night metric calculations when using single event mode. See the ONE TRACK keyword section for description of the data input format.

Keyword **USERBAND**

USERBAND triggers a smaller subset of one-third octave bands to be used in the noise metric calculations rather than the full one-third octave band range contained in the sound spheres. The allowable range of one-third octave center band numbers are 10 (10 Hz) through 40 (10,000 Hz) (Table 3-23).

Table 3-23. USERBAND Keyword Format

Line	Position	Max Length	Description
1	1	A8	USERBAND for specifications of metric bands in output
2	1	I10	Lower octave band number (minimum 10)
3	1	I10	Upper octave band number (maximum 40)

Keyword **VIDEO**

VIDEO keyword is used to generate a time history file. VIDEO generation capability is only permitted with the COMPUTEGRD keyword. The COMPUTEPOI and AUDIB keywords are also incompatible with the VIDEO keyword.

Table 3-24. VIDEO Keyword Format

Line	Column	Format	Description
1	1	A5	VIDEO keyword for sound animation analysis
2	1	A256	Video .TIG path and filename

Note: Filename and path may NOT contain spaces.

A sample .TIG file fragment is given in Figure 3-8. The time is in seconds in the same reference frame as the input flight track (or with the first point in the flight track assigned t=0 if TIMETRAJ is not used). A companion file containing the interpolated source trajectory is also created. This file will bear the input filename prefix with a .TRJ extension. 3DVisualizer is a post-processor which

reads the trajectory files and time history files, assembles them and performs a temporal redistribution into uniformly spaced time increments for the purpose of creating graphical sound animations. A tutorial on the video generation process is described in detail in Section 5.5. An example snapshot of one such video is shown in Figure 3-9.

```
Filename: paxriver.tig
pax1.elv
pax1.imp



ii:    1   51   51
jj:    1   35   35
Fig8.TRJ
heli.SRC
---End File Header---
Site: 00010001
Integ:                    Spec: 105
Lat: 0.0000000  Long: 0.0000000  User X: 333186.  User Y: 4224258. Grnd Z: 91.12   Recv Z:  96.12
UTM Zone:  18    Easting:   333186.    Northing: 4224258.
31-03-2006
Echo
SP#    TIME       F     A    10   11   12   13   ...   40      DOPPLER
*** ************ **** **** **** **** **** ****   ... **** ************
  0 AMBIENT      -990 -990 -990 -990 -990 -990   ... -990
  1      152.701  358  118 -407  319  308  284   ... -999    1.0000000
  2      172.658  353  118 -411  314  303  276   ... -999    1.0000000
  3      192.637  304  118 -461  265  255  225   ... -999    1.0000000
  4      212.639  301  118 -463  262  253  219   ... -999    1.0000000
  5      232.666  296  117 -467  258  249  212   ... -999    1.0000000
  6      252.720  291  117 -471  253  245  204   ... -999    1.0000000 …
```

Figure 3-8. Sample .TIG File Fragment

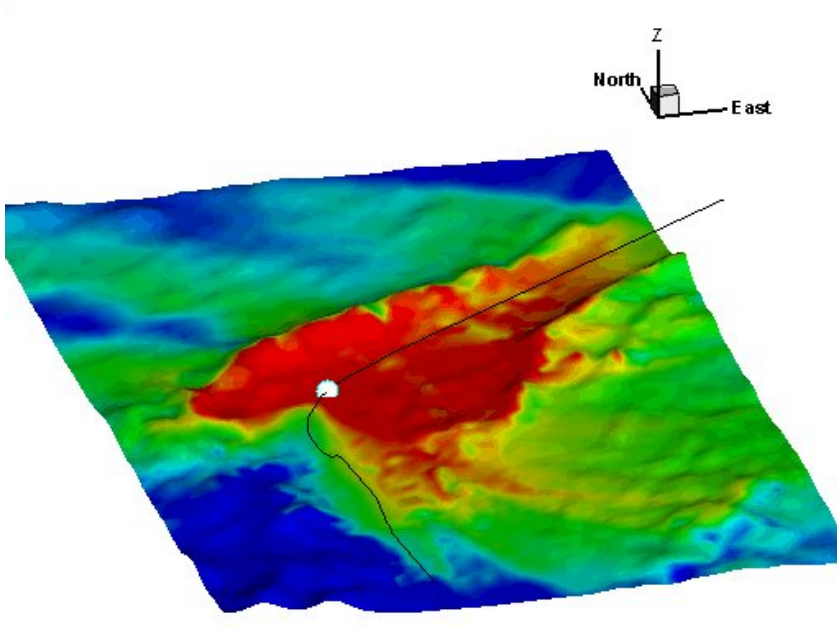

Figure 3-9. Ground Noise at a Single Time in a Video Animation

Two keywords will generate an output .TIG file: VIDEO and AUDIB. Figure 3-10 shows a sample .TIG output file for a narrow band analysis.

```
Filename: NB256.TIG
flatsoft.elv
soft.imp



ii:    1    0    0
jj:    1    0    0
NB256.TRJ
heli.SRC
---End File Header---
Site: 00020002
Integ:                    Spec:   4
Lat:   0.0000000    Long:  0.0000000   User X:  0.   User Y:  0.    Grnd Z:   0.00    Recv Z:
5.00
UTM Zone:   0    Easting:        0.    Northing:       0.
21-11-2005
NB:  256    0        4.883        0.000        4.900        9.800       14.600  ...
SP#    TIME         F    A    1    2    3    4    5    6    7    8    9   10    ...
DOPPLER
*** ************ **** **** **** **** **** **** **** **** **** **** **** ****    ...
************
0 AMBIENT                -990 -990 -990 -990 -990 -990 -990 -990 -990 -990
1        4.475 1869 1838 1660 1720 1718 1716 1713 1711 1707 1704 1701 1697    ...      1.0000000
2       21.251 1991 1957 1755 1815 1814 1812 1811 1810 1808 1807 1805 1804    ...      1.0000000
3       41.000 1991 1957 1755 1815 1814 1812 1811 1810 1808 1807 1805 1804    ...      1.0000000
4       63.725 1869 1838 1660 1720 1718 1716 1713 1711 1707 1704 1701 1697    ...      1.0000000
---End of This Data Section---
Site: 00020002
Integ:                    Spec:   4
Lat:  0.0000000   Long:  0.0000000   User X:   500.   User Y:   500.   Grnd Z:   0.00   Recv Z:
5.00
UTM Zone:   0    Easting:      152.    Northing:     152.
21-11-2005
NB:  256    0        4.883        0.000        4.900        9.800       14.600  ...
SP#    TIME         F    A    1    2    3    4    5    6    7    8    9   10    ...
DOPPLER
*** ************ **** **** **** **** **** **** **** **** **** **** **** ****    ...
************
0 AMBIENT                -990 -990 -990 -990 -990 -990 -990 -990 -990 -990    ...
1        4.942 1853 1818 1652 1711 1709 1707 1705 1701 1698 1694 1691 1687    ...      1.0000000
2       21.746 1968 1940 1730 1790 1789 1787 1786 1784 1782 1781 1779 1777    ...      1.0000000
3       40.648 2021 1992 1778 1838 1837 1836 1835 1834 1832 1831 1830 1828    ...      1.0000000
4       63.303 1884 1856 1669 1728 1727 1725 1722 1720 1717 1714 1711 1707    ...      1.0000000
---End of This Data Section---
```

Figure 3-10. Sample Narrow Band .TIG Output File

Table 3-25 explains the format and meaning of the .TIG output file.

Table 3-25. Time History (.TIG) Narrow Band Output File Description

Line	Description
1	.TIG output path and filename (256 characters max, including .TIG extension)
2	Elevation file used in the analysis
3	Impedance file used in the analysis
4-6	Intentionally left blank
7	Grid analysis size i dimension
8	Grid analysis size j dimension
9	Trajectory file describing the vehicle motion (12 characters max, including the .TRJ extension)
10	Source photo for video rendering default: heli.SRC
11	--- End File Header --- delimiter
12	File index
13	Spec: Number of time steps at this output point
14	Coordinates of this output point Lat and long are not currently supported Coordinate system output data point will appear in the User X, User Y, Recu Z fields and the ground altitude below this receiver point is given in the Ground Z field Note that the units of Recu Z are in feet, above ground level
15	UTM zone, Easting, Northing
16	Analysis date Day-Month-Year
17	NB: Narrow band keyword indicating NB analysis was performed This is followed by: Number of bands – corresponds to .NC files Bandwidth – the number indicated on the input in the AUDIB keyword section Frequencies – a list of frequencies contained in the input .NC file These need not be contiguous, but must monotonically increase
18	Header Labels SP# – Point index Time – Arrival time (sec) A – A-weighted sum Freq # – Repeated for the number of bands Doppler – Doppler frequency multiplier; non zero if the .NC files are reflective of a stationary source
19	Delimiter of **
20+	Data defined in line 18 repeated for each time step

Note: Filenames and paths may NOT contain spaces.

Keyword **WEATHER**

WEATHER signals the use of the curved ray tracing propagation methodology. When using the WEATHER keyword, two related files must be available. The first is the weather spectral propagation (.RAZ) file; the second is the atmospheric profile (.WEA) file which was used during the RNMwea creation of the .RAZ file. These files must be co-located in the directory indicated on line 2 of the WEATHER keyword section. The format of the .WEA file must conform to that specified in the RNMwea utility program in Section 4.15. This specifically requires that the first line of the .WEA file begin with Weather. Using the WEATHER keyword prohibits the use of the ATMOS keyword. Acoustic source data must not have the Doppler shift removed (Table 3-26). This keyword is presently only available for use with broadband or narrow band spheres over uniform terrain.

Table 3-26. WEATHER Keyword Format

Line	Position	Max Length	Description
1	1	A7	WEATHER keyword to engage the curved ray capability
2	1	A256	Weather (RAZ) filename including path if needed

Notes: (1) RAZ file described in Section 6.0.
(2) Filename and path may NOT contain spaces.
(3) Corresponding .WEA file must be stored with the .RAZ file.

3.4.2 Multiple-Operations Format

Community noise impact modeling typically requires the analysis of multiple operations. These may entail many different flight tracks, flight profiles, and vehicle operations. In addition to single event mode, AAM has the capability to compute cumulative noise exposure from multiple operational events, e.g., those occuring at an airbase or heliport. AAM utilizes a dual input file structure in order to analyze multiple operations and remain compatible with the DoD standard tools for community noise exposure.

As mentioned in the Preface, the motivation behind the creation of AAM was twofold: computation of nonlinear propagation-phenomena and the ability to account for thrust vectoring effects as exhibited by recent advanced aircraft designs, such as the F18-E/F, F-22 and F-35. Legacy aircraft noise contours may still be computed using NOISEMAP, while AAM is used for the newer flight vehicles, including rotary wing aircraft. As the noise sphere database is expanded acoustic computations will be transitioned from NOISEMAP to AAM. The present implementation of the suite of programs are fully compatible with one another via output grid files.

Analyses of aircraft noise exposure and noise-compatible land uses around Department of Defense (DoD) facilities are normally accomplished using a group of computer programs collectively called NOISEMAP. Prior to the advent of RNM and AAM, the NOISEMAP suite of computer programs consisted of BaseOps Version 7.0,[14] NMAP Version 7.0,[6] and NMPlot Version 4.955.[16] The BaseOps program allows entry of runway coordinates, airfield information, flight tracks, flight profiles along each track for each aircraft, numbers of daytime, evening, and nighttime events, run-up coordinates, run-up profiles, and run-up events. The core NOISEMAP program, NMAP Version 7.2, incorporates the above information to calculate cumulative noise exposure (e.g., DNL) on a grid of receiver positions. The NMPlot program draws contours of equal DNL for overlay onto maps.

Figure 3-11 presents the current organization of the NOISEMAP suite of computer programs. AAM is another component of the NOISEMAP group of programs. Output from NMAP and RNM and AAM, i.e., noise grids, can be combined in NMPlot producing the total noise exposure from fixed and rotary wing aircraft at an airfield.

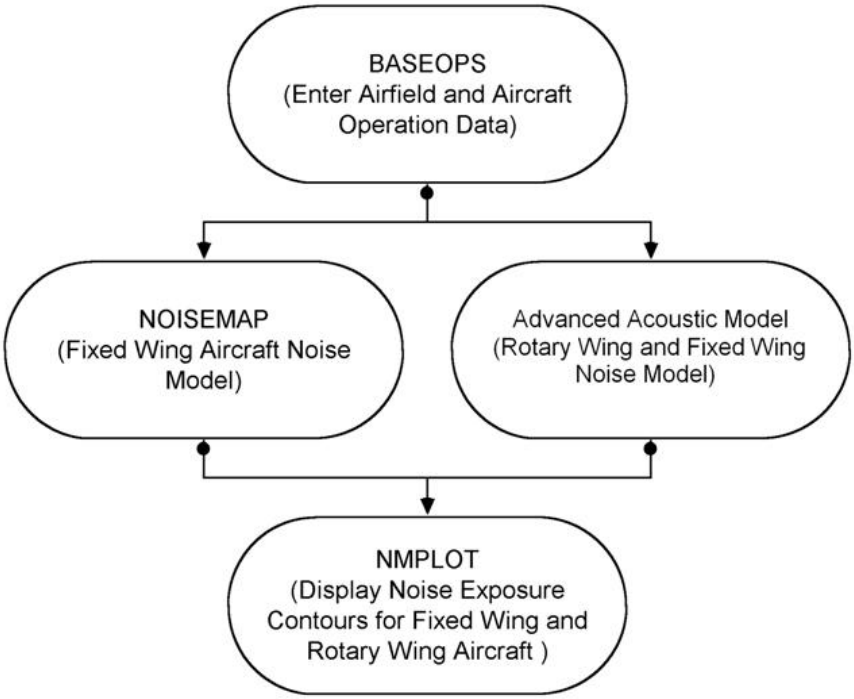

Figure 3-11. Organization of AAM and NOISEMAP

BaseOps supports the data entry of airfield and aircraft operational data. BaseOps creates ASCII text files with .RUN and .OPS extensions. The .RUN file contains general analysis information such as the grid and point of interest parameters, terrain description filenames, and operation filenames. The .RUN file controls the computational features. The .OPS file contains all the flight operations details. The .RUN and .OPS file structures are common to NMAP and AAM. It is recommended the user enter the airfield and operation data through the BaseOps computer program when creating .RUN and .OPS files.

Once the .RUN and .OPS files have been created, AAM may be run from the command prompt. To run the computational module, type AAM followed by the name of the .RUN file. The rules governing file locations and system paths are identical to those defined for running AAM for a single track.

The following sections define the structure of the .RUN and .OPS files.

3.4.2.1 Run (.RUN) File Description

Figure 3-12 displays a sample .RUN file. The .RUN file contains the primary control and analysis directives. It includes pointers to the operations, terrain, and ground impedance files. The grid dimensions and orientation are also included. The .RUN file may also be generated using BaseOps. The following sections describe the contents of each keyword section.

```
12345678901234567890123456789012345678901234567890123456789012345678901234567890
RUN
sample.run                1.0 30-Apr-2008 12:00:00        1
This is a sample run file for the purpose of testing
c:\projects\aam\
sample.ops
not_used.log
COMPUTEPOI          sample.poi               DAILY       0
IGNORETOP
IGNOREGRD           sample.grd                DNL
-10000    -10000    10000     10000
500       500             0  W
MAP              1
c:\you_gotta_be_kidding_me\
1984 SPOT satellite imagery
Washington, D.C.
ENDRUN
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

Figure 3-12. Sample .RUN File

As in other portions of this report, three letters are used in the format column to classify the input: A, I, and F. A signifies a character input; I signifies an integer value; and F signifies a floating point number. For example, A10 represents a data field that may be 10 characters long. I10 represents a integer data field that may be 10 elements long. All text strings (A* format) must be left-justified in their respective fields and must be capitalized where noted. The letter F represents a floating point number whose number of digits (both before and after the decimal point) is given after the letter F. For example, F3.1 signifies a floating-point number, 3 digits in length with 1 digit to the right of the decimal. The number 10.0 is of format F5.1.

Keyword **RUN**

RUN keyword formats are shown in Table 3-27. The RUN keyword must appear on the first line of the .RUN file. Lines 2 and 3 serve to self-document the .RUN file as they contain the full name of the .RUN file, its date and time (when it was last saved), and a user-specified description of the .RUN file. The description may be up to 5 lines of 60 characters each . Upon execution of the noise model, status information (including error and warning messages) is written to the .TXT file.

Data pertaining to the computation of Points of Interest (POI) or alternative POI are contained in Lines 7 through 9. POI may be specified by the user in the .OPS file. Alternative POI are usually specified by the user during an interactive session of NMPlot. The flags COMPUTEPOI and IGNOREPOI instruct the noise model to perform POI calculations and to ignore the POI, respectively; however, if alternative POI exist in the .RUN file, the noise model automatically performs POI calculations for the alternative POI only. If COMPUTEPOI is specified, then a .POI filename must be specified. The AAM .POI format is not the same as NOISEMAP's POI file.

If alternative POI are utilized they are specified as shown on line 8 via their (x,y,z) and (latitude, longitude) coordinates and a 42-character description for each point. The sample .RUN file of Figure 3-12 does not contain alternative POI.

AAM has the ability to account for topographical and terrain effects in the noise calculations. The flags COMPUTETOP and IGNORETOP instruct the noise model to perform topographical and terrain attenuation calculations or to ignore these effects, respectively.

The computation of the noise grid is controlled via lines 10 through 12. The grid filename (extension .GRD) is specified on line 11. The flags COMPUTEGRD and IGNOREGRD instruct the noise model to perform grid calculations and write the results to the .GRD file or not.

If COMPUTEGRD is specified, then the user must also specify: (a) the full .GRD filename on line 10, and (b) grid parameters on lines 11 and 12. The grid parameters are the bounds of the grid (coordinates of its lower left and upper right corners), the grid spacings (for the x and y), and the grid orientation (magnetic declination in degrees relative to true North). If IGNOREGRD is specified, grid calculations will not be performed and the contents per lines 11 and 12 must not be present in the .RUN file. All output metrics are computed for a receiver height 5.0 ft above ground level.

The noise metric must always be present on Line 10 regardless of the grid computation status. Acceptable noise metric qualifiers are:

- DNL, Day-Night Average Sound Level.
- CNEL, Community Noise Equivalent Level.
- LEQ, (24-hour) Equivalent Sound Level.
- NEF, Noise Exposure Forecast.
- WECPNL, Weighted Equivalent Continuous Perceived Noise Level.
- AMAX, Maximum A-weighted Sound Level.
- NA*xxx*YYYY, Number-of-events Above (NA) Supplemental Metric.
- TA*xxx*, Time Above (TA) seconds, Supplemental Metric.

Supplemental Metrics can now be output in the form of a Grid File and within the Text Output from a Multiple-Operations Case. To access this capability, within the .RUN file, a formatted string is used to specifiy the metric desired in place of the normal metric on what is noted as Line 10 of the .RUN file description in this manual. The two possibilities are NA and TA. NA*xxx*YYYY where NA indicates use of the Number-of-events Above, *xxx* is the level specification for number-of-events in dB, and YYYY is the metric specification for number-of-events Computation. Allowable metrics include SEL, ALM (LMax), and PNLT. TA*xxx* where TA indicates use of the Time Above metric, *xxx* is the threshold level specification in dBA.

For example, NA090SEL will cause RNM to output a Number-of-events Above (NA) Grid (if grid computation is enabled) indicating the count of events above a level of 90 dB SEL. In addition, if the COMPUTEPOI keyword is enabled, the Points of Interest information, including contributor ranking and totals for each point, is written to the text file output.

The notes in Table 3-27 below contain additional rules and conditions for the items defined by the RUN keyword.

Keyword **ENDRUN**

ENDRUN must appear at the end of the .RUN file, as presented in Table 3-28.

Table 3-27. RUN Keyword Format

Line	Column	Format	Description
1	1–3	A3	Keyword for run options/specification data (RUN)
2	1–12	A12	.RUN filename
	27–29	F3.1	.RUN file version (e.g., 7.0)
	31–41	A11	Date of .RUN file (dd-mm-yyyy)
	43–50	A8	Time of .RUN file (hh:mm:ss)
	59–60	I2	Number of RUN case description lines (5 max)
3	1–60	A60	RUN case description
4	1–243	A243	Path to the user's case directory where I/O files reside (last character must be a '\')
5	1–12	A12	.OPS filename
6	1–12	A12	Log filename
7	1–10	A10	Flag for computing POINT data ("COMPUTEPOI" or "IGNOREPOI")
	21–32	A12	.POI filename
	46–50	A5	Flag for contributor ranking (by "DAILY" metric or by "EVENT" metric)
	58–60	I3	Number of *alternative* points (100 max)
8	1–10	A10	Identification of alternative point
	11–20	I10	X-coordinate (ft)
	21–30	I10	Y-coordinate (ft)
	31–40	I10	Z-coordinate (ft, AGL)
	41-59	D19.12	Longitude (decimal degrees)
	60	A1	Longitude direction ("W" or "E" for West or East)
	61–79	D19.12	Latitude (decimal degrees)
	80	A1	Latitude direction ("N" or "S" for North or South)
	82–123	A42	Description of alternative point
9	1–10	A10	Flag for computing with topography and ground impedance data ("COMPUTETOP" or "IGNORETOP")
	21–32	A12	Topography (ELV) filename
	41–52	A12	Ground Impedance (IMP) filename
10	1–10	A10	Flag for computing .GRD data ("COMPUTEGRD" or "IGNOREGRD")
	21–32	A12	.GRD filename
	46–51	A6	Noise metric (DNL, CNEL, LEQ, NEF, WECPNL, AMAX, NA*xxx*YYYY)
11	1–10	I10	X-coordinate of lower left corner of grid (ft)
	11–20	I10	Y-coordinate of lower left corner of grid (ft)
	21–30	I10	X-coordinate of upper right corner of grid (ft)
	31–40	I10	Y-coordinate of upper right corner of grid (ft)
12	1–10	I10	Grid spacing in x direction (ft)
	11–20	I10	Grid spacing in y direction (ft)
	27–29	I3	Magnetic grid declination (degrees, 0–180)
	30	A1	Magnetic grid declination direction ("W" or "E" for West or East)

Notes:
(1) Line 3 should be repeated to satisfy the number of case description lines given in line 2, columns 59-60.
(2) If alternative points are entered in the .RUN file, the points in the OPS file are ignored.
(3) Line 8 should be repeated to satisfy the number of alternative points.
(4) The data in lines 11 and 12 should yield a grid size no larger than 200,000 ft by 200,000 ft and/or grid spacing less than 200 ft
(5) The exact quotient of the difference of like grid coordinates and the associated grid spacing must be a whole number (e.g., if x-coordinate upper right = 50,000 ft and x-coordinate lower left = -50,000 ft, then grid spacing in x direction must be a number that divides evenly into the difference between upper right and lower left.
(6) Only include lines 11 and 12. Would not exist if the COMPUTEGRD flag were set in line 10.
(7) AMAX reports the maximum A-weighted SEL at a particular grid point considering all operations in the analysis. For single event AMX run only one operation.
(8) NA number-of-events metric where *xxx* is the numeric user-supplied threshold and YYYY is the single event metric (SEL, ALM, EPNL or PNLT).
(9) Daily flag for contributor ranking means contributors will be sorted by NA.
(10) All output metrics are calculated for a receiver height 5.0 ft AGL.

Table 3-28. ENDRUN Keyword Format

Line	Column	Format	Description
1	1–6	A6	ENDRUN keyword for end of run data ENDRUN

3.4.2.2 Multiple-Operations Input File (.OPS/.OPX) Description

BaseOps can prepare two data files containing the data required to describe the modeled flight and run-up events—the Operations (.OPS) and the Executable Operations (.OPX) as denoted by the file extensions. The only difference between the two files is the .OPX file contains the reference noise data required by NOISEMAP. The .OPS file does not contain the reference noise data required by NOISEMAP. Because the model can utilize either file structure, both files are referenced in this section.

The .OPS file is a fixed format ASCII text file. Information is grouped by keyword. Table 3-29 lists the keywords associated with .OPS and .OPX files. This section describes the format and content of each keyword. The required keywords are: CASE, AIRFIELD, POINT, NAVAID, RUNWAY, VTOLPAD, STATICPAD, TRACK, ROTARYWINGAC and ROTARYWINGPROF for helicopters and tiltrotors or FIXEDWINGAC and FIXEDWINGPROF for fixed wing aircraft and ENDOPS. It may also include the optional CALCALL keywords.

Figure 3-13 shows a sample .OPS file. The CASE keyword must be first and the ENDOPS keyword must be last. The remaining keywords may appear in any sequence; however, it is suggested they appear in the order shown in Table 3-29.

Table 3-29. .OPS/.OPX Keywords

File	Keyword	Noise Model	
		NOISEMAP	AAM
OPS or OPX	CASE	R	R
	AIRFIELD	R	R
	POINT	R	R
	NAVAID	R	R
	RUNWAY	R	R
	VTOLPAD	R*	R
	STATICPAD	R	R
	TRACK	R	R
	FLIGHTAC	R	n/a
	ROTARYWINGAC	n/a	R
	FIXEDWINGAC	n/a	R
	FLIGHTPROF	R	n/a
	ROTARYWINGPROF	n/a	R
	FIXEDWINGPROF	n/a	R
	STATICAC	R	n/a
	STATICPROF	R	n/a
	ENDOPS	R	R
	CALCALL	n/a	O
	NOTERRCHECK	n/a	O
OPX only	FLIGHTNOISE	R (1, 3)	n/a
	STATICNOISE	R (2, 3)	n/a
	ENDNOISE	R	n/a

Notes: * Not currently enabled.
R = required keyword.
O = optional keyword.
n/a = not available.

```
12345678901234567890123456789012345678901234567890123456789012345678901234567890
CASE
sample.ops                7.0 01-Aug-1998 12:00:00        3
          PROPSED AIRFIELD, BASELINE 1998 NOISE STUDY
          [Author :Mr. Chop Chop]  This case is for demonstration
          purpose only.

AIRFIELD
          Unnamed Airfield
 AirfldRP:         0         0       500    77.010000000000W    38.540000000000N
          Airfield Reference Point
     4.40W         2         3
          [Annual Flying Days: 365.00]  Demonstration File
          This field is reserved for description of the run file.

ANYDGL.DGL          01-JAN-1997 10:20:30
  Modeled:     66.0F   70.0%RH 29.90inHg
  Monthly:     66.0    70.0    29.90
               66.0    70.0    29.90
               66.0    70.0    29.90
               66.0    70.0    29.90
               66.0    70.0    29.90
               66.0    70.0    29.90
               66.0    70.0    29.90
               66.0    70.0    29.90
               66.0    70.0    29.90
               66.0    70.0    29.90
               66.0    70.0    29.90
               66.0    70.0    29.90
               66.0    70.0    29.90
POINT             6
01             7000         0         5    77.010000000000W    38.540000000000N Point 1
02            10000         0         5    77.010000000000W    38.540000000000N Point 2
03             7000      6000         5    77.010000000000W    38.540000000000N Point 3
04             7000      3000         5    77.010000000000W    38.540000000000N Point 4
05            -3000         0         5    77.010000000000W    38.540000000000N Point 5
06            -6000         0         5    77.010000000000W    38.540000000000N Point 6
NAVAID            1
TACA              0     -5000       500    77.010000000000W    38.540000000000N TACA
RUNWAY            2
09                0         0       500      4000         0       500
    77.010000000000W    38.540000000000N    77.010000000000W    38.540000000000N300
27             4000         0       500         0         0       500
    77.010000000000W    38.540000000000N    77.010000000000W    38.540000000000N300
VTOLPAD           1
PAD01             0      2000       500    77.010000000000W    38.540000000000N
STATICPAD         1
HH01              0     -2000       500    77.010000000000W    38.540000000000N TC
TRACK             4
09D1            DEP09                        0.00         1         1
Example departure from runway 09
             300000      0.0     300000    300000
27D1            DEP27                        0.00         1         1
Example departure from runway 27
             300000      0.0     300000    300000
27A1            ARR          27              0.00         1         3
Example arrival onto runway 27
               3000      0.0       3000      3000
               3000    180.0L      9424     12424
             287576      0.0     287576    300000
27A2            ARR          27              0.00         1         5
Example of a pattern flown over runway prior to landing
               6000      0.0       6000      6000
               3000    180.0R      9424     15424
               6000      0.0       6000     21424
               3000    180.0R      9424     30848
             300000      0.0     300000    330848
```

Figure 3-13. Sample .OPS File (*continued next page)*

```
FIXEDWINGAC        1
AV8B_     TestField, Canada
FIXEDWINGPROF      4
0001      FIXEDWING  AV8B_
09D1               0         0      25.0      0.00      0.00         0         5
                   0       550        40         0         0         0        90         0
                2000       975        40         0         0         0        90         0
                4000      1250        65         0         0         0        90         0
               10000      1250        70         0         0         0        90         0
              300000      1250        80         0         0         0        90         0
0002      FIXEDWING  AV8B_
09D1               0         0      9.00      3.00      0.00         0         5
                   0       550        40         0         0         0        90         0
                3000      1200        60         0         0         0        90         0
                4000      1200        70         0         0         0        90         0
               10000      1200        70         0         0         0        90         0
              300000      1200        80         0         0         0        90         0
0003      FIXEDWING  AV8B_
27A1               0         0      15.0      0.00      0.00         0         5
                   0       550        50         0         0         0        90         0
                3000      1025        60         0         0         0        90         0
                4000      1025        70         0         0         0        90         0
               10000      1025        80         0         0         0        90         0
              300000      1025        90         0         0         0        90         0
0004      FIXEDWING  AV8B_
27A2               0         0      10.0      0.00      0.00         0         5
                   0       500        50         0         0         0        90         0
                3000      1025        60         0         0         0        90         0
                4000      1025        70         0         0         0        90         0
               10000      1025        80         0         0         0        90         0
              300000      1025        95         0         0         0        90         0
ENDOPS
```

```
123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
```

Figure 3-13. Sample .OPS File *(concluded)*

Keyword **CASE**

The **CASE** keyword contents and format is given in Table 3-30. Line 1 is for the CASE keyword. The .OPS file is self-documented in lines 2 and 4 as they contain the full name of the .OPS file, its date and time, and a user-specified .OPS case description. The case description starts with a banner line and then can be followed by up to four more lines of 60 characters each (e.g., "Wright-Patt AFB Existing 1998 Ops, 260 operational days/year").

Table 3-30. CASE Keyword Format

Line	Column	Format	Description
1	1–4	A4	keyword for case data
2	1–12	A12	.OPS filename
	13–26	Blank	
	27–29	F3.1	.OPS file version (e.g., 7.0)
	30	Blank	
	31–41	A11	date of .OPS file (dd-mmm-yyyy)
	42	Blank	
	43–50	A8	time of .OPS file (hh:mm:ss)
	51–58	Blank	
	59–60	I2	number of case description lines (5 max)
3	1–10	Blank	
	11–70	A60	.OPS case banner (long name)
4	1–10	Blank	
	11–70	A60	.OPS case description

Note: Line 4 should be repeated to satisfy the number of case description lines.

Keyword **AIRFIELD**

The **AIRFIELD** keyword content and data format is presented in Table 3-31. This block of data generally includes the airbase name, the airfield reference point, the feature file, and climatological information. The airfield reference point is defined in terms of (x,y,z) and (latitude, longitude) coordinates. This is the point from which all other (x,y,z) coordinates in the earth-fixed coordinate system inputs are defined. The Z value is the elevation of the airfield reference point in feet (ft) above Mean Sea Level (MSL) and care should be taken to ensure it matches the elevations of the runways in the terrain files (if used). The number of daily periods (2: day, nighttime or 3: day, evening, nighttime) should be consistent with the noise metric specified in the .RUN file. The DNL and NEF metrics require 2 daily periods whereas the CNEL and WECPNL metrics require 3 daily periods.

The climatological information for the airfield in terms of modeled and monthly average temperatures, relative humidities, and atmospheric pressures, as defined in the NOISEMAP input deck, is compatible with BaseOps. Presently, AAM uses a U.S. Standard Atmosphere and assumes a 70 percent relative humidity for multiple track analysis. A user-defined atmospheric profile is currently only available in single track mode.

Keyword **POINT**

For the **POINT** keyword, content and format is defined in Table 3-32, and is used to describe the Points of Interest (POI) for which more detailed noise exposure calculations are made.

The (x,y,z) and (latitude, longitude) coordinates of each POI as well as a 42-character description are included. Note that the Z value is in terms of feet Above Ground Level (AGL) and not MSL. This height is added to the local ground altitude when utilizing terrain. Latitude and longitude values are ignored.

Table 3-31. AIRFIELD Keyword Format

Line	Column	Format	Description
1	1–8	A8	CASE keyword for airfield data
2	1–10	Blank	
	11–70	A60	Airbase name (e.g., Wright-Patterson AFB)
3	1	Blank	
	2–10	A9	“AirfldRP:”
	11–20	I10	X-coordinate airfield reference point (+x=feet east of reference point)
	21–30	I10	Y-coordinate airfield reference point (+y=feet north of reference point)
	31–40	I10	Z-coordinate airfield reference point (+z=feet above MSL)
	41–59	D19.12	Longitude (decimal degrees)
	60	A1	Longitude direction (“W” or “E” for West or East)
	61–79	D19.12	Latitude (decimal degrees)
	80	A1	Latitude direction (“N” or “S” for North or South)
4	1–10	Blank	
	11–70	A60	Reference point description
5	1–3	Blank	
	4–9	F6.2	Magnetic declination (degrees, 0.00–180.00)
	10	A1	Magnetic declination direction (“W” or “E” for West or East)
	11–18	Blank	
	19–20	I2	Number of daily periods (2 or 3)
	21–28	Blank	
	29–30	I2	Number of comment lines (15 max)
6	1–10	Blank	
	11–70	A60	Comment text
7	1–12	A12	Feature (.DLG) filename (Not used)
	13–20	Blank	
	21–31	A11	Date of .DLG file (dd-mmm-yyyy in the form: 15-DEC-1997)
	32–33	Blank	
	34–41	A8	Time of .DLG file (hh:mm:ss)
8	1–2	Blank	(Not used)
	3–10	A8	“Modeled:”
	11–15	Blank	
	16–19	F4.1	Modeled temperature (degrees F or C)
	20	A1	Temperature units (“F” or “C” for Fahrenheit or Celsius)
	21–23	Blank	
	24–27	F4.1	Modeled relative humidity (%RH)
	28–30	A3	Humidity units (“%RH”)
	31	Blank	
	32–36	F5.2	Modeled barometric pressure (inHg)
	37–40	A4	Pressure units (“inHg”)
9	1–2	Blank	(Not used by AAM)
	3–10	A8	“Monthly:”
	11–15	Blank	
	16–19	F4.1	Monthly temperature (same units as modeled)
	20–23	Blank	
	24–27	F4.1	Monthly relative humidity (same units as modeled)
	28–31	Blank	
	32–36	F5.2	Monthly barometric pressure (same units as modeled)

Notes: (1) Line 6 should be repeated to satisfy the number of comment lines.
(2) Line 9 fields 11–36 (with blanks in fields 1–10) would be repeated to satisfy 12 months of data. Present for compatibility with other noise models.
(3) Modeled temperature and humidity is not relevant and would typically be computed by BaseOps from the monthly values.
(4) The first AIRFIELD comment line must contain the number of operational days per year in the form: XXX operational days per year.

Table 3-32. POINT Keyword Format

Line	Column	Format	Description
1	1–5	A5	POINT keyword for points of interest
	6–18	Blank	
	19–20	I2	Number of points (100 max)
2	1–10	A10	Point identification
	11–20	I10	X-coordinate (ft)
	21–30	I10	Y-coordinate (ft)
	31–40	I10	Z-coordinate (ft, AGL)
	41–59	D19.12	Longitude (decimal degrees)
	60	A1	Longitude direction (“W” or “E” for West or East)
	61–79	D19.12	Latitude (decimal degrees)
	80	A1	Latitude direction (“N” or “S” for North or South)
	81	Blank	
	82–123	A42	Description of point

Notes: (1) Line 2 should be repeated to satisfy the number of points.
(2) Z-axis for Points of Interest is in units of feet AGL, all other Z-axis values are in feet MSL.

Keyword **NAVAID**

The **NAVAID** keyword (Table 3-33) describes Navigational Aids (navaids), points on the ground usually representing facilities providing Terminal Area Control and Navigation (TACAN) services, Very-high Omnidirectional Radio (VOR) signals or Non-Directional Beacon (NDB) signals. Navaids can also be ground points representing significant features such as road intersections used to guide pilots. Navaids are not used for noise exposure calculations but are passed into the NMPlot program for plotting via the .GRD file. Navaids are typically used to develop the flight tracks. Latitude and longitude values are ignored.

Table 3-33. NAVAID Keyword Format

Line	Column	Format	Description
1	1–6	A6	NAVAID keyword for navigational aid data
	7–18	Blank	
	19–20	I2	Number of navigational aids (15 max)
2	1–10	A10	Navaid identification
	11–20	I10	X-coordinate (ft)
	21–30	I10	Y-coordinate (ft)
	31–40	I10	Z-coordinate (ft, MSL)
	41–59	D19.12	Longitude (decimal degrees)
	60	A1	Longitude direction (“W” or “E” for West or East)
	61–79	D19.12	Latitude (decimal degrees)
	80	A1	Latitude direction (“N” or “S” for North or South)
	81	Blank	
	82–123	A42	Description of navigational aid

Note: Line 2 should be repeated to satisfy the number of navigational aids

Keyword **NOTTERCHECK**

The **NOTTERCHECK** signals RNM to skip the checking of the integrated flight tracks and profiles against the terrain data extents (domain of coverage) and local ground altitudes. If any discrepancies are encountered (such as aircraft trajectories extending beyond the extent of the terrain grid or aircraft flying below the local ground altitude) they are treated as warnings and output to the screen rather than treated as errors and program execution halted. This feature should only be used with extreme caution!

Keyword **RUNWAY**

The **RUNWAY** keyword (Table 3-34) defines the active runways at an airfield. For each runway, an identification and the (x,y,z) centerline coordinates and runway width (in feet) are read. Latitude and longitude values are ignored.

Table 3-34. RUNWAY Keyword Format

Line	Column	Format	Description
1	1–6	A6	RUNWAY keyword for runway data
	7–18	Blank	
	19–20	I2	Number of runways (20 max)
2	1–10	A10	Runway identification
	11–20	I10	X-coordinate at beginning of runway(ft)
	21–30	I10	Y-coordinate at beginning of runway (ft)
	31–40	I10	Z-coordinate at beginning of runway (ft, MSL)
	41–50	I10	X-coordinate at end of runway(ft)
	51–60	I10	Y-coordinate at end of runway (ft)
	61–70	I10	Z-coordinate at end of runway (ft, MSL)
3	1–19	D19.12	Longitude at beginning (decimal degrees)
	20	A1	Longitude direction (“W” or “E” for West or East)
	21–39	D19.12	Latitude at beginning (decimal degrees)
	40	A1	Latitude direction (“N” or “S” for North or South)
	41–59	D19.12	Longitude at end (decimal degrees)
	60	A1	Longitude direction (“W” or “E” for West or East)
	61–79	D19.12	Latitude at end (decimal degrees)
	80	A1	Latitude direction (“N” or “S” for North or South)
	81–83	I3	Runway width (feet)

Note: Lines 2 and 3 should be repeated to satisfy the number of runways.

Keyword **VTOLPAD**

The **VTOLPAD** keyword section (Table 3-35) describes each Vertical Takeoff and Landing (VTOL) pad to be used by rotary wing aircraft and vertical lift aircraft. See the RUNWAY, TRACK, ROTARYWINGPROF, and FIXEDWINGPROF keywords. VTOL pads can be passed to NMPlot via the GRD file for plotting and documentation purposes.

Table 3-35. VTOLPAD Keyword Format

Line	Column	Format	Description
1	1–7	A7	VTOLPAD keyword for VTOL pad data
	8–18	Blank	
	19–20	I2	Number of VTOL pads (20 max)
2	1–10	A10	VTOL pad identification
	11–20	I10	X-coordinate (ft)
	21–30	I10	Y-coordinate (ft)
	31–40	I10	Z-coordinate (ft, MSL)
	41–59	D19.12	Longitude (decimal degrees)
	60	A1	Longitude direction (“W” or “E” for West or East)
	61–79	D19.12	Latitude (decimal degrees)
	80	A1	Latitude direction (“N” or “S” for North or South)
	81	Blank	
	82–123	A42	Description of VTOL pad

Note: Line 2 should be repeated to satisfy the number of VTOL pads.

Keyword **STATICPAD**

The **STATICPAD** keyword section (Table 3-36) describes each static pad at which static maintenance checks typically called "run-ups" are performed on engines/aircraft. Run-up is a term named after the power cycle executed during maintenance checks whereby an engine is initially run at low power settings and then increased to higher power settings. Run-ups may be conducted individually on installed engines or on engine test stands, indoors (e.g., in a test cell building or an acoustical enclosure, known as a "hush house") or outdoors. The STATICPAD keyword describes the static pad(s) location, (x,y,z), (latitude, longitude) coordinates, and a 42-character description. Static pads can be passed to NMPlot via the .GRD file for plotting and documentation purposes.

Table 3-36. STATICPAD Keyword Format

Line	Column	Format	Description
1	1–9	A9	STATICPAD keyword for static pad data
	10–18	Blank	
	19–20	I2	Number of static pads (50 max)
2	1–10	A10	Static pad identification
	11–20	I10	X-coordinate (ft)
	21–30	I10	Y-coordinate (ft)
	31–40	I10	Z-coordinate (ft, MSL)
	41–59	D19.12	Longitude (decimal degrees)
	60	A1	Longitude direction ("W" or "E" for West or East)
	61–79	D19.12	Latitude (decimal degrees)
	80	A1	Latitude direction ("N" or "S" for North or South)
	81	Blank	
	82–123	A42	Description of static pad

Note: Line 2 should be repeated to satisfy the number of static pads.

Keyword **TRACK**

The **TRACK** keyword section (Table 3-37) describes the modeled flight track parameters, namely, the projection of an aircraft's path on the ground. Track parameters consist of segment details and such identification as track type: arrival, departure, closed pattern, and interfacility. Arrival and departure tracks are self-explanatory. A closed pattern track is one that begins and ends at the same point, and is typically used to model touch-and-go, field carrier landing practice, and ground-controlled approach box events. An interfacility track begins at one airfield and ends at another (nearby) airfield/location. For example, Medivac flights usually proceed from a hospital to return to an airport/heliport. Interfacility tracks require specification of a destination runway/VTOL pad on Line 2. If the track originates from a VTOL pad, the initial magnetic heading is written to Line 2.

Track segments are described via a turn angle (degrees left or right) and length (radius for turn segments) and the running cumulative track length distance. A departure track is defined by segments beginning at the runway and proceeding in the direction of travel. An arrival track, however, is specified opposite the direction of travel.

Table 3-37. TRACK Keyword Format

Line	Column	Format	Description
1	1–5	A5	TRACK keyword for flight track data
	6–17	Blank	
	18–20	I3	Number of flight tracks (400 max)
2	1–10	A10	Flight track identification
	11–17	Blank	
	18–20	A3	Type of flight track (“ARR”, “DEP”, “PAT”, or “ITF” for Arrival, Departure, Closed Pattern, or Interfacility, respectively)
	21–30	A10	Identification of runway/VTOL pad of origination
	31–40	A10	Identification of runway/VTOL pad of destination
	41–44	Blank	
	45–50	F6.2	VTOL magnetic heading (degrees)
	51–58	Blank	
	59–60	I2	Number of comment lines (15 max)
	61–68	Blank	
	69–70	I2	Number of flight track segments (50 max)
3	1–10	Blank	
	11–70	A60	Comment text
4	1–10	Blank	
	11–20	I10	Segment distance (straight) or radius (turn), (ft)
	21–23	Blank	
	24–29	F6.1	Segment turn angle (degrees)
	30	A1	Segment turn direction (“L”, “R”, or Blank for Left, Right, or Straight)
	31–40	I10	Segment length (ft)
	41–50	I10	Cumulative flight track length (ft)

Notes: (1) Line 3 should be repeated to satisfy the number of comment lines.
(2) Line 4 should be repeated to satisfy the number of flight track segments.
(3) Lines 2-4 should be repeated to satisfy the number of flight tracks.
(4) Line 2 columns 21–40 can be populated for closed patterns and interfacility departures would only have columns 21–30 populated. Arrivals would only have columns 31–40 populated.
(5) Segment distance or radius must be greater than 0 and the first segment must be a straight segment
(6) Segment turn angle must be greater than or equal to 0.
(7) Segment turn angle is actually F5.1 excluding its sign, which NMAP subsequently assigns.
(8) Cumulative track length should be ascending with ascending segment number.

Keyword **ROTARYWINGAC**

The **ROTARYWINGAC** keyword (Table 3-38) is used to identify all of the aircraft for which rotary wing flight profiles are given in the ROTARYWINGPROF keyword section. The aircraft identification is expected to have a five-character name.

Table 3-38. ROTARYWINGAC Keyword Format

Line	Column	Format	Description
1	1–12	A12	ROTARYWINGAC keyword for flight aircraft data
	13–17	Blank	
	18–20	I3	Number of unique flight aircraft IDs in all flight profiles (200 max)
2	1–10	A10	Rotary wing aircraft identification
	11–30	A20	Rotary aircraft name
	31–50	A20	Rotary aircraft’s engine name (optional)

Note: Line 2 should be repeated to satisfy the number of flight aircraft IDs.

Keyword **ROTARYWINGPROF**

The **ROTARYWINGPROF** keyword (Table 3-39) is used to describe the flight profiles for each of the flight aircraft listed under the ROTARYWINGAC keyword. A rotary wing flight profile defines yaw angle, angle of attack, roll angle, and nacelle tilt angle as a function of cumulative track distance. Inputs are in the coordinate reference systems described in Chapter 2.

Table 3-39. ROTARYWINGPROF Keyword Format

Line	Column	Format	Description
1	1–14	A14	ROTARYWINGPROF keyword for flight profile data
	15–16	Blank	
	17–20	I4	Number of flight profiles (1000 max)
2	1–10	A10	Flight profile identification
	11–20	A10	Aircraft category (“HELICOPTER”)
	21–30	A10	Rotary wing aircraft ID
3	1–10	A10	Flight track ID
	11–20	I10	Takeoff displacement (ft)
	21–30	I10	Landing displacement (ft)
	31–32	Blank	
	33–40	F8.3	Number of daytime (0700-1900 or 0700-2200) events
	41–42	Blank	
	43–50	F8.3	Number of evening (1900-2200) events
	51–52	Blank	
	53–60	F8.3	Number of nighttime (2200-0700) events
	61–68	Blank	
	69–70	I2	Number of comment lines (15 max)
	71–78	Blank	
	79–80	I2	Number of profile segments (30 max)
4	1–10	Blank	
	11–70	A60	Comment text
5	1–10	Blank	
	11–20	I10	Cumulative flight track distance (ft)
	21–30	I10	Altitude (ft, MSL)
	31–40	I10	Indicated airspeed (kts)
	41–50	I10	Yaw Angle (angle of the aircraft relative to its vertical axis in degrees, positive nose left)
	51–60	I10	Angle of Attack (angle between the climb angle and the pitch angle in degrees, positive nose up. The climb angle is the angle between the horizontal and the velocity vector, positive up (same convention). The pitch angle is the angle between the horizontal and the thrust vector (same convention)
	61–70	I10	Roll Angle (angle of the aircraft relative to its longitudinal axis in degrees, positive port wing down)
	71–80	I10	Nacelle Tilt Angle (angle of engine nacelle pylon relative to the horizontal (airplane) mode in degrees, positive up; maximum of 90°)

Notes: (1) Line 4 should be repeated to satisfy the number of comment lines.
(2) Line 5 should be repeated to satisfy the number of flight profile segments.
(3) Lines 2-5 should be repeated to satisfy the number of flight profiles.
(4) Flight profiles should be grouped or sorted by aircraft ID.
(5) The .OPS file must only contain profiles with non-zero events.

The following profile parameters must be defined: identification (ID), aircraft category (HELICOPTER), rotary wing aircraft ID, pre-flight aircraft ID, track ID with displacement, numbers of events, and profile comment lines.

Each flight profile is assigned to the specified flight track. Each flight track is assigned to a runway/VTOL pad. However, since some rotary wing flight events do not in turn, coincide with runway endpoints or thresholds, a takeoff or landing displacement may be specified. Only interfacility tracks/profiles may use takeoff and landing displacements. Displacements do not apply to tracks associated with VTOL pads. The number of operations per day is specified in terms of daytime, evening, and nighttime events, consistent with the number of daily periods entered in the AIRFIELD keyword section.

The profile altitude, airspeed (knots), yaw angle, angle of attack, roll angle, and nacelle tilt angle are defined at each cumulative (track) distance. All angles must be specified in units of degrees. For compatibility and consistency with NOISEMAP, when using multiple operations mode a minimum of 5 ft AGL height will be utilized for all input profiles. If 0 altitude is entered in the input .OPS file it will automatically be adjusted to 5 ft AGL. A warning message will be generated in the log file (see Section 3.6). When using the TERRAIN keyword or specifying an elevation file in the analysis, profile altitudes are input in ft AGL and adjusted inside AAM to account for the local terrain height.

Keyword **FIXEDWINGAC**

The **FIXEDWINGAC** keyword (Table 3-40) is used to identify all of the fixed wing aircraft for which flight profiles are given in the FIXEDWINGPROF keyword section. The aircraft identification is expected to have a five-character name.

Table 3-40. FIXEDWINGAC Keyword Format

Line	Column	Format	Description
1	1–11	A11	FIXEDWINGAC keyword for flight aircraft data
	12–17	Blank	
	18–20	I3	Number of unique flight aircraft IDs in all flight profiles (200 max)
2	1–10	A10	Fixed wing aircraft identification
	11–30	A20	Fixed aircraft name
	31–50	A20	Fixed aircraft's engine name (optional)

Note: Line 2 should be repeated to satisfy the number of flight aircraft IDs.

Keyword **FIXEDWINGPROF**

The **FIXEDWINGPROF** keyword (Table 3-41) is used to describe the flight profiles for each of the flight aircraft listed under the FIXEDWINGAC keyword. A fixed wing flight profile defines power setting, aircraft configuration state, thrust vector angle, altitude, and airspeed as a function of distance along a given flight track. Inputs are in the coordinate reference systems described in Chapter 2.

The following profile parameters must be defined: identification (ID), aircraft category, aircraft ID, pre-flight run-up duration and power units, track ID with displacement, numbers of events, and profile comment lines.

Each flight profile is assigned to the specified flight track. Each flight track is assigned to a runway/VTOL pad. However, since some flight events in turn, coincide with runway endpoints or thresholds, a takeoff or landing displacement may be specified. Only interfacility tracks/profiles may use takeoff and landing displacements. Displacements do not apply to tracks associated with VTOL pads. The number of operations per day is specified in terms of daytime, evening, and nighttime events, consistent with the number of daily periods entered in the AIRFIELD keyword section.

Table 3-41. FIXEDWINGPROF Keyword Format

Line	Column	Format	Description
1	1–13	A13	FIXEDWINGPROF keyword for flight profile data
	14–16	Blank	
	17–20	I4	Number of flight profiles (1000 max)
2	1–10	A10	Flight profile identification
	11–20	A10	Aircraft category (“FIXEDWING”)
	21–30	A10	Fixed wing aircraft ID
	31-47	Blank	
	48-50	I3	Pre-flight run-up duration (seconds)
	51	Blank	
	52-58	A7	“Seconds”
	59-60	Blank	
	61-70	A10	Power unit test
3	1–10	A10	Flight track ID
	11–20	I10	Takeoff displacement (ft)
	21–30	I10	Landing displacement (ft)
	31–32	Blank	
	33–40	F8.3	Number of daytime (0700-1900 or 0700-2200) events
	41–42	Blank	
	43–50	F8.3	Number of evening (1900-2200) events
	51–52	Blank	
	53–60	F8.3	Number of nighttime (2200-0700) events
	61–68	Blank	
	69–70	I2	Number of comment lines (15 max)
	71–78	Blank	
	79–80	I2	Number of profile segments (30 max)
4	1–10	Blank	
	11–70	A60	Comment text
5	1–10	Blank	
	11–20	I10	Cumulative flight track distance (ft)
	21–30	I10	Altitude (ft, MSL)
	32–40	F9.2	Engine operation state (thrust or power) defined in units consistent with the NetCDF source noise data files.
	41-50	I10	Aircraft configuration state, consistent with those in the NC files. Standard ACCONFIG parameters are 0 = clean, 1 = deployed flaps, 2 = deployed flaps & gear (only for arrivals), 3 = Static Run-Up (only for departures (1st point only))
	51–60	I10	Indicated airspeed (kts)
	61–70	I10	Yaw Angle (angle of the aircraft relative to its vertical axis in degrees, positive nose left)
	71–80	I10	Angle of Attack (angle between the climb angle and the pitch angle in degrees, positive nose up. The climb angle is the angle between the horizontal and the velocity vector, positive up (same convention). The pitch angle is the angle between the horizontal and the thrust vector (same convention)
	81–90	I10	Roll Angle (angle of the aircraft relative to its longitudinal axis in degrees, positive port wing down)
	91-100	I10	Thrust vector angle (degrees) 0° for engine thrust vector pointing aft, positive 90° for engine thrust vector perpendicular to longitudinal axis, towards belly of aircraft.

Notes: (1) Line 4 should be repeated to satisfy the number of comment lines.
(2) Line 5 should be repeated to satisfy the number of flight profile segments.
(3) Lines 2-5 should be repeated to satisfy the number of flight profiles.
(4) Flight profiles should be grouped or sorted by aircraft ID.
(5) The .OPS file must only contain profiles with non-zero events.

The profile altitude (ft, MSL), thrust vector angle, aircraft configuration state, airspeed (knots), yaw angle, angle of attack, roll angle, and engine operating state (thrust) are defined at each cumulative (track) distance. All angles must be specified in units of degrees.

For compatibility and consistency with NOISEMAP, when using multiple operations mode a minimum of 5 ft AGL height will be utilized for all input profiles. If 0 altitude is entered in the input .OPS file it will automatically be adjusted to 5 ft AGL. A warning message will be generated in the log file (see Section 3.6).

Keyword **CALCALL**

CALCALL triggers the inclusion of 100% of the operations in its acoustic analysis. Ordinarily the model looks at the track proximity to the point in question and decides if it meets the acoustic criteria (see keyword SETUP PARA) for analysis. When using the CALCALL keyword (Table 3-42), this checking is skipped and all tracks are analyzed regardless of the criteria.

Table 3-42. CALCALL Keyword Format

Line	Column	Format	Description
1	1–7	A7	CALCALL keyword to force 100% operation calculations

Keyword **NOTERRCHECK**

NOTERRCHECK relaxes the program pre-screening of input flight trajectories and does not generate error or warning messages if the following situations are encountered:

- Aircraft below ground level; and
- Aircraft source location extending beyond the extent of the elevation or impedance file.

Keyword **ENDOPS**

The **ENDOPS** keyword (Table 3-43) concludes the operations portion of the .OPS/.OPX file.

Table 3-43. ENDOPS Keyword Format

Line	Column	Format	Description
1	1–6	A6	ENDOPS keyword for end of operations data

3.5 Error and Warning Messages

Error messages fall into three categories: Error, Warning and general information. Error messages are created when fatal situations are encountered that require cessation of program execution. These are preceded by ERROR: in the output. Warning messages are preceded by WARNING: and give critical information about analysis. Under warning conditions, execution is continued, however the user should be aware that non-standard program operation has occurred. All other messages and output fall into the informational category.

The ERROR and WARNING messages are itemized here in **BOLD type** along with an explanation and where appropriate, recommended changes to the input file. In some instances, values of particular variables are provided to the user. These are indicated in *italics* and explained with each error message. At the end of every message is the name of the subroutine that generated the message. While this is not likely to be of significant value to the user it should be reported when inquiring about AAM to Wyle Laboratories.

Error messages are generated based on problems in two different areas: Input file errors and run time errors. Input file error message are generated after screening of the inputs and are standardized and conform to the general output listed in Table 3-44, with details as explained in

Table 3-45. Run time errors are generated later in program execution and may include a variety of output messages, all of which appear in alphabetical order in this section of the manual.

Table 3-44. Input File Error Message Standardized Output

ERROR: Read Error in the Advanced Acoustic Model. **Problem in the following file: Filename** ***Detailed Message*** **Problem detected at line number *line#*** **Error located at or above this line:** ***Input file content***

This is a generalized error reporting message, which is generated when problems are encountered in the input file, *filename*. The line number at which the error occurs is identified (*line* #), as well as a repeat of the *Input file content*. A *Detailed Message* is provided for the user's benefit and a summary of possible error messages are given below. The last word on the detailed message line contains the name of the subroutine, which reported the error. This additional diagnostic information is useful when contacting Wyle Laboratories with questions about AAM.

Table 3-45. ERROR: Read Error *Detailed Message* Descriptions

Excessive input, alternate points, .RUN file. RDRUN The maximum number of alternate points has been exceeded in the specified input .RUN file. Reduce the number of alternate points to 100 or less.
Excessive input. AIRFIELD The number of airfield descriptive lines exceeds the current limit of 15. Reduce the number of descriptive lines to 15 or less.
Excessive input. ATMOS keyword, points, .INP file. ATMOSP The input atmospheric profile has exceeded the maximum number of altitudes, 32. Reduce the number of atmospheric profile points to 32 or less.
Excessive input, CASE keyword, .RUN file. RDRUN The number of cases in the .RUN input file exceeds the current limit of 5. Reduce the number of cases in the input file to 5 or less.
Excessive input, CASE keyword, description, .OPS file. CASEKEY The number of lines describing the case contained in the input .OPS file has been exceeded. The maximum allowable number of descriptive lines is 5.
Excessive input, FIXEDWINGAC keyword. RWINGAC The number of fixed wing aircraft types listed in the multiple-operations format input file exceeds the current limit of 20. Reduce the number of different fixed wing aircraft types in the input file to 20 or less.
Excessive input, FIXEDWINGPROF keyword, .OPS file. RWINGPRO The number of profiles specified in the multiple-operations format input file in the FIXEDWINGPROF keyword section exceeds the current limit of 200. Reduce the number of different rotary fixed aircraft types in the input file to 200 or less.
Excessive input, FIXEDWINGPROF keyword, comments, .OPS file. RWINGPRO The number of profile comment lines specified in the multiple-operations format input file in the FIXEDWINGPROF keyword section exceeds the current limit of 15. Reduce the number profile comment lines in the identified profile in the specified .OPS file accordingly.

Table 3-45. ERROR: Read Error *Detailed Message* Descriptions (*continued*)

Excessive input, FIXEDWINGPROF keyword, segments, .OPS file. RWINGPRO The number of profile segments specified in the multiple-operations format input file in the FIXEDWINGPROF keyword section exceeds the current limit of 30. Reduce the number profile segments in the identified profile in the specified .OPS file accordingly.
Excessive input, MAP keyword, .RUN file. RDRUN The number of supplemental maps listed in the input file exceeds the current limit of 10. Reduce the number of supplemental maps in the input file to 10 or less. Note: AAM is compatible with NMPlot and BaseOps by permitting use of the MAP keyword, but does not utilize the data during AAM program execution.
Excessive input, metrics, .INP file. INPUTTRK The number of metrics to be calculated at one time has been exceeded. The maximum number of different metrics that can be put into the grid (.GRD) file in single track input mode is one.
Excessive input, MAP keyword, files, .RUN file. RDRUN The number of map files listed in the input file exceeds the current limit of 10. Reduce the number of map files in the input .RUN file to 10 or less.
Excessive input. NAVAID The number of navigational aids listed in the input file exceeds the current limit of 15. Reduce the number of navigational aids in the input file to 15 or less.
Excessive input, POI. POIREAD The number of specific points listed in the single track format input file exceeds the current limit of 1000. Reduce the number of specific points in the input file to 1000 or less.
Excessive input. POINT The number of specific points listed in the multiple-operations format input file exceeds the current limit of 1000. Reduce the number of specific points in the input file to 1000 or less.
Excessive input. RDOPS The number of profiles listed in the multiple-operations format input file exceeds the current limit of 200. Reduce the number of profiles in the input file to 200 or less.
Excessive input, ROTARYWINGAC keyword. RWINGAC The number of rotary wing aircraft types listed in the multiple-operations format input file exceeds the current limit of 20. Reduce the number of different rotary wing aircraft types in the input file to 20 or less.
Excessive input, ROTARYWINGPROF keyword, .OPS file. RWINGPRO The number of profiles specified in the multiple-operations format input file in the ROTARYWINGPROF keyword section exceeds the current limit of 200. Reduce the number of different rotary wing aircraft types in the input file to 200 or less.
Excessive input, ROTARYWINGPROF keyword, comments, .OPS file. RWINGPRO The number of profile comment lines specified in the multiple-operations format input file in the ROTARYWINGPROF keyword section exceeds the current limit of 15. Reduce the number profile comment lines in the identified profile in the specified .OPS file accordingly.
Excessive input, ROTARYWINGPROF keyword, segments, .OPS file. RWINGPRO The number of profile segments specified in the multiple-operations format input file in the ROTARYWINGPROF keyword section exceeds the current limit of 30. Reduce the number profile segments in the identified profile in the specified .OPS file accordingly.
Excessive input, RUN keyword, case description, .RUN file. RDRUN The number of description lines specified in the multiple-operations format input .RUN file in the RUN keyword section exceeds the current limit of 5. Reduce the number description lines defined in the specified .RUN file accordingly.
Excessive input, .RUN keyword, alternative points, .RUN file. RDRUN The number of alternative points specified in the multiple-operations format .RUN input file in the RUN keyword section exceeds the current limit of 100. Reduce the number of alternative points specified in the .RUN file accordingly.

Table 3-45. ERROR: Read Error *Detailed Message* Descriptions (*continued*)

Excessive input, RUNWAY keyword, .OPS file. RWYKEY The number of runways specified in the multiple-operations format input file in the RUNWAY keyword section exceeds the current limit of 20. Reduce the number runways defined in the specified .OPS file accordingly.
Excessive input, segments, ONE TRACK keyword, .INP file. ONETRK The number of segments used to define the flight track in the single track format (.INP) file in the ONE TRACK keyword section exceeds the current limit of 1000 points.
Excessive input, STATICAC keyword, .OPS file. STATAC The number of static aircraft specified in the multiple-operations format .OPS input file in the STATICAC keyword section exceeds the current limit of 200. Reduce the number static aircraft defined in the specified .OPS file accordingly.
Excessive input, STATICPAD keyword, .OPS file. STATPAD The number of static pads specified in the multiple-operations format .OPS input file in the STATICPAD keyword section exceeds the current limit of 50. Reduce the number static aircraft defined in the specified .OPS file accordingly.
Excessive input, STATICPROF keyword, comments, .OPS file. STATPROF The number of comment lines describing a static profile specified in the multiple-operations format .OPS input file in the STATICPROF keyword section exceeds the current limit of 15. Reduce the number static aircraft defined in the specified .OPS file accordingly.
Excessive input, STATICPROF keyword, profiles, .OPS file. STATPROF The number of static profiles specified in the multiple-operations format .OPS input file in the STATICPROF keyword section exceeds the current limit of 50. Reduce the number static aircraft defined in the specified .OPS file accordingly.
Excessive input, STATICPROF keyword, segments, .OPS file. STATPROF The number of static profiles specified in the multiple-operations format .OPS input file in the STATICPROF keyword section exceeds the current limit of 20. Reduce the number static aircraft defined in the specified .OPS file accordingly.
Excessive input, TOFORMAT keyword, high bound .INP file. INPUTTRK The one-third octave band number input upper bound in the single track format .INP file exceeds the highest frequency of band 40 (10,000 Hz). Adjust the data contained in the TOFORMAT keyword section of the specified .INP file.
Excessive input, TOFORMAT keyword, low bound .INP file. INPUTTRK The one-third octave band number input lower bound in the single track format .INP file exceeds the lowest frequency of band 10 (10 Hz). Adjust the data contained in the TOFORMAT keyword section of the specified .INP file.
Excessive input. TRACK keyword, comments, TRACK The number of comment lines describing a flight track specified in the multiple-operations format .OPS input file in the TRACK keyword section exceeds the current limit of 15. Reduce the number track comment lines defined in the specified .OPS file accordingly.
Excessive input. TRACK keyword, segments, TRACK The number of segments describing a flight track specified in the multiple-operations format .OPS input file in the TRACK keyword section exceeds the current limit of 50. Reduce the number of segments defining the indicated flight track in the specified .OPS file accordingly.
Excessive input. TRACK keyword, tracks, TRACK The number of flight tracks specified in the multiple-operations format .OPS input file in the TRACK keyword section exceeds the current limit of 400. Reduce the number of flight tracks defined in the specified .OPS file accordingly.
Excessive input, VTOLPADS, .OPS file. VTOLPAD The number of vertical takeoff and landing pads specified in the multiple-operations format .OPS input file in the VTOLPAD keyword section exceeds the current limit of 20. Reduce the number of vertical takeoff and landing pads defined in the specified .OPS file accordingly.

Table 3-45. ERROR: Read Error *Detailed Message* Descriptions (*continued*)

Incompatible input, WEATHER ATMOS keywords, .INP file. INPUTTRK Two keywords found in the single track format .INP file are incompatible: ATMOS and WEATHER. If specifying an atmospheric profile with the ATMOS keyword, the straight ray module will be applied. If curved rays are to be used the RNMwea preprocessor must be used before running with the WEATHER keyword.
Incomplete input, Runway/VTOLpad. NMPLOT4 AAM was unable to locate the specified runway or VTOL pad when attempting to write the NMPlot output file for the specific flight track indicated. Add the required runway or VTOL pad or change the specified runway in the flight track.
Input error, ATMOS keyword, press. units, .INP file. ATMOSP AAM did not recognize the units used in the input file to specify the temperature data in the user defined atmospheric profile. Only 'PSI (pounds per square inch), 'MB' (millibars) or 'KPA (kilopascals) are permitted. Adjust the input file to utilize one of these units.
Input error, ATMOS keyword, alt. units, .INP file. ATMOSP AAM did not recognize the units used in the input file to specify the altitude data in the user defined atmospheric profile. Only 'FEET' or 'METER' are permitted. Adjust the input file to utilize either of these units.
Input error, ATMOS keyword, temp. units, .INP file. ATMOSP AAM did not recognize the units used in the input file to specify the temperature data in the user defined atmospheric profile. Only 'F' (degrees Farenheit), 'C' (degrees Celcius) or 'K' (degrees Kelvin) are permitted. Adjust the input file to utilize one of these units.
Input Error, ART keyword, Spectral format missing, .INP file. INPUTTRK The ART keyword must be followed by either the NBFORMAT or TOFORMAT keyword indicating the type of data to be used in the preparation of ART files. When reading the indicated .INP file the required keyword was not found.
Input Error, ART keyword, Sphere Radius, .INP file. INPUTTRK The sphere radius (ft) must be defined on line 5 of the ART keyword section.
Input error, .BAK file. BACKGRND AAM encountered a general error when reading in the header information from the specified background .BAK file.
Input error, .BAK file, band nums. BACKGRND AAM encountered an error reading in the number of background frequencies contained in the specified background (.BAK) file.
Input error, .BAK file, band data. BACKGRND AAM encountered an error reading in the spectral data contained in the specified background (.BAK) file.
Input error, .BAK file, data type. BACKGRND AAM encountered an error reading in the spectral data type contained in the specified background (.BAK) file. Valid inputs are TODATA for one-third octave band background data or NBDATA for narrow band background data.
Input error, .BAK file, frequency. BACKGRND AAM encountered an error reading in the frequency data contained in the specified background (.BAK) file. When specifying one-third octave band background data as indicated by the TODATA keyword, band numbers must be indicated in the .BAK file (Band 10 = 10 hz, Band 40 = 10,000 Hz). When specifying narrow band data in the background file the actual center band frequencies (Hz) must be provided.
Input error, .BAK file, num spectra. BACKGRND AAM encountered an error reading in the number of background spectra specified in the identified .BAK file.
Input error, .BAK file, spectra. BACKGRND AAM encountered an error reading in the background level spectral data contained in the specified background (.BAK) file. Levels must be specified in centibels.

Table 3-45. ERROR: Read Error *Detailed Message* Descriptions (*continued*)

Input error, COMPUTEGRD, x-axis. RDRUN When reading the .RUN file in the COMPUTEGRD section, the input lower left corner x value was equal to or greater than the input upper right corner x value. Adjust the .RUN file so that the grid computational area is specified from lower left to upper right corner using an orthogonal coordinate system with x increasing from left to right and y increasing from bottom to top.
Input error, COMPUTEGRD, y-axis. RDRUN When reading the .RUN file in the COMPUTEGRD section, the input lower left corner y value was equal to or greater than the input upper right corner y value. Adjust the .RUN file so that the grid computational area is specified from lower left to upper right corner using an orthogonal coordinate system with x increasing from left to right and y increasing from bottom to top.
Input error, FIXEDWINGPROF, Adjacent zero velocity, .OPS file. RWINGPRO Two adjacent segments read in from a flight profile in the FIXEDWINGPROF keyword section both had zero flight speeds. Revise the identified profile in the specified .OPS file accordingly.
Input error, FIXEDWINGPROF, Aircraft ID, .OPS file. RWINGPRO The Aircraft ID read in from a flight profile in the FIXEDWINGPROF keyword section does not match any of the aircraft IDs included in the FIXEDWINGAC keyword section. Revise the input file for aircraft identifier completeness and consistency. All aircraft IDs must be exactly 5 characters long.
Input error, FIXEDWINGPROF, First Profile Segment non-Zero, .OPS file. RWINGPRO The track distance for the first point in the first segment in a flight profile in the FIXEDWINGPROF keyword section must be zero. Revise the identified profile in the specified .OPS file accordingly.
Input error, FIXEDWINGPROF, Flight Track ID, .OPS file. RWINGPRO The flight track ID read in from a flight profile in the FIXEDWINGPROF keyword section does not match any of the flight track IDs included in the TRACK keyword section. Revise the input file for aircraft identifier completeness and consistency. All track IDs must be exactly 4 characters long.
Input error, FIXEDWINGAC, Grid. MAIN *FixedID* The specified *FixedID* was not found in the FIXEDWINGAC keyword section in the input file. The error occurred while working on the grid calculations.
Input error, FIXEDWINGAC, POI. MAIN *FixedID* The specified *RotorID* was not found in the ROTARYWINGAC keyword section in the input file. The error occurred while working on the point of interest calculations.
Input error, MAP keyword, category, .RUN file. RDRUN AAM encountered an error reading in the map category information specified in the .RUN file in the MAP keyword section.
Input error, MAP keyword, description, .RUN file. RDRUN AAM encountered an error reading in the map description information specified in the .RUN file in the MAP keyword section.
Input error, MAP keyword, path, .RUN file. RDRUN AAM encountered an error reading in the path name to the map files specified in the .RUN file in the MAP keyword section. The path name should end with a trailing \ character. Spaces are not permitted in paths or filenames.
Input error, MAP keyword, .RUN file. RDRUN AAM encountered a general error reading in the first line of data in the MAP keyword section of the specified .RUN file.
Input error, ROTARYWINGAC, Grid. MAIN *RotorID* The specified *RotorID* was not found in the ROTARYWINGAC keyword section in the input file. The error occurred while working on the grid calculations.
Input error, ROTARYWINGAC, POI. MAIN *RotorID* The specified *RotorID* was not found in the ROTARYWINGAC keyword section in the input file. The error occurred while working on the point of interest calculations.
Input error, ROTARYWINGPROF, Adjacent zero velocity, .OPS file. RWINGPRO Two adjacent segments read in from a flight profile in the ROTARYWINGPROF keyword section both had zero flight speeds. Revise the identified profile in the specified .OPS file accordingly.

Table 3-45. ERROR: Read Error *Detailed Message* Descriptions (*continued*)

Input error, ROTARYWINGPROF, Aircraft ID, .OPS file. RWINGPRO The Aircraft ID read in from a flight profile in the ROTARYWINGPROF keyword section does not match any of the aircraft IDs included in the ROTARYWINGAC keyword section. Revise the input file for aircraft identifier completeness and consistency. All aircraft IDs must be exactly 5 characters long.
Input error, ROTARYWINGPROF, First Profile Segment non-Zero, .OPS file. RWINGPRO The track distance for the first point in the first segment in a flight profile in the ROTARYWINGPROF keyword section must be zero. Revise the identified profile in the specified .OPS file accordingly.
Input error, ROTARYWINGPROF, Flight Track ID, .OPS file. RWINGPRO The flight track ID read in from a flight profile in the ROTARYWINGPROF keyword section does not match any of the flight track IDs included in the TRACK keyword section. Revise the input file for aircraft identifier completeness and consistency. All track IDs must be exactly 4 characters long.
Input error, RUN keyword, alternative point data, .RUN file. RDRUN AAM encountered a problem reading in the alternative point data contained in the specified .RUN file in the RUN keyword section.
Input error, RUN keyword, grid data, .RUN file. RDRUN AAM encountered a problem reading in the grid coordinate data contained in the specified .RUN file in the RUN keyword section.
Input error, RUN keyword, grid spacing, .RUN file. RDRUN AAM encountered a problem reading in the grid spacing information contained in the specified .RUN file in the RUN keyword section.
Input error, RUN keyword, grid information, .RUN file. RDRUN AAM encountered a problem reading in the grid specification information contained in the specified .RUN file in the RUN keyword section.
Input error, .RUN keyword, description, .RUN file. RDRUN AAM encountered a problem reading in the RUN description contained in the specified .RUN file in the RUN keyword section.
Input error, .RUN keyword, log file, .RUN file. RDRUN AAM encountered a problem reading in the log filename contained in the specified .RUN file in the RUN keyword section.
Input error, .RUN keyword, operations file, .RUN file. RDRUN AAM encountered a problem reading in the operations filename contained in the specified .RUN file in the RUN keyword section.
Input error, RUN keyword, path, .RUN file. RDRUN AAM encountered a problem reading in the path to the files contained in the specified .RUN file in the RUN keyword section. Make sure the path ends with a trailing \ character. Spaces are not permitted in paths or filenames.
Input error, RUN keyword, point of interest data, .RUN file. RDRUN The program encountered a problem reading in the point of interest data contained in the specified .RUN file in the RUN keyword section.
Input error, RUN keyword, topography data, .RUN file. RDRUN The program encountered a problem reading in the topography specification information contained in the specified .RUN file in the RUN keyword section.
Input error, RUN keyword, X grid, .RUN file. RDRUN There is a problem with the X dimension of the computational grid specified in the RUN keyword section of the .RUN file.
Input error, RUN keyword, Y grid, .RUN file. RDRUN There is a problem with the Y dimension of the computational grid specified in the RUN keyword section of the .RUN file.
Input error, RUN keyword, version consistency, .RUN file. RDRUN The version indicated in the .RUN file does not match the version of the AAM executable. Check that the input .RUN file.

Table 3-45. ERROR: Read Error *Detailed Message* Descriptions (*continued*)

Input error, RUN keyword, file consistency, .RUN file. RDRUN The Run file in use does not match the filename included in the .RUN file. Revise the input file for filename consistency.
Input error, TERRAIN keyword, impedance file. INPUTTRK The program encountered a problem reading in the path and filename of the .IMP file from the input file. The error was encountered when reading in data from the TERRAIN keyword section. Spaces are not permitted in paths or filenames.
Input error, TERRAIN keyword, terrain file. INPUTTRK The program encountered a problem reading in the path and filename of the .ELV file from the input file. The error was encountered when reading in data from the TERRAIN keyword section. Spaces are not permitted in paths or filenames.
Input error, TIMESPACING keyword, delta time. INPUTTRK The program encountered a general problem reading a line of data from the input file. The format of the data or sequence was not as expected. At the time the error was encountered the input module was attempting to read in the time increment from the TIMESPACING keyword section of the specified input file.
Input error, USERBAND keyword, 1/3 OB limits. INPUTTRK The program encountered a general problem reading a line of data from the input file. The format of the data or sequence was not as expected. At the time the error was encountered the input module was attempting to read in the one-third octave band limits from the USERBAND keyword section of the specified input file.
Input error, VIDEO keyword, video file. INPUTTRK The program encountered a problem reading in the user specified path and filename of the video output (.TIG) file from the input file. The error was encountered when reading in data from the VIDEO keyword section. Spaces are not permitted in paths or filenames.
Input error, WEATHER keyword, .RAZ file. INPUTTRK The program encountered a problem reading in the user specified path and filename of the weather curved ray data (.RAZ) file from the input file. The error was encountered when reading in data from the WEATHER keyword section. Spaces are not permitted in paths or filenames.
Input format problem. AIRFIELD The program encountered a general problem reading a line of data from the input file. The format of the data or sequence was not as expected. At the time the error was encountered the input module was attempting to read in the airfield information.
Input format problem. ATMOSP The program encountered a general problem reading a line of data from the input file. The format of the data or sequence was not as expected. At the time the error was encountered the input module was attempting to read in the user specified atmosphere.
Input format problem, AUDIB keyword. INPUTTRK The program encountered a general problem reading a line of data from the input file. The format of the data or sequence was not as expected. At the time the error was encountered, the input module was attempting to read in the narrow band spacing used for the audibility calculations and the user defined TIG path and filename in which the AAM.TIG output will be stored. Spaces are not permitted in paths or filenames.
Input format problem, BACKGROUND keyword. INPUTTRK The program encountered a general problem reading a line of data from the input file. The format of the data or sequence was not as expected. At the time the error was encountered the input module was attempting to read in the background path and filename from the specified single track format .INP file in the BACKGROUND keyword section. Spaces are not permitted in paths or filenames.
Input format problem, CASE keyword, .OPS file. CASEKEY The program encountered a general problem reading a line of data from the input file. The format of the data or sequence was not as expected. At the time the error was encountered the input module was attempting to read in the case information.

Table 3-45. ERROR: Read Error *Detailed Message* Descriptions (*continued*)

Input format problem, MAST TILT keyword. INPUTTRK The program encountered a general problem reading a line of data from the input file. The format of the data or sequence was not as expected. At the time the error was encountered the input module the input module was attempting to read in the user defined fixed mast tilt angle (degrees).
Input format problem. NAVAID The program encountered a general problem reading a line of data from the input file. The format of the data or sequence was not as expected. At the time the error was encountered the input module was attempting to read in the navigational aid data.
Input format problem, NBFORMAT keyword, freq, .INP file. INPUTTRK The program encountered a general problem reading a line of data from the specified single track format .INP file. The format of the data or sequence was not as expected. At the time the error was encountered, AAM was attempting to read in the list of narrow band frequencies specified in the NBFORMAT keyword section.
Input format problem, NBFORMAT keyword, num. freq, .INP file. INPUTTRK The program encountered a general problem reading a line of data from the specified single track format .INP file. The format of the data or sequence was not as expected. At the time the error was encountered, the input module was attempting to read in the number of narrow band frequencies specified in the NBFORMAT keyword section.
Input format problem, NCSPEC keyword. INPUTTRK The program encountered a general problem reading a line of data from the input file. The format of the data or sequence was not as expected. At the time the error was encountered the input module was attempting to read in the sound sphere data file path and base 5-digit vehicle identifier in the NCSPEC keyword data section of the specified single track format .INP file. Spaces are not permitted in paths or filenames.
Input format problem. ONETRK The program encountered a general problem reading a line of data from the input file. The format of the data or sequence was not as expected. At the time the error was encountered the input module was attempting to read in the flight trajectory data.
Input format problem. POINT The program encountered a general problem reading a line of data from the multiple-operations format input file. The format of the data or sequence was not as expected. At the time the error was encountered the input module was attempting to read in the point of interest data.
Input format problem. POIREAD The program encountered a general problem reading a line of data from the single track format input file. The format of the data or sequence was not as expected. At the time the error was encountered the input module was attempting to read in the point of interest data.
Input format problem, ROTARYWINGAC keyword, .OPS file. RWINGAC The program encountered a general problem reading a line of data from the input file. The format of the data or sequence was not as expected. At the time the error was encountered the module was attempting to read in the aircraft information contained within the ROTARYWINGAC keyword section.
Input format problem, RUNWAY keyword, .OPS file. RWYKEY The program encountered a general problem reading a line of data from the input file. The format of the data or sequence was not as expected. At the time the error was encountered the input module was attempting to read in the runway information from the specified .OPS file.
Input format problem, SETUP PARA keyword, .INP file. SPARA The program encountered a general problem reading a line of data from the input file. The format of the data or sequence was not as expected. At the time the error was encountered the input module was attempting to read in the SETUP PARA keyword information.
Input format problem, SETUP PARA keyword, name, .INP file. SPARA The 5 digit rotary wing aircraft ID in the SETUP PARA section of the single track format .INP file could not be read. Revise the specified single track input file.

Table 3-45. ERROR: Read Error *Detailed Message* Descriptions (*continued*)

Input format problem, SETUP PARA keyword, num BB, .INP file. SPARA A problem was encountered reading the number of broadband sound spheres used to model the specified rotary wing aircraft. The problem was encountered in the SETUP PARA keyword section of the specified single track format .INP file.
Input format problem, SETUP PARA keyword, num NB, .INP file. SPARA A problem was encountered reading the number of narrow band sound spheres used to model the specified rotary wing aircraft. The problem was encountered in the SETUP PARA keyword section of the specified single track format .INP file.
Input format problem, SETUP PARA keyword, num PT, .INP file. SPARA A problem was encountered reading the number of pure tone with phase sound spheres used to model the specified rotary wing aircraft. The problem was encountered in the SETUP PARA keyword section of the specified single track format .INP file.
Input format problem, SETUP PARA keyword, BB data, .INP file. SPARA A problem was encountered reading the (X,Y,Z) location data for the specified number of broadband sound spheres used to model the specified rotary wing aircraft. The problem was encountered in the SETUP PARA keyword section of the specified single track format .INP file.
Input format problem, SETUP PARA keyword, NB data, .INP file. SPARA A problem was encountered reading the (X,Y,Z) location data for the specified number of narrow band sound spheres used to model the specified rotary wing aircraft. The problem was encountered in the SETUP PARA keyword section of the specified single track format .INP file.
Input format problem, SETUP PARA keyword, PT data, .INP file. SPARA A problem was encountered reading the (X,Y,Z) location data for the specified number of pure tone and phase sound spheres used to model the specified rotary wing aircraft. The problem was encountered in the SETUP PARA keyword section of the specified single track format .INP file.
Input format problem, STATICAC keyword, .OPS file. STATAC The program encountered a general problem reading a line of data from the input file. The format of the data or sequence was not as expected. At the time the error was encountered the input module was attempting to read in the static aircraft parameters from the STATICAC keyword section of specified .OPS file.
Input format problem, STATICPAD keyword, .OPS file. STATPAD The program encountered a general problem reading a line of data from the input file. The format of the data or sequence was not as expected. At the time the error was encountered the input module was attempting to read in static run-up pad parameter data from the STATICPAD keyword section.
Input format problem, STATICPROF keyword, .OPS file. STATICPROF The program encountered a general problem reading a line of data from the input file. The format of the data or sequence was not as expected. At the time the error was encountered the input module was attempting to read in static profile parameter data from the STATICPROF keyword section.
Input format problem, STATICPROF keyword, comments .OPS file. STATICPROF The program encountered a general problem reading a line of data from the input file. The format of the data or sequence was not as expected. At the time the error was encountered the input module was attempting to read in comments associated with a particular static profile in the STATICPROF keyword section.
Input format problem, STATICPROF keyword, ops data .OPS file. STATICPROF The program encountered a general problem reading a line of data from the input file. The format of the data or sequence was not as expected. At the time the error was encountered the input module was attempting to read in the static profile operations data in the STATICPROF keyword section.
Input format problem, TOFORMAT keyword, freq, .INP file. INPUTTRK The program encountered a general problem reading a line of data from the specified single track format .INP file. The format of the data or sequence was not as expected. At the time the error was encountered, the input module was attempting to read in the list of one-third octave band frequencies specified in the TOFORMAT keyword section.

Table 3-45. ERROR: Read Error *Detailed Message* Descriptions (*continued*)

Input format problem, TOFORMAT keyword, num. freq, .INP file. INPUTTRK The program encountered a general problem reading a line of data from the specified single track format .INP file. The format of the data or sequence was not as expected. At the time the error was encountered, the input module was attempting to read in the number of one-third octave band frequencies specified in the TOFORMAT keyword section.
Input format problem, VTOLPAD keyword, .OPS file. VTOLPAD The program encountered a general problem reading a line of data from the input file. The format of the data or sequence was not as expected. At the time the error was encountered the input module was attempting to read in the vertical takeoff and landing pad data in the VTOLPAD keyword section.
Keyword not found, END. INPUTTRK The program was attempting to read the single track format input file and was expecting to find the keyword END but was unable to locate it. Check that it is included in the input file and check that the keywords and associated data contained in the input file are structured properly.
Keyword not found, ENDOPS. RDOPS The program was attempting to read the multiple-operations format input file and was expecting to find the keyword ENDOPS but was unable to locate it. Check that it is included in the input file and check that the keywords and associated data contained in the input file above ENDOPS are structured properly.
Keyword not found, ENDRUN, .RUN file. RDRUN The required ENDRUN keyword was not found in the specified .RUN file.
Keyword not found, RUN. RDRUN The RUN keyword is expected on the first line and should be left-justified. Check the input .RUN file.
Open file error, .BAK file, background. INPUTTRK The program was unable to create or open the background spectral file with the extension .BAK. Check that no other application has the .BAK file already opened, thus preventing AAM from accessing it.
Open file error, .FOT file. INPUTTRK The program was unable to create or open the input file with the extension .FOT. If running from the command line, check that no other application has the .FOT file already opened, thus preventing access. If the file already exists, it will automatically be overwritten with new data.
Open file error, .NC file. MAIN The program was unable to locate the NETCDF files. Check the following items: • Environment variable SET ROTOR_NOISE=C:\AAM\NCFILES • Does the 5 character vehicle names of the aircraft appearing in the input file match the 5 character vehicle names appearing in the NCFILES directory? • Does AAM have access to the file netcdf.dll? • If running using multiple-operations format .INP file, does the specified .RUN file use the correct path name?
Open file error, .POI file. INPUTTRK The program was unable to create or open the input file with the extension .POI. If running from the command line, check that no other application has the .POI file already opened, thus preventing AAM from accessing it. If the file already exists, it will automatically be overwritten with new data.
Open file error, .PLT file. INPUTTRK The program was unable to create or open the input file with the extension .PLT. If running from the command line, check that no other application has the .PLT file already opened, thus preventing RNM from accessing it. If the file already exists, it will automatically be overwritten with new data.
Open File error. RDOPS The program was unable to open the specified multiple-operations format input file. Check the spelling and path in the .RUN file. Spaces are not permitted in paths or filenames.
Open File error, .RUN filename mismatch. RDRUN The program encountered a mismatch between the .RUN filename and path specified in the .RUN file and the actual name and path of the file itself. Be sure that the specified file path ends with a trailing \ symbol. Spaces are not permitted in paths or filenames.

Table 3-45. ERROR: Read Error *Detailed Message* Descriptions (*continued*)

Open file error, .RUN. RDRUN The program was unable to locate or open the input file with the extension .RUN. If running from the command line, check that the .RUN file is in your current working directory. Also check that no other application has the .RUN file already opened, thus preventing access.
Open file error, .TIG file. INPUTTRK The program was unable to create or open the input file with the extension .TIG. If running from the command line, check that no other application has the .TIG file already opened, thus preventing access. If the file already exists, it will automatically be overwritten with new data.
Read error, category, MAP keyword, .RUN file. RDRUN The program encountered a general problem reading a line of data from the input file. The format of the data or the sequence was not as expected. At the time the error was encountered the input module was attempting to read in the category of geographic data in the MAP keyword data from the .RUN input file.
Read error, description, MAP keyword, .RUN file. RDRUN The program encountered a general problem reading a line of data from the input file. The format of the data or the sequence was not as expected. At the time the error was encountered the input module was attempting to read in the map file description in the MAP keyword data from the .RUN input file.
Read error, path, .RUN file. RDRUN The program encountered a fatal error when attempting to read the path to the .RUN file from the input .RUN file. The filename and the file location must match between the .RUN file and the physical storage of the file. The path should be left justified and end with a \ symbol. Spaces are not permitted in paths or filenames.
Read error, path, MAP keyword, .RUN file. RDRUN The program encountered a fatal error when attempting to read the path to the map files, specified in the MAP keyword section of the input .RUN file. The path should be left justified and end with a \ symbol. Spaces are not permitted in paths or filenames.
Read error, MAP keyword, .RUN file. RDRUN The program encountered a general problem reading a line of data from the input file. The format of the data or the sequence was not as expected. At the time the error was encountered the input module was attempting to read in the MAP keyword data from the .RUN input file.
Read error, .RUN file. RDRUN The program encountered a general problem reading a line of data from the .RUN input file. The format of the data or the sequence was not as expected. At the time the error was encountered the input module was attempting to read in the MAP keyword data from the .RUN input file.
Read error, .RUN keyword, .RUN file. RDRUN The program encountered a fatal error when attempting to read a line of data in the input .RUN file. Data was incomplete, not of the form expected (integer / real / character) or not in the required format.
Read error, CASE keyword, .RUN file. RDRUN The program encountered a fatal error when reading in the case description from the .RUN file. A maximum of 60 characters are permitted.
Read Error, ENDRUN keyword, .RUN file. RDRUN The program encountered a fatal error when attempting to read the first line in the .RUN file. The RUN keyword is expected on the first line and should be left-justified.
Read error, logfile, .RUN file. RDRUN The program encountered a fatal error when reading in the log filename specification from within the .RUN file. The log filename should be left justified and may have any 3 digit extension.
Read error, opsfile, .RUN file. RDRUN The program encountered a fatal error when reading in the opsfile specification from within the .RUN file. The .OPS filename should be left justified.
Read error, RUN keyword, .RUN file. RDRUN The program encountered a fatal error when attempting to read the first line in the .RUN file. The RUN keyword is expected on the first line and should be left-justified.

Table 3-45. ERROR: Read Error *Detailed Message* Descriptions (*concluded*)

Unexpected end of file, MAP keyword, .RUN file. RDRUN AAM encountered an unexpected end of file when attempting to read data in the MAP keyword section in the .RUN file.
Unexpected end of file, ENDRUN keyword, .RUN file. RDRUN The program encountered an unexpected end of file when attempting to read the ENDRUN keyword in the .RUN file.
Version inconsistency, AAM 1, .RUN file. RDRUN The .RUN file does not refer to the same version as found in the executable. .RUN file should include reference to AAM1.x.

The following are runtime and screening error messages that may be generated by the model. They are listed in alphabetical order.

ERROR: ART and COMPUTEGRD incompatible. INPUTTRK
The ART and COMPUTEGRD keywords may not be used together in the same input file.

ERROR: ART and COMPUTEPLT incompatible. INPUTTRK
The ART and COMPUTEPLT keywords may not be used together in the same input file.

ERROR, BACKGROUND keyword, BB mismatch, .INP file BACKGRND
nBack, nOctL, nOctU
The number of bands used to define the broadband background spectra in the BACKGROUND keyword section of the .INP file does not match the one-third octave bands in the narrow band source data sphere .NC files. The number of one-third octave bands defining the background spectra in the .INP file is *nBack*. The lowest and highest band numbers in the source data sound sphere are *nOctL*, *nOctU*, respectively. Adjust the input background spectra and / or the source data files to match one another.

ERROR, BACKGROUND keyword, NB mismatch, .INP file BACKGRND
nback nFreNB
The number of bands used to define the narrow band background spectra in the BACKGROUND keyword section of the .INP file does not match the number of narrow bands in the narrow band source data sphere .NC files. The number of narrow bands defining the background spectra in the .INP file is *nBack*. The number of narrow bands in the source data sound sphere is *nFreNB*. Adjust the input background spectra or the source data files to match one another.

ERROR: BB/NB/PT missing. INVENTORY *filename, BB, NB, PT*
The source spectral data file, *filename*, did not contain a valid value for the spectral flag type. The sum of *BB*, *NB* and *PT* must be identically equal to 1.

ERROR: Below ground. TERRAIN
zGround, x1, y1, z1
Zreceiver, x0, y0, z0
The specified flight trajectory point, *X1, Y1, Z1* is below the terrain file ground elevation of *zGround*. The receiver point, *X0, Y0, Z0,* has a ground elevation of *Zreceiver*.

ERROR: Excessive hotspots. HOTPOI *n, nmax*
With *n* points, requested calculations exceeded maximum number of hotspot output points. Change the parameters in the HOTSPOT keyword data in the single track format input (.INP) file. The current point limit is *nmax* points.

ERROR: Excessive segments. FLTTRK *IDfltTrk*
The number of segments required to resolve the curved segments in the input flight track, *IDfltTrk,* exceeds the current limit of 500. Simplify the input flight track definition.

ERROR: Excessive Segments. FLYOVER *limit, TrackNum, IDfltTrk*
The number of segments required to resolve all segments in the sequentially input track, numbered, *TrackNum*, with the flight track name, *IDfltTrk,* exceeds the current limit of *limit*.

ERROR: Excessive trajectory points. INTRTIME *FDfltTrk*
The number of simultaneous trajectory time steps, iACpts exceeds the maximal allowable *npts* for integrated track profile with identifier, *IDfltTrk*.

ERROR: First segment turn. FLTTRK *IDfltTrk*
The first segment in the identified flight track, *IDfltTrk* is not a straight segment as required. This error was encountered when processing a multiple track format (.OPS) input file.

ERROR: First segment turn. ONETRK *IDfltTrk*
The first segment in the identified flight track, *IDfltTrk* is not a straight segment as required. This error was encountered when processing a single track format (.INP) input file.

ERROR: Grid dimensions. GRID *nx, ny, minimum*
The specified grid dimensions (lower left, upper right corner and grid spacing in X and Y) do not meet the minimum number of grid point requirement of *minimum* rows and columns.

ERROR: Impedance allocation, .IMP file. TERRAIN
NX, NY, .IMPfilename
AAM encountered an error allocating memory for the specified input impedance *.IMPfilename* with dimensions *NX, NY*.

ERROR: Impedance data, .IMP file. TERRAINCHK
Grid*, gridxll, gridyll, gridxur, gridyur*
IMP*, impxll, impyll, impxur, impyur*
impfile
The requested computational domain grid with corners *(gridxll, gridyll)* and *(gridxur, gridyur)* is not completely covered by the specified impedance property file, *impfile*, whose corners are *(impxll, impyll)* and *(impxur, impyur)*.

ERROR: NBfreq mismatch. GETNB
Frequency, *Freq1, Freq2*
Source files, *NCfile1, NCfile2, NCfile3, NCfile4*
Track, *FltTrkID* Profile *FltProfID*

The narrow band frequencies, *Freq1* and *Freq2* for the data contained in the narrow band source sound data files does not match between the four identified sphere files: *NCfile1*, *NCfile2*, *NCfile3*, *NCfile4.* At the time this error was encountered the input module was attempting to perform an interpolation between the specified .NC files in order to obtain the source characteristics for flight track, *FltTrkID* and profile, *FltProfID.*

ERROR: NetCDF Acoustic Type. SEARCH *X, Y, Z, NCfileName1, NCfileName2*
The program was unable to find an acoustic sound sphere (.NC file) with the appropriate acoustic data type (BB / NB / PT) with center coordinates (*X*, *Y*, *Z*). Check spheres *NCfileName1* through *NCfileName2*. When using the ART keyword be sure that the sphere spectral types and center locations in the SETUP PARA keyword section match the ART.

ERROR: NetCDF Center. SEARCH *X, Y, Z, NCfileName1, NCfileName2*
The program was unable to find an acoustic sound sphere with the source center coordinates (*X*, *Y*, *Z*) matching those specified in the input file. Check spheres *NCfileName1* through *NCfileName2*.

ERROR: NetCDF Message, 1D array. RMNETCDF
NCfileName
Errstring
An error was encountered when attempting to write a one dimensional array of real data to the specified *NCfileName* NetCDF file. The NetCDF i/o error message is *Errstring*.

ERROR: NetCDF Message, 3D array. RMNETCDF
NCfileName
Errstring
An error was encountered when attempting to write the three dimensional array of acoustic data to the specified *NCfileName* NetCDF file. The NetCDF i/o error message is *Errstring*.

ERROR: NetCDF Message, attribute. RMNETCDF
NCfileName
Errstring
An error was encountered when attempting to write attribute data to the specified *NCfileName* NetCDF file. The NetCDF i/o error message is *Errstring*.

ERROR: NetCDF Message, BB. RMNETCDF
NCfileName
Errstring
An error was encountered when attempting to read in the broadband acoustic data from the specified *NCfileName* NetCDF file. The NetCDF i/o error message is *Errstring*.

ERROR: NetCDF Message, label. RMNETCDF
NCfileName
Errstring
An error was encountered when attempting to read in label data from the specified *NCfileName* NetCDF file. The NetCDF i/o error message is *Errstring*.

ERROR: NetCDF Message, real. RMNETCDF
NCfileName
Errstring
An error was encountered when attempting to read in real data from the specified *NCfileName* NetCDF file. The NetCDF i/o error message is *Errstring*.

ERROR: NetCDF Message, real array. RMNETCDF
NCfileName
Errstring
An error was encountered when attempting to read in an array of real data from the specified *NCfileName* NetCDF file. The NetCDF i/o error message is *Errstring*.

ERROR: NetCDF Message, scalar. RMNETCDF
NCfileName
Errstring
An error was encountered when attempting to write attribute data to the specified *NCfilename* NetCDF file. The NetCDF i/o error message is *Errstring*.

ERROR: Number PTfreq mismatch. GETPT
Number of Frequencies, *NumFreq1*, *NumFreq2*
Source files, *NCfile1*, *NCfile2*, *NCfile3*, *NCfile4*
Track, *FltTrkID* Profile *FltProfID*
The number of pure tone frequencies for the data contained in the pure tone and phase source sound data files is not the same in the four identified sphere files: *NCfile1*, *NCfile2*, *NCfile3*, *NCfile4.* At the time this error was encountered AAM was attempting to perform an interpolation between the specified .NC files in order to obtain the source characteristics for flight track, *FltTrkID* and profile, *FltProfID.*

ERROR: Numbers, Empty String, .INP file. READNUMS *LineNumber*, *ElementNumber*
There was a general error reading a list of numbers from the .INP file. The error was encountered on line *LineNumber* near the element *ElementNumber*. An Empty String was received by the ReadNums function, which usually indicates insufficient data.

ERROR: Numbers, .INP file. READNUMS *LineNumber*, *ElementNumber*
There was a general error reading a list of numbers from the .INP file. The error was encountered on line *LineNumber* on the specific element, *ElementNumber*.

ERROR: ONE TRACK & HOTSPOT incompatible. INPUTTRK
The ONE TRACK keyword (used to specify a flight trajectory) and the HOTSPOT keyword (used to specify a vehicle location and orientation and a series of receiver points) may not be used simultaneously in a single track format .INP file.

ERROR: PARA & HOTSPOT sequence. INPUTTRK
The SETUP PARA keyword must appear before the HOTSPOT keyword in the input file.

ERROR: POI & HOTSPOT incompatible. INPUTTRK
The POI keyword (used to specify a specific receptor points) and the HOTSPOT keyword (used to specify a vehicle location and orientation and a series of receiver points) may not be used simultaneously in a single track format .INP file.

ERROR: Power unit mismatch. SCANFILE NCfilename
The power units specified in the .NC files are not consistent for the specified vehicle. This inconsistency was encountered when scanning file *NCFilename*.

ERROR: PTfreq mismatch. GETPT
Frequency, *Freq1, Freq2*
Source files, *NCfile1, NCfile2, NCfile3, NCfile4*
Track, *FltTrkID* Profile *FltProfID*
The pure tone frequencies, *Freq1* and *Freq2* for the data contained in the pure tone and phase source sound data files does not match between the four identified sphere files: *NCfile1*, *NCfile2*, *NCfile3*, *NCfile4*. The frequency values contained in the .NC file must be within 3% of one another to be considered a match. At the time this error was encountered the input module was attempting to perform an interpolation between the specified .NC files in order to obtain the source characteristics for flight track, *FltTrkID* and profile, *FltProfID*.

ERROR: QSAM1 and FIXEDWINGAC incompatible. INPUTTRK
The QSAM1 keyword may not be used with FIXEDWINGAC operations. Isolate any rotary wing operations with QSAM1 keyword in a separate input file. The radius of the one-third octave band source sound data does not match between the four identified sphere files: *NCfile1*, *NCfile2*, *NCfile3*, *NCfile4*. At the time this error was encountered the input module was attempting to perform an interpolation between the specified .NC files in order to obtain the source characteristics.

ERROR: Radius mismatch. GETNB *NCfile1, NCfile2, NCfile3, NCfile4*
The radius of the narrow band source sound data does not match between the four identified sphere files: *NCfile1*, *NCfile2*, *NCfile3*, *NCfile4*. At the time this error was encountered the input module was attempting to perform an interpolation between the specified .NC files in order to obtain the source characteristics.

ERROR: Same profile data found in multiple spheres. SORT
Sphere1, Sphere2
AAM has encountered multiple sound spheres, which contain the same nacelle angle, flight path angle, and speed. Results may be invalid due to the improper sphere being used. See NCSPEC keyword to force usage of a specific sphere. Spheres, which triggered the warning, are output as *Sphere1* and *Sphere2*.

ERROR: Segments. REFORMAT *IDfltTrk, nseg*
The number of segments defining a track plus the number of segments subdividing a turn exceed the current limit of *nseg* segments. Reduce the number of turns on a track by separating the track into two separate tracks or increasing the time spacing between segment points. The problem occurred on track *IDfltTrk*.

ERROR: Source data, array dimensions, .NC file. SCANFILE
NCFILES, ***filenames list***
PHI, ***phi list***
THETA, ***theta list***
FREQUENCY, ***frequency list***
When using the NCSPEC keyword, all the .NC files must match one another in data dimensions *phi, theta, and frequency*. The filenames and dimensions found in each file are listed following the ERROR message.

ERROR: Source data, band limits, .NC file. INVENTORY, ***filename, BLow, BHigh***
The one-third octave band lower bound (*BLow*) or upper bound (*BHigh*) in the source data .NC file (*filename*) were not within the inclusive range of bands 10 to 40.

ERROR: Source data, frequency, .NC file. INVENTORY, ***filename, frequency***
The absolute value of the narrow band frequency (*frequency*) contained within the specified source data .NC file (*filename*) was less than .01 Hz. This is not permitted within AAM.

ERROR: Source data, frequency units, .NC file. INVENTORY, ***filename, units***
AAM did not recognize the units (*units*) used in the source data sound sphere .NC file (*filename*) to specify the frequency data. Only 'HERTZ or '1/SEC' are permitted. Adjust the source data file to utilize either of these units.

ERROR: Source data, phase units, .NC file. INVENTORY, ***filename, units***
AAM did not recognize the units (*units*) used in the source data sound sphere .NC file (*filename*) to specify the phase data. Only 'DEGREE' or 'RADIAN' are permitted. Adjust the source data file to utilize either of these units.

ERROR: Source data, sound units, .NC file. INVENTORY, ***filename, units***
AAM did not recognize the sound data level units (*units*) used in the source data sound sphere .NC file (*filename*) to specify the noise data. Only 'DECIBEL' is permitted. Adjust the source data file to utilize either this unit.

ERROR: Source data, spectral inconsistency, .NC file. INVENTORY
filename, BLow, BHigh, PLow, PHigh
The one-third octave band lower bound (*BLow*) or upper bound (*BHigh*) in the source data .NC file (*filename*) were inconsistent with the lower bound (*PLow*) or the upper bound (*PHigh*) of the previously accessed source data .NC file.

ERROR: Source data, spectral type, .NC file. SCANFILE, ***filename***
The frequency data types permitted, BB, NB, or PT, were not found in the *filename* .NC file.

ERROR: SPECTRUM & ART incompatible. INPUTTRK
The SPECTRUM keyword (which triggers detailed spectral output) is only valid when running AAM with a single track format input file and computing output at points of interest. If detailed spectral information is required for multiple operations or receptor locations, they must be run separately using the .INP file format. This error was encountered because the input file used the ART keyword.

ERROR: SPECTRUM & COMPUTEGRD incompatible. INPUTTRK
The SPECTRUM keyword (which triggers detailed spectral output) is only valid when running with single track format input file and computing output at points of interest. If detailed spectral information is required for multiple operations or receptor locations, they must be run separately using the .INP file format. This error was encountered because the input file included the COMPUTEGRD keyword.

ERROR: SPECTRUM & COMPUTEPLT incompatible. INPUTTRK
The SPECTRUM keyword (which triggers detailed spectral output) is only valid when running with a single track format input file and computing output at points of interest. If detailed spectral information is required for multiple operations or receptor locations, they must be run separately using the .INP file format. This error was encountered because the input file used the COMPUTEPLT keyword.

ERROR: SPECTRUM & Multiple Tracks incompatible. INPUTTRK
The SPECTRUM keyword (which triggers detailed spectral output) is only valid when running with single track format input file and computing output at points of interest. If detailed spectral information is required for multiple operations or receptor locations, they must be run separately using the .INP file format. This error was encountered because the input file was in the multiple-operations format.

ERROR: Terrain allocation, .ELV file. TERRAIN
NX, NY, .ELVfilename
An error was encountered when allocating memory for the specified input terrain *.ELVfilename* with dimensions *NX*, *NY*.

ERROR: Terrain data, .ELV file. TERRAINCHK
Grid, *gridxll, gridyll, gridxur, gridyur*
ELV, *elvxll, elvyll, elvxur, elvyur*
elvfile
The requested computational domain grid with corners *(gridxll, gridyll)* and *(gridxur, gridyur)* is not completely covered by the specified terrain elevation file, *elvfile*, whose corners are *(elvxll, elvyll)* and *(elvxur, elvyur)*.

ERROR: TERRAIN & HOTSPOT sequence. INPUTTRK
The TERRAIN keyword must appear before the HOTSPOT keyword in the input file.

ERROR: TOBAND mismatch. GETBB
Bands, *Band1*, *Band2*
Source files, *NCfile1*, *NCfile2*, *NCfile3*, *NCfile4*
Track, *FltTrkID* Profile *FltProfID*
The one-third octave band numbers, *Band1* and *Band2* for the data contained in the source sound data files does not match between the four identified sphere files: *NCfile1*, *NCfile2*, *NCfile3*, *NCfile4*. At the time this error was encountered the input module was attempting to perform an interpolation between the specified .NC files in order to obtain the source characteristics for flight track, *FltTrkID* and profile, *FltProfID*.

ERROR: Track data, .INP/.OPS file, TERRAINCHK
Grid, *GridXll, Grid Yll, GridXur, GridYur*
Track: *track* Profile: *profile* Segment: *segment*
Point: *x, y*
A *segment* of the specified flight *track* and *profile* leaves the grid area defined by lower left corner (*GridXll*, *GridYll*) and upper right corner (*GridXur*, *GridYur*). The segment end point is defined as (*x*, *y*).

ERROR: Track distance. FLYOVER *FltTrkID, FltProfID*
The input flight track, *FltTrkID*, cumulative ground track distance must be greater than or equal to the profile, *FltProfID*, cumulative distance.

ERROR: Turn angle. FLTTRK *IDfltTrk, nseg*
The input flight track *IDfltTrk* turn segment index, nseg, contains too small a heading angle change for the turn segmentation algorithm.

ERROR: Turn angle. REFORMAT *IDfltTrk, Angle*
The user specified input turn angle is too small. The problem occurred on track *IDfltTrk* with a specified input turn angle of *Angle* degrees. Specify a larger turn angle or model it as connecting line segments.

ERROR: VTOL pad, .OPS file. CONSTTRK
Flight track identification: *IDfltTrk*
Runway/VTOL pad origination: *Orig*
Runway/VTOL pad destination: *Dest*
The program was unable to locate for the stated flight track ID, *IDfltTrk* the specified Runway or VTOL pad of origin, *Orig*, or the Runway or VTOL pad of destination, *Dest*.

ERROR: WEATHER & ATMOS keywords incompatible. INPUTTRK
Both WEATHER and ATMOS may not be used together. The WEATHER keyword is reserved for utilizing the RNMwea curved ray module data (.RAZ file). The ATMOS keyword should be used to define atmospheric temperature and humidity profiles, which are used with the straight ray propagation module.

WARNING: Altitude below lower limit. ATM *zflight zatmo*
The flight trajectory extends below the lowest altitude in the atmospheric profile. The computational module will use the atmospheric data (temperature and pressure) defined at the lowest altitude available. The trajectory point being analyzed has the flight altitude at *zflight* ft MSL. The lowest atmospheric profile altitude defined is *zatmo* ft, MSL.

WARNING: Altitude above upper limit. ATM *zflight zatmo*
The flight trajectory extends above the highest altitude in the atmospheric profile. The computational module will use the atmospheric data (temperature and pressure) defined at the highest altitude available. The trajectory point being analyzed has the flight altitude at *zflight* ft MSL. The highest atmospheric profile altitude defined is *zatmo* ft, MSL.

WARNING: Below 5 ft AGL. CHKTRACKS
One or more flight trajectory points place the vehicle source below the minimum 5 ft above the ground elevation. In the context of a multiple operations case, the flight trajectory is automatically adjusted to place this trajectory point at 5 ft AGL. In single track mode the warning is issued, but the track itself is not automatically adjusted.

WARNING: Collocated Sphere. CHKTRACKS
At one or more points along the flight trajectory a situation was encountered where the sphere center was collocated with the point to which AAM was trying to propagate. To prevent this, the trajectory point was moved .001 ft in the +x direction from the point with which it would have been collocated.

WARNING: Doppler Shifted NB Freq outside 1/3 OB Shift. Freq *freNB* Low Limit *freL* High Limit *freU* ADDNB
The received narrow band signal will not be binned because it falls outside of the available one-third octave band bins. *FreNB* (Hz) is the new frequency after applying the Doppler shift due to vehicle motion. The available one-third octave band frequency window has a lower limit of *freL* (Hz) and an upper limit of *freU* (Hz). Message reported in routine ADDNB, which sums up the narrow band received signal(s) and bins them into the appropriate one-third octave bands.

WARNING: Doppler Shifted PT Freq outside 1/3 OB Shift. Freq *frePT* Low Limit *freL* High Limit *freU* ADDPT
The received pure tone signal will not be binned because it falls outside of the available one-third octave band bins. *FrePT* (Hz) is the new frequency after applying the Doppler shift due to vehicle motion. The available one-third octave band frequency window has a lower limit of *freL* (Hz) and an upper limit of *freU* (Hz). Message reported in ADDPT, which sums up the pure tone received signal(s) and bins them into the appropriate one-third octave bands.

WARNING: GRID auto adjust. GRID *nx*, *ny*, *delta*
The user requested grid dimensions (lower left, upper right corner and grid spacing in X and Y) exceeded the maximum number of grid points. The adjusted dimensions resulted in *nx* rows and *ny* columns with a grid spacing of *delta* feet. The auto adjust results in a grid with square cells.

WARNING: NB Freq outside 1/3 OB. Freq *freNB* Low Limit *freL* High Limit *freU* ADDNB
The received narrow band signal will not be binned because it falls outside of the available one-third octave band bins. *FreNB* (Hz) is the source and receiver frequency. The available one-third octave band frequency window has a lower limit of *freL* (Hz) and an upper limit of *freU* (Hz). Message reported in routine ADDNB, which sums up the narrow band received signal(s) and bins them into the appropriate one-third octave bands.

WARNING: Pressure below 0, *press*. ATM
When interpolating or extrapolating the pressure from the specified atmospheric profile during execution, 0 was exceeded. The value of the pressure, which triggered the warning message, is *press*.

WARNING: PT Freq outside 1/3 OB. Freq *frePT* Low Limit *freL* High Limit *freU* ADDPT
The received pure tone signal will not be binned because it falls outside of the available one-third octave band bins. *FrePT* (Hz) is the source and receiver frequency. The available one-third octave band frequency window has a lower limit of *freL* (Hz) and an upper limit of *freU* (Hz). Message reported in ADDPT, which sums up the pure tone received signal(s) and bins them into the appropriate one-third octave bands.

WARNING: Temperature below -459 F, *temp*. ATM
When interpolating or extrapolating the temperature from the specified atmospheric profile during execution, -459° F was exceeded. The value of the temperature, which triggered the warning message, is *temp*.

WARNING: Track data, .INP/.OPS file, TERRAINCHK
Grid, *GridXll*, *GridYll*, *GridXur*, *GridYur*
Track: *track* Profile: *profile* Segment: *segment*
Point: *x, y*
A *segment* of the specified flight *track* and *profile* leaves the grid area defined by lower left corner (*GridXll*, *GridYll*) and upper right corner (*GridXur*, *GridYur*). The segment end point is defined as (*x, y*). Because TERRAIN has not been enabled, this is a warning alerting you that the flight track has left the predefined study area.

WARNING: Units inconsistency, .ELV & .IMP. TERRAIN
Units*, *ELVfilename
IMPfilename
AAM encountered inconsistent units between the user specified *ELVfilename* and *IMPfilename*. The Elevation file *units* will be used for the analysis.

4.0 Utility Programs

AAM is comprised of a suite of programs designed as a toolbox with a wide variety of functions. The main propagation algorithms are contained within the code called AAM, a fixed wing aircraft and nonlinear propagation extension to the Rotorcraft Noise Model, whose physics and function are explained in detail in Chapters 2 and 3. This section of the manual is dedicated to explaining all additional utility programs that are included with the suite of software. Details about installing the full set of tools are included in Section 3.2 and an itemization of all the programs is given in Table 3-2. Table 4-1 lists all of the tools, their primary functions, and the section number where additional information may be found.

Table 4-1. Utility Programs

Program	Description	Section
ART	Acoustic Repropagation Technique used to generate acoustic source .NC files.	4.1
BACKTIG	Inserts a background into a .TIG file.	4.2
BUILDIMP	Builds a binary impedance file from ASCII input data.	4.3
BULLWINK	Creates binary NetCDF .NC files from ASCII spectral input data.	4.4
DEDOPPLERIZER	Module for removing the Doppler shift from spectral time history files due to the source motion.	4.5
ELV2PLT	Reads an .ELV file and creates a Tecplot .PLT file.	4.6
ELVBUILDER	Interactive graphical program, which builds .ELV and .IMP, files.	4.7
FLATTENELV	Reduces all terrain data in a specified .ELV file to a uniform height.	4.8
IMPCHANGER	Changes all impedance values in an .ELV file to a uniform value.	4.9
NCDUMP	ASCII output of a .NC file to the standard output device.	4.10
PLT2ELV	Reads a Tecplot file and builds an impedance (.IMP) or elevation (.ELV) file	4.11
POI2MIC	Reads in a .POI file and reformats it for use in ART as microphone input.	4.12
RAZ2PLT	Reads a binary weather .RAZ file and creates an ASCII Tecplot .PLT file.	4.13
RAZSUBTRACT	Computes the difference between two weather (.RAZ) files and writes the answer to an ASCII Tecplot file.	4.14
RNMWEA	Preprocessor, which calculates the effects of, curved ray paths due to a horizontally stratified atmosphere with winds.	4.15
SPHERE	Creates an ASCII Tecplot file from a binary NetCDF .NC file in one-third octave band or narrow band formats.	4.16
TH2MIC	Reads a .TH file and reformats it for use in ART as microphone input.	4.17
TRJRESAMPLER	Interpolates the specified .TRJ file to a new uniform time increment.	4.18
3DVISUALIZER	Acoustic visualization tool for creating 3D sound animation videos.	4.19

4.1 Acoustic Repropagation Technique (ART)

Aircraft source noise data, defined in body fixed coordinates, are provided to the computational module in a packed binary NetCDF[26] format. Source data may contain broadband, narrow band or pure tone and phase information. Typically the data are provided in 5-degree increments on the sphere and up to 10 sound spheres may be used per vehicle per trajectory point in individual flight track mode. These may be situated at different locations in body fixed coordinates in order to model the individual noise components. Each sphere represents one flight condition: airspeed,

flight path angle, nacelle angle for rotorcraft and engine operating state (thrust) and thrust vector angle for fixed wing aircraft. Significant enhancements have been made to ART for the evaluation of fixed wing aircraft noise spheres, including such complex features as nonlinear propagation and thrust vectoring.

Sound sphere filenames are defined as:

vvvvvnnn.nc

where vvvvv is a 5-character vehicle description and nnn is the sound sphere index number. Example filenames are ch46e001.nc, ch46e099.nc, and ah-lw012.nc.

Using this naming convention, each aircraft may have a maximum of 1000 sound spheres. These may each represent different source locations (defined in body fixed coordinates) and different vehicle operating conditions. They will be propagated independently and combined at the receiver location accounting for amplitude and phase.

A tutorial for creating NetCDF acoustic sound files from measured data is described in Section 5-11.

Source acoustic files are a critical and required input. These NetCDF files may be created from flight test acoustic data, wind tunnel acoustic measurements or from computational fluid dynamics model output. The process by which measured data is used to determine vehicle source characteristics is called the Acoustic Repropagation Technique (ART). Measured values are combined with predicted atmospheric propagation effects in order to "reverse engineer" the source level, spectra and three-dimensional directivity pattern. AAM is used to predict the atmospheric propagation effects (the physics). A separate utility called ART is used to combine the physics with the measurement data and assemble a NetCDF source file containing the full three-dimensional spectral source description. This section explains the process of creating NetCDF files from measured data.

ART Version 7.0 contains no propagation physics. Instead the AAM module must be used to first determine the effects of atmospheric propagation between the source and receiver. The ART keyword is used which generates a time history (.TH) file containing all the spectral and geometric propagation information from a vehicle flight trajectory through an arrangement of points of interest corresponding to the measurement microphone locations. The full capabilities, such as the effects of terrain, non-uniform ground impedance, and curved rays (horizontally stratified atmosphere with winds), may then be used to correct measurement data and obtain the most accurate sound source description possible.

Enhancements found in prior versions of ART, and also included here, consider data from a third set of measurement locations, oriented in front of the vehicle on a vertical array called the "North Pole." Acoustic measurements on this array are treated using the same physics as the main lateral array. The results are then applied to the sound sphere by ART using a North Pole specific procedure explained below.

Included in ART is the ability for the user to define the size and resolution of the output sound sphere. A full sphere may be used, or a portion of a sphere may be used. In the input deck the user may choose the minimum and maximum theta and phi (θ, ϕ) and the resolution of the mesh. Regions on the sound sphere where the acoustic data is not defined, are set to 1E35. This value is understood in the propagation code, and any source points containing this value are not propagated to the ground. The reason for this feature is due to the grid topology. It is possible to

have a North Pole microphone, with valid data above the rotor or wing plane, yet have no valid data on the sides of the vehicle. In prior versions of ART, the data extrapolation procedure in was adopted in order to fill in missing regions, generating data where no measurements existed. In the current suite of programs, this was changed so that areas for which no reasonable source data exists are not generated. The source values are set to 1E35 by the ART utility and such regions on the sound sphere are not propagated.

With the extension of the source domain above the rotor or wing plane the prior ART3[25] technique with linear interpolation was found to be unsuitable for full spheres and North Pole microphone locations. Performing the physical atmospheric propagation in one code and the mapping onto the sound sphere in a separate code reduced the program maintenance requirements significantly, since any updates to the atmospheric propagation could be used immediately in the creation of source spheres.

Perhaps the most significant change to ART has been the incorporation of the ZGRID[42] algorithms for taking "control points" and gridding the sound sphere mesh. ZGRID gives a user selectable blend of LaPlace or Spline interpolation. We recommended that LaPlace interpolation be used whenever possible. Additional controls include the ability to define the range of the interpolation in terms of the final mesh points. Larger range blends the control points over a larger section of the mesh. This feature could be used to control the application of sparse measurements onto the sound sphere. Given the generalized control point structure of the ZGRID routine, future addition of randomly placed microphone locations can be easily incorporated into the gridding algorithm.

Starting with ART Version 5.1 a high frequency absorption limit was implemented in order to prevent unrealistically high depropagated source characteristics in the sphere. This method takes the computed absorption value in the 4kHz one-third octave band (band #36) for a given arrival time and uses it for all higher frequencies. This feature may be turned off by using the NOABSCAP keyword.

4.1.1 Technical Description

The following procedure is used in ART to develop sound spheres from experimental flight test data:

- The atmospheric propagation between the source (flight vehicle) and receiver (microphone) is calculated by AAM using the level of analysis and fidelity selected by the user. An omnidirectional source of the spectral variety desired by the user is input. At each receiver point (microphone location) the spectral time history is calculated in detail, namely the spherical spreading, ground effect, absorption and curved ray effects. This voluminous output is written as a function of time and frequency into a time history (.TH) file, which is then read by ART. In addition to the acoustic and arrival time information, critical geometric data is also stored in this file, namely the vehicle orientation and the (θ, ϕ) location on the sound sphere of the direct ray pointing to the receiver.
- Within ART each point in the time history file corresponds to a point on the sound sphere. The measured microphone data is interpolated to the exact arrival time. The atmospheric propagation corrections (as calculated by AAM) are then applied spectrally to the microphone data and the source characteristics obtained for the control point. Each propagation correction in the .TH file is applied to the microphone data.

- The Signal-to-Noise ratio specified by the user is then applied and those control points not meeting the criteria are eliminated.
- The depropagated results on the sphere surface are then passed as random points into the ZGRID algorithm where the sphere mesh is populated. The user may control the sphere extent and resolution. The ZGRID algorithm has a user-controlled blend between a LaPlace and a Spline interpolation. Additionally, the user may specify the range over which each control point has authority during the mesh sequence.
- At $\theta = 0$ degrees and 180 degrees, where all ϕ represent the same physical point, a single value is obtained by averaging the front edge of the sphere mesh. This average value is applied to all ϕ values at $\theta = 0$ degrees and 180 degrees.
- Values at θ adjacent to the next two columns of the "nose" and "tail" are filled via linear interpolation. This provides a smooth transition in the region of the poles of the sphere.
- The North Pole microphones are treated in the same fashion as the regular lateral array microphones.
- Within the regions specified by the NPOLEGRIDAREAS keyword only the North Pole source characteristics are energy averaged in each frequency band and applied directly to the sound sphere over those regions.

The final step in the procedure is the use of the NetCDF routines to write the noise sphere. ART invokes the Bullwink subroutine and, based on the inputs defined in the NCFILE keyword section, creates a NetCDF sphere file.

Source level noise data is presented to the computational module in the form of a sound sphere (Figure 2-1) containing one-third octave band, narrow band, or pure-tone and phase noise levels. Points on the sphere are described in terms of a fixed radius and two spherical angles. The spherical coordinate system assumes the origin of the coordinate system is located at the center of the noise source and the X-axis is parallel to the main portion of the fuselage. The direction angle, θ, points from the center to the bow ($\theta = 0^\circ$), and to the stern, ($\theta = 180^\circ$). Phi is zero directly underneath the vehicle, positive 90 degrees on the starboard side, and minus 90 degrees on the port side. While the angles of θ and ϕ are defined in different ways by different authors, the notation in ART is consistent with that used by the Aircraft Noise Prediction Program (ANOPP), AAM, and RNM to facilitate comparison between the programs (Figure 2-2).

4.1.2 System and Installation

Two different software distributions kits are available. One distribution is for a personal computer (PC) running Microsoft Windows. The other distribution kit is for a workstation running the UNIX operating system. The PC version is in the form of a self-extracting executable, which will automatically uncompress the executable modules, and sample input files. The UNIX distribution kit includes the source code for building the executable modules and several sample input files. Tables 4-2 and 4-3 show a listing of the files contained on the distribution disks. Not shown in these tables are the installation programs, the sample input files, and the acoustic source data.

Table 4-2. Software Distribution for a Personal Computer Running Microsoft Windows

File Name	Description
NETCDF.DLL	Dynamic link library used by NetCDF software to read and write the sound sphere acoustic data.
NCDUMP.EXE	NetCDF utility used to display the contents of a NetCDF file.
ART.EXE	Acoustic Repropagation Technique (ART) model.
SPHERE.EXE	Reads a sound sphere NetCDF file and writes a text file that is used by Tecplot to display a 3-dimensional image of the sound sphere.

Table 4-3. Software Distribution for a Personal Computer Running UNIX

File Name	Description
libnetcdf.a	Dynamic link library used by NetCDF software to read and write the sound sphere acoustic data.
Ncdump	NetCDF utility used to display the contents of a NetCDF file.
ART	Acoustic Repropagation Technique (ART) model.
Sphere	Reads a sound sphere NetCDF file and writes a text file that is used by Tecplot to display a 3-dimensional image of the sound sphere.

4.1.2.1 Microsoft Windows Version

The following table lists the system requirements for the Windows version of ART.

Table 4-4. System Requirements

Category	Requirement
Hardware	32-bit Pentium II or better microprocessor, 300 MHz or faster VGA or higher resolution video display adapter Hard disk with 1.8 gigabytes (GB) minimum free space CD-ROM drive
Memory	512 MB recommended minimum
Software	Windows 95 or higher, Windows 2000, Windows NT or Windows XP. Tecplot (not necessary but recommended)

To install ART, copy the ART_INSTALL.EXE into the directory where you would like ART to be installed. For the purposes of explanation this will be c:\AAM\BIN\. From explorer, double-click on the ART_INSTALL.EXE file to unpack the ART program. Alternatively, you may type:

ART_INSTALL.EXE

from a windows aware command prompt, or browse and select ART_INSTALL.EXE from the Run option under the Start menu button,. This will unpack a series of executables, and sample files. ART_INSTALL.EXE is a self-extracting zip file archive.

4.1.2.2 UNIX

The following is the procedure for installing ART on a UNIX based platform:

1. Copy the contents on the CDROM into a subdirectory which the user has previously created.
2. Visit the FTP unidata.ucar.edu site and download the file pub/NetCDF/NetCDF.tar.z. Make sure that the file is transferred in BINARY mode. AAM uses NetCDF Version 3.5.0.
3. Follow the instructions that come with NetCDF distribution to build a binary library.

4. Copy this library into a location that the FORTRAN compiler will have permission to access.

Using a text editor open the file RESOURCE.INC. Contained in this file are the following FORTRAN parameters: nsphrBB0, nsphrPT0, ntheBB0, nthePT0, nphiBB0, nphiPT0, and nfrePT0. Read the instructions included in the file and determine if the intended application for ART requires these parameters to be adjusted.

4.1.3 Input/Run File Description

To run ART from a Windows aware command prompt, enter

ART runfile >output.txt

Figure 4-1 shows a sample .RUN file for one-third octave band analysis. This file contains seven mandatory keyword sections:

- GRIDOPTIONS
- NBFORMAT or TOFORMAT
- MICROPHONE
- SPHERE
- NCFILE
- THFILE
- END

The following describes each of the data fields and their corresponding format.

When ART reads the .RUN file, certain assumptions are made about the data. These assumptions are as follows:

- All length dimensions are in units of feet.
- Altitudes are in feet above ground level.

In the tables presented in this chapter, three letters appear in the format column: A, I, and F. The letter A appearing under the format column signifies an alphanumeric character input, while the letter I signifies an integer value. F indicates a fixed real number input format. For example, A10 represents a data field that may be 10 characters long. I10 represents an integer data field that may be 10 elements long. On lines that take multiple input parameters, all numerical fields may be space- or comma-delimited. Table 4-5 describes a list of key words.

```
REM456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
REM
REM  TH57 input file for ART5, February 2005
REM
REM FloRes: 1000000 = Hard, 200 = Soft
REM.............X.............Y.............Z......... FloRes.....Acoustic Data File & Path
MICROPHONE
20
01        -46.6200       397.4100       173.5400            200.     Run_33_Mic_01.txt
02        -46.6200       397.4100       149.8800            200.     Run_33_Mic_02.txt
03        -46.6200       397.4100        99.5400            200.     Run_33_Mic_03.txt
04        -46.6200       397.4100        50.2900            200.     Run_33_Mic_04.txt
05        -41.8000       372.6400         0.0000            200.     Run_33_Mic_05.txt
06        -30.6500       273.2900         0.0000            200.     Run_33_Mic_06.txt
07        -19.5200       174.0100         0.0000            200.     Run_33_Mic_07.txt
08        -11.1500        99.3900         0.0000            200.     Run_33_Mic_08.txt
09         -5.5800        49.7900         0.0000            200.     Run_33_Mic_09.txt
10          0.0000         0.0000         0.0000            200.     Run_33_Mic_10.txt
11          5.5900       -49.8100         0.0000            200.     Run_33_Mic_11.txt
12         11.1400       -99.3400         0.0000            200.     Run_33_Mic_12.txt
13         16.7300      -149.1400         0.0000            200.     Run_33_Mic_13.txt
14         22.2900      -198.7400         0.0000            200.     Run_33_Mic_14.txt
15         30.6500      -273.2800         0.0000            200.     Run_33_Mic_15.txt
16         41.8200      -372.8000         0.0000            200.     Run_33_Mic_16.txt
17         42.6600      -395.0200        50.2900            200.     Run_33_Mic_17.txt
18         42.6600      -395.0200        99.5400            200.     Run_33_Mic_18.txt
19         42.6600      -395.0200       149.8500            200.     Run_33_Mic_19.txt
20         42.6600      -395.0200       168.5000            200.     Run_33_Mic_20.txt
REM
TOFORMAT
  30
11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
30 31 32 33 34 35 36 37 38 39 40 41
SPHERE
5          Theta Delta
0          Theta Min
180        Theta Max
5          Phi Delta
-90        Phi Min
90         Phi Max
4000.      Slant Max
REM  Specify the minimum Signal-to-Noise Ratio in Centibels.  Default = 50 cB
SNRATIO
50.0
REM
THFILE
Run_33.TH
GRIDOPTIONS
2           NRNG
0           CAY
REM NetCDF File Parameters
NCFILE
TH57B033.NC
SOUND HEMISPHERE FOR TH57B, Run 033 Eglin Florida 9.19.03 ART3:01/12/04
2475       EW
0          FW
0          LW
100.       RadBB
90         pylon ang
```

Figure 4-1. Sample .RUN File

Table 4-5. ART Keyword List

Keyword	Description
ACCONFIG	Aircraft configuration state parameter. Required keyword for fixed wing aircraft.
ALL MESSAGES	Signals to ART to provide additional diagnostics.
ALTHFSHAPE	Applies to the $\phi = 90°$; $\phi = 0°$ high frequency shape to all sphere data points.
DOPPLERSTATE	Indicates whether the source is stationary (=0) or moving (=1)
END	Announcing the end of the file.
EXTEND45	Fills in the sphere above $\phi = 45°$ and $\phi = -45°$.
GRIDOPTIONS	Specifies the parameters, which control the sound sphere grid interpolation.
INTERPOLATIONSTATE	Aircraft interpolation state parameter.
LOGFILE	Signals the output of a log file specified by the filename.
MICROPHONE	Defines the microphone location, parameters and noise filenames.
NBFORMAT	Signals ART that the acoustic time history files are in narrow band format and specifies the frequencies of interest.
NCFILE	Specifies the output sound sphere filename and vehicle parameters in the sphere file header.
NOABSCAP	Disables the default high frequency absorption cap in ART.
NOSETAILTEXT	Allows for spectral directivity data at user-defined nose and tail regions to be extended to the nose and tail of the aircraft.
NPOLE	Defines the in-plane (aka North Pole) microphone locations, parameters and noise filenames.
NPOLEGRIDAREAS	Specifies areas for user-defined incremental averaging and interpolation when using the NPOLE keyword.
POWER	Specifies the engine operating state parameter for fixed wing noise spheres.
SNRATIO	Defines the minimum signal-to-noise ratio for depropagation to occur.
SPHERE	Defines the noise sphere control parameters: minimum, maximum, and delta sphere angles and maximum slant range.
SYMMETRICAL	Forces sphere symmetry about the vertical plane.
THFILE	Specifies the TH.filename.
THRUSTANGLE	Specifies the engine operating orientation parameter for fixed wing noise spheres.
TOFORMAT	Signals ART that the acoustic time history files are in one-third octave format and specifies the one-third octave bands of interest.
WRAPAROUND	Mirror images a lower hemisphere onto the top hemisphere.

Keyword **ACCONFIG**

ACCONFIG describes the aircraft configuration state parameter. It is a required keyword when creating fixed wing aircraft noise spheres. This integer variable describes the condition of the aircraft represented by the noise sphere: 0 = clean, 1 = flaps, 2 = flaps + gear, 3 = Static Run-Up. This keyword is required for fixed wing aircraft noise spheres. If rotary wing aircraft are in use, the configuration state is irrelevant and will not be used by AAM.

Table 4-6. ACCONFIG Keyword Format

Line	Position	Max Length	Description
1	1	A8	ACCONFIG Keyword
2	1	I1	Aircraft configuration state parameter, 0 = clean, 1 = flaps, 2 = flaps + gear, 3 = static run-up

Keyword **ALL MESSAGES**

ALL MESSAGES signals the output of a log file specified by the .RUN filename.

Table 4-7. ALL MESSAGES Keyword Format

Line	Position	Max Length	Description
1	1	A11	ALL MESSAGES Keyword

Keyword **ALTHFSHAPE**

ALTHFSHAPE applies a set high frequency spectral shape to the entire sphere based on the computed spectra immediately below the aircraft ($\phi = 90°, \phi = 0°$). This procedure was developed for fighter aircraft exhibiting nonlinear acoustic behavior. This forced spectral shape is applied above a user specified frequency. Typically sound spheres for fixed wing aircraft are generated using a 1000 ft sphere radius. This foroced spectral shape methodology has been developed specifically for this distance because the measured flyover data was obtained for flights at 1000 ft AGL. It is recommended that the ALTHFSHAPE keyword only be used for sphere generation when the sphere radius matches the flyover altitude. ART creates an extra .NC file with keyword enabled. The first file will be NCFILE keyword defined name, and the second file, which contains the forced high frequency spectral shape, will be appended with ALT (i.e., F22_A224.NC and F22_A224ALT.NC).

Table 4-8. ALTHFSHAPE Keyword Format

Line	Position	Max Length	Description
1	1	A10	ALTHFSHAPE Keyword
2	1	F38	Alternate spectral shape minimum frequency

Keyword **END** (required keyword)

END signifies the end of the input deck. No data appearing in the file after the END keyword will be read.

Keyword **DOPPLERSTATE**

DOPPLERSTATE sets the flag which indicates whether the source is stationary (=0) or moving (=1).

Table 4-9. DOPPLERSTATE Keyword Format

Line	Position	Max Length	Description
1	1	A12	DOPPLERSTATE Keyword
2	1	I1	Alternate spectral shape minimum frequency

Keyword **EXTEND45**

EXTEND45 takes the depropagated sphere values at $\phi = 45°$ (port side) and repeats them to the upper extent of the SPHERE keyword defined domain. Note that the mapped data at at $\phi = -45°$ is used on both sides of the new sphere. This keyword feature was developed specifically for fixed wing aircraft.

Keyword **GRIDOPTIONS** (required keyword)

GRIDOPTIONS specifies the parameters which control the sound sphere grid interpolation.

Table 4-10. GRIDOPTIONS Keyword Format

Line	Position	Max Length	Description
1	1	A11	GRIDOPTIONS Keyword
2	1	I10	NRNG The number of grid nodes searched out to during interpolation
3	1	F38	CAY Defines the interpolation scheme: value must be greater than or equal to zero. As the value is increased the interpolation tends to be smoother, but too large value may cause significant detail to be missed

Notes: (1) NRNG = 2 is a good start point.
(2) CAY = 0 is recommended.

Keyword **INTERPOLATIONSTATE**

INTERPOLATIONSTATE defines whether a particular noise sphere may be used in an acoustic interpolation. A value of 0 indicates that the sphere data may not be interpolated. A value of 1 indicates that the sphere may be used for interpolation. In the cases of rotarywing .NC files which do not contain the INTERPOLATIONSTATE parameter, a default value of 1 (Interpolation permitted) is assumed. This ensures backwards compatiblity with older .NC files.

Table 4-11. INTERPOLATIONSTATE Keyword Format

Line	Position	Max Length	Description
1	1	A18	INTERPOLATIONSTATE Keyword
2	1	I1	Interpolation parameter, 0 = no interpolation, 1 = interpolation

Note: (1) Spaces are not permitted in filenames or paths.

Keyword **LOGFILE**

LOGFILE triggers the creation of an execution information ascii file as described in Table 4-11.

Table 4-12. LOGFILE Keyword Format

Line	Position	Max Length	Description
1	1	A7	LOGFILE Keyword
2	1	A256	Logfile name and path

Note: (1) Spaces are not permitted in filenames or paths.

Keyword **MICROPHONE** (required keyword)

MICROPHONE defines the microphone parameters, location, name, flow resistivity, the filename and path to spectral microphone time history input data and the background microphone fill (for narrowbased only).

Table 4-13. MICROPHONE Keyword Format

Line	Position	Max Length	Description
1	1	A10	MICROPHONE Keyword
2	1	I10	Number of microphones
3	1 2 3 4 5	I10 F38 F38 F38 F38	Microphone number X location of microphone Y location of microphone Z location of microphones Flow resistivity (1E6 = hard, 200 = soft)
4	1	A256	Microphone acoustic data filename and path
5	1	A256	Microphone background noise file and path for narrowband microphones only

Notes: (1) Line 3 should be repeated to satisfy the number of microphones.
(2) Microphone number must match line 2, column 17-18 in the external noise data file.
(3) Microphone number must match AMBIENT keyword microphone number.
(4) Path names in lines 4 and 5 must be left justified.
(5) Line 5 should be left blank if broadband files are used.
(6) Filename and path may NOT contain spaces.

Keyword **NBFORMAT**

NBFORMAT is used to signify that the acoustic input data file (both microphone and ambient files) are in the ART narrow band format. See the spectral data file format description in the BACKTIG section for an explanation of this format (Section 4.2). NBFORMAT also allows the user to define which specific narrow bands are to be included in the output .NC file.

Table 4-14. NBFORMAT Keyword Format

Line	Position	Max Length	Description
1	1	A8	NBFORMAT signals ART that the acoustic time history files are in narrow band format.
2	1	I10	Number of frequencies to be analyzed
3	*	F*	Frequencies of interest to be included in the output .NC file (values must match source frequency exactly).

Notes: (1) * Each frequency has an open format and must be separated by a space or comma.
(2) Repeat line 3, as needed, to satisfy the number of frequencies specified in line 2.

Keyword **NCFILE** (required keyword)

NCFILE defines the header parameters and description, which will be put into the NetCDF sphere file. These are used to define the conditions under which the acoustic data was originally gathered.

Table 4-15. NCFILE Keyword Format

Line	Position	Max Length	Description
1	1	A6	NCFILE Keyword
2	1	A80	.NC filename and path (must be left-justified)
3	1	A77	.NC file header description
4	1	F38	Vehicle empty weight (lbs)
5	1	F38	Fuel weight
6	1	F38	Load weight (lbs)
7	1	F38	Output sphere radius (ft)
8	1	F38	Angle of the pylons (helicopter mode = 90°, airplane mode = 0°)

Note: Filenames and paths may NOT contain spaces.

Keyword **NOABSCAP**

NOABSCAP is used when the default treatment of atmospheric absorption (i.e., the forced rolloff limit for high frequencies) needs to be disabled. See Section 4.1 for a technical description of the high frequency absorption cap.

Keyword NOSETAILTEXT

NOSETAILTEXT forces the mapped sphere data at $\theta = \theta_{nose}$ to be averaged with adjacent data one index closer to the nose ($i_\theta = i_\theta - 1$) and repeats it for sphere points in the region $0° \le \theta \le \theta_{nose}$. Additionally, the mapped sphere data at $\theta = \theta_{tail}$ is averaged with adjacent data one index closer to the tail ($i_\theta = i_\theta + 1$) and repeated for sphere points $\theta_{tail} \le \theta \le 180°$. This keyword creates an additional NC output file with the root name as defined in the NCFILE keyword section with NTX appended (i.e., F22_A224.NC and F22_A224NTX.NC).

Table 4-16. NOSETAILTEXT Keyword Format

Line	Position	Max Length	Description
1	1	A11	NOSETAILEXT Keyword
2	1	F38	θ nose
3	1	F38	θ tail

Keyword **NPOLE**

NPOLE is used when a forward microphone is available; this data better describes the forward projecting noise components in the plane of the main rotor blades of a helicopter. Because of the coordinate system used to define the spheres, this region appears as a "pole", hence the NPOLE keyword.

Table 4-17. NPOLE Keyword Format

Line	Position	Max Length	Description
1	1	A5	NPOLE Keyword
2	1	I10	Number of North Pole microphones
3	1 2 3	I10 F38 F38	Microphone number Minimum Range (ft) for use in generating the sphere Maximum Range (ft) for use in generating the sphere

Keyword **NPOLEGRIDAREAS**

NPOLEGRIDAREAS define the areas which are divided into finer grids based on the theta and phi *(θ, ϕ)* spacing. The microphone data from all North Pole microphones within the individual domains are averaged and applied to the sphere. If multiple NPOLEGRIDAREAS are defined for the same region, the last defined area takes precedence over the previously defined areas. This is a change from prior versions of ART where each North Pole microphone's influence was applied to the sphere separately.

4-18. NPOLEGRIDAREAS Keyword Format

Line	Position	Max Length	Description
1	1	I10	NPOLEGRIDAREAS keyword
2	1	I10	Number of North Pole grid areas
3	1 2 3 4	A5 A5 A5 A5	Minimum Theta (deg) Maximum Theta (deg) Minimum Phi (deg) Maximum Phi (deg)

Keyword POWER

POWER is used to specify the engine operating state which is put in the output NCfile header. Table 4-14 defines these parameters. This keyword is required for fixed wing aircraft.

Table 4-19. POWER Keyword Format

Line	Position	Max Length	Description
1	1	A5	POWER Keyword
2	1	A3	Units of power (i.e., LBS, N1, N2, EPR)
3	1	F38	Value of power in defined units

Keyword **SNRATIO**

SNRATIO defines the minimum signal-to-noise ratio in centibels. Measurements, which do not equal or exceed the background by SNRATIO, are not used. There is NO subtraction of ambient noise from the signal. Default value is 50 cB or 5 dB.

Table 4-20. SNRATIO Keyword Format

Line	Position	Max Length	Description
1	1	A7	SNRATIO Keyword
2	1	F38	Signal-to-noise ratio in cB

Keyword **SPHERE** (required keyword)

SPHERE defines the noise sphere parameters and description, which will be put into the NetCDF sphere file.

Table 4-21. SPHERE Keyword Format

Line	Position	Max Length	Description
1	1	A6	SPHERE Keyword
2	1	I10	Theta delta (deg)
3	1	I10	Theta minimum (deg)
4	1	I10	Theta maximum (deg)
5	1	I10	Phi delta (deg)
6	1	I10	Phi minimum (deg)
7	1	I10	Phi maximum (deg)
8	1	F38	Maximum slant range to depropagate (ft)

Notes: (1) Possible theta values range from 0 to 180 deg.
(2) Possible phi values range from -180 to 180 deg.
(3) Angle range divided by angle delta must result in a whole number.

Keyword **SYMMETRICAL**

SYMMETRICAL keyword forces symmetry about the vertical plane, i.e., the starboard and port sides of the sphere are mirror images of one another. The values applied to both sides are computed by taking the geometric average (in dB) of corresponding points on either side of the sphere. This keyword creates an additional .NC file with the root name as defined in the NCFILE keyword section with SYM appended (i.e., F22_A224.NC and F22_A224SYM.NC).

Keyword **THFILE**

THFILE specifies the filename of the time history (.TH) file that contains the spectral propagation details.

Table 4-22. THFILE Keyword Format

Line	Position	Max Length	Description
1	1	A6	THFILE Keyword
2	1	A80	.TH file filename including path (must be left justified).

Note: Filenames and paths may NOT contain spaces.

Keyword **THRUSTANGLE**

THRUSTANGLE is used to define the NCfile header flight condition descripption of the engine operating state. This keyword is required for fixed wing aircraft.

Table 4-23. THRUSTANGLE Keyword Format

Line	Position	Max Length	Description
1	1	A11	THRUSTANGLE keyword.
2	1	F38	Angle of thrust (deg).

Keyword **TOFORMAT** (required keyword)

TOFORMAT is used to signify that the acoustic input data files are in the one-third octave band format. See the spectral data file format description in the BACKTIG section for an explanation of this format (Section 4.2). TOFORMAT also allows the user to define specific one-third octave bands to be included in the output .NC file.

Table 4-24. TOFORMAT Keyword Format

Line	Position	Max Length	Description
1	1	A8	TOFORMAT signals ART that the acoustic time history files are in one-third octave band format.
2	1	I10	Number of one-third octave bands to be analyzed.
3	*	F*	One-third octave bands to be included in the output .NC file.

Notes: (1) * Each one-third octave band has an open format and must be separated by a space or comma.
(2) Repeat line 3, as needed, to satisfy the number of one-third octave bands specified in line 2.

Keyword **WRAPAROUND**

WRAPAROUND keyword takes a hemisphere (lower half) as created by ART and mirror images the values on the top half of the sphere. This feature is used so that a fully defined sphere will be populated with reasonable source levels instead of 1E35 (no data) points. This keyword creates

an additional .NC file with the root name as defined in the NCFILE keyword section with RAP appended. (i.e., F22_A224.NC and F22_A224RAP.NC)

4.1.4 Microphone Data Input File Format Description

Noise measurement data file and path is defined in the MICROPHONE keyword section. The structure of these files are presented in Table 4-24 for one-third octave band noise, and Table 4-25 for narrow band noise.

Table 4-25. One-third Octave Band Noise File Format

Line	Column	Format	Description
1	1-60	A60	Description of file name
2	17-18 25-27	I2 I3	Microphone number Run number
3	31-34	I4	Number of spectra lines in the file (not including AMBIENT)
4-7			Comment lines
8	28+(I to N)*4	N*F4.0	Band numbers for .MIC file position: I is lowest band number, position N is highest.
10	27-N*5	N*I5	Ambient noise in cB: N is number of bands.
11 + no. of spectra lines	1-4 5-6 8-9 11-16 27-N	I4 I2 I2 F6.3 N*I5	Sequential measurement index number Hours after midnight Minutes after the hour Seconds after the minute Sound pressure level in cB for specified input bands

Note: Microphone number (line 2, column 17-18) must match line 3, column 12 on MICROPHONE Keyword.

Table 4-26. Narrow Band Noise File Format

Line	Column	Format	Description
1	1-9 10-12	 A3	Mic No.: label field Microphone ID Label
2	1-9 10-17	 I8	Run No.: label field Run number index ID
3	1-11 12-24	 F12	Start time: label field Start time of the data in this file, seconds after midnight.
4	1-28 29-33	 I5	No. narrow band frequencies: label field Number of frequencies (NF) appearing in this file
5	1-255		Label field
6 repeat	1-80	10(F8.1)	Frequency list (Hz) written as (10(F8.1)). N is the number of lines required to write out NF data points, 10 per line.
N+1	1-255		Blank Line
N+2	1-6		Time: label field
N+3	1-20		Narrow Band Spectra: label field
N+4 repeat	1-80	10(8.2)	Acoustic Spectra in dB. One level for each frequency in lines 6-N

Notes: (1) Line 6 is repeated, as needed, to satisfy the number of frequencies specified in line 4.
(2) Line N+4 is repeated, as needed, to satisfy the number of frequencies specified in line 4.

The narrow band noise file format external files are used to input source characteristics to ART for source sphere assembly. These files are flexible in that discrete frequencies may be included and a full spectra is not necessary.

4.1.5 Source Data File (.NC) Description

Sound sphere (or hemisphere) files each contain for one noise source for a single flight condition. The NetCDF format is self-describing. Each file contains a set of variables and attributes which

define the flight condition and the location of the noise data on the sphere. The three independent variables that describe the quasi-steady flight condition for a rotorcraft are the flight path angle, the pylon angle, and the airspeed. For conventional helicopters, only flight path angle and airspeed are needed. For fixed wing aircraft the three parameters used to determine which sound sphere is a representative of the specific flight condition are Engine Operating State (Thrust). Flight speed and engine thrust vector angle (for such vehicles with the capability to change the nozzle angle.) There may be more than one sound sphere for each set of conditions. For instance, there may be one broadband and one pure-tone sound sphere. For each set of flight conditions there can be up to ten broadband, ten narrowhead, and ten pure-tone sound spheres centered at different points on the air (i.e., engine, main rotor, tail rotor, and MR/TR wake interference, engine exhaust, forward thruster etc.).

The source characteristics are stored in a packed binary file using Network Common Data Form (NetCDF).[26] This data format is an abstract data type with access to the data performed by a set of functions and routines. The details of data compression and retrieval are hidden from the user. NetCDF efficiently stores and retrieves the data, and is platform independent. Raw binary files can be passed between computers over the network and accessed so long as the NetCDF library is used in the code. A complete distribution of NetCDF utilities including a user manual is available at the web site ftp.unidata.ucar.edu. Table 4-26 presents a list of sound sphere file keywords are used for vehicle descriptors and flight conditions.

Table 4-27. Variable Names and Attributes in the Sound (NetCDF) Files

Variable Name	Unit	Description
BB	None	Value: 0 or 1
NB	None	Value: 0 or 1
PT	None	Value: 0 or 1
DOPPLER_SHIFT_REMOVED	None	Value: 0 or 1
EMPTY_WEIGHT	pounds or kilograms	Vehicle Empty Weight
FUEL_WEIGHT	pounds or kilograms	Vehicle Fuel Weight
LOAD_WEIGHT	pounds or kilograms	Vehicle load Weight
RADIUS	feet or meters	Radius of sound hemisphere
FLIGHT_PATH_ANGLE	degrees or radians	Elevation angle of flight: Track, 0° level flyover, positive = departure, negative = arrival
PYLON_ANGLE	degrees or radians	Pylon angle: 0° airplane mode, 90° helicopter mode
SPEED	knots or meters/sec	Aircraft speed
XYZ	feet or meters	Center of noise sphere in body-fixed coordinates. Array ordered by X, Y, and Z
PHI	degrees or radians	Spherical angle phi (ϕ) -90° to +90°
THETA	degrees or radians	Spherical angle theta (θ) 0° to 180°
FREQUENCY	hertz	One-third octave center frequencies or pure-tone frequency
AMPLITUDE (Phi, Theta, Frequency)	decibels	Amplitude of band or tone
PHASE(Phi, Theta, Frequency)	degrees or radians	Phase of tone relative to reference time
POWER	user defined	Engine operating state parameter
THRUSTANGLE	degrees	Thrust vector angle flight condition
ACCONFIG	none	Value 0 = clean, 1 = flaps, 2 = flaps + gear, 3 = Static Run-Up
INTERPOLATIONSTATE	none	0 = no interpolation, 1 = interpolation permitted

Notes: (1) 0 = False; 1 = True
(2) Each sphere may contain only one source type: BB + NB + PT must = 1.
(3) PHASE is only required when specifying pure tone source characteristics

4.2 BACKTIG

The BackTIG program overwrites the background information contained in a .TIG or .HS file with the user-specified background data. To run BackTIG from the command prompt:

BackTIG controlfile.BT

where the control file contents are described in Table 4-27.

Table 4-28. BACKTIG Control File Format

Line	Position	Max Length	Description
1	1	A1024	Input .TIG or hotspot (.HS) path and filename to which background is to be applied.
2	1	A1024	Output .TIG path and filename
3	1	A1024	Background spectra data path and filename (.BAK) to be applied.

The background spectral data file referenced in the control file is structured as follows:

Table 4-29. Spectra Data File Format

Line	Position	Max Length	Description
1	1-80	A80	Description of background data file.
2	1-4 5-10	I4 A6	Number of background spectra (1024 Max.). Type specifier: TODATA for one-third octave band, NBDATA for narrow band.
3	n	I5 or F15	Frequencies or band numbers (Hz). TODATA requires data to be band numbers, NBDATA requires frequencies.
4	n	F15	Background spectra. One entry per band or frequency number. Narrow band data is expected in dB. One-third octave band is expected in dB.

Notes: (1) Line 3 length for band numbers is I5 for TODATA formats.
(2) Line 3 length for frequencies is F15 for NBDATA formats.

4.3 BuildIMP

The BuildIMP program reads in an ASCII impedance file (Figure 4-2) and creates a binary terrain (.ELV) file.

```
Hard Ground                    ! Title (a20)
     50000     50000           ! di,dj (mesh size)
         2         2           ! ir,jr (grid reference point indicies)
         3         3           ! ni,nj (input IMP file size)
       0.0       0.0           ! xr,yr (Reference point coords)
   1000000
   1000000
   1000000
   1000000
   1000000
   1000000
   1000000
   1000000
   1000000
```

Figure 4-2. Portion of an ASCII Impedance File

To run BuildIMP from the command prompt:

BuildIMP control.BI

where the control file (.BI) is as defined in Table 4-29.

Table 4-30. BuildIMP Control File Format

Line	Position	Max Length	Description
1	1	A1024	Input filename
2	1	A1024	Output filename

4.4 Bullwink

The Bullwink utility is a stand alone version of the NetCDF .NC file format sphere writing routines. It is used to create NetCDF format data files from ASCII input. Data may contain broadband, narrow band or pure tone and phase description.

Three files—a control file (.BLW), an input file (.INP), a data file (.DAT) and if including nonlinear corrections a .NLC file—are needed to run Bullwink from the command line. The control file contains four pieces of information:

- The name and path of the input file,
- The name and path of the data file,
- The name and path of the nonlinear acoustic correction file, and
- The eleven (11) digit NetCDF output filename.

Two examples of a broadband input file for a rotorcraft and fixed wing aircraft are given in Figure 4-3.

```
SOUND SPHERE Broadband Sphere
1          BB
0          NB
0          PT
0          DS
5000       EW
0          FW
0          LW
100.       R
0          Elev
90         pylon ang
100.0      Airspeed
0.0,0.0,0.0   XYZ
```

(Example 1)

```
AIRPLANE SOUND HEMISPHERE TEST Uniform: BB, ...
1          BB
0          NB
0          PT
0          DS
1000.      R
100.0      AIRSPEED
0.0,0.0,0.0     XYZ
N2    POWER UNITS (MAX 4 CHAR)
77.   POWER
0.    THRUST ANGLE
0     ACCONFIG
1     Interpolation State
```

(Example 2)

Figure 4-3. Sample Bullwink Broadband Input File

The description of the input file parameters is given in Table 4-30.

Table 4-31. Bullwink Input File Description

Line	Position	Max Length	Description
1	1	A80	Label to be inserted into the NetCDF file (see note 5)
2	1	I 10	Broadband type (1 = yes 0 = No)
3	1	I 10	Narrow band type (1 = yes 0 = No)
4	1	I 10	Pure tone/Phase type (1 = yes 0 = No).
5	1	I 10	Doppler shift status (0=moving source, 1= stationary source)
6	1	F38	Empty weight of vehicle (lbs)
7	1	F38	Full weight (lbs)
8	1	F38	Load weight (lbs)
9	1	F38	Sphere radius (ft)
10	1	F38	Flight path angle (deg), pylon angle (90° = helicopter)
11	1	F38	Pylon angle (90°=helicopter mode, 0° = airplane mode)
12	1	F38	Airspeed (knots)
13	1-3	3F-	Sphere origin on vehicle (x,y,z) feet
14	1	A5	Power unit identifier (LBS,N1,N2,EPR)
15	1	F38	Power setting valve in units prescribed in Line 14
16	2	F38	Thrust vector angle (degrees)
17	1	1	Aircraft configuration state parameter, 0 = clean, 1 = flaps, 2 = flaps + gear, 3 = static run-up
18	1	1	Interpolation state parameter (0 = no interpolation, 1 = interpolate)

Notes: (1) Lines 6, 7 and 8 should add up to the vehicle weight representative of the source data.
(2) Line 13 is unformatted -- (x,y,z) data should be space- or comma-delimited.
(3) Only the first data position is read by Bullwink. The remainder of these lines may be used for user comments.
(4) Lines 10 and 11 are used only for rotary wing aircraft.
(5) For fixed wing aircraft the first 8 characters of Line 1 must be AIRPLANE.

A sample broadband data file fragment is given in Figure 4-4. This file contains a description of the acoustic spectral properties on the noise sphere. A description of the file structure is given in Table 4-29. For this particular example a sound sphere will be created which has a 100.0 ft radius with 100 dB (1000 cB) source tone at band 10 (10 Hz) and 0.1 dB (1 cB) everywhere else. Computations involving logarithms of zero (0) are invalid; use 1 cB instead of 0 dB.

```
     100.           ! Radius (ft)
   31   37   37      ! nFreq, nTheta, nPhi
  Theta     Phi   10   11   12   13   14   15   16   17   18   19 ..
     .0   -90.0 1000 0001 0001 0001 0001 0001 0001 0001 0001 0001 ..
    5.0   -90.0 1000 0001 0001 0001 0001 0001 0001 0001 0001 0001 ..
   10.0   -90.0 1000 0001 0001 0001 0001 0001 0001 0001 0001 0001 ..
   15.0   -90.0 1000 0001 0001 0001 0001 0001 0001 0001 0001 0001 ..
   20.0   -90.0 1000 0001 0001 0001 0001 0001 0001 0001 0001 0001 ..
   25.0   -90.0 1000 0001 0001 0001 0001 0001 0001 0001 0001 0001 ..
   30.0   -90.0 1000 0001 0001 0001 0001 0001 0001 0001 0001 0001 ..
```

Figure 4-4. Sample Bullwink Acoustic Data File

Table 4-32. Bullwink Acoustic Data File Description

Line	Position	Max Length	Description
1	1	F38	Radius of source noise in this file will be used for reference purposes.
2	1 2 3	3I10	Number of frequencies Number of Theta points Number of Phi points on the sound sphere.
3	1	I10	Band number.
4	1 2 3	F38 F38 I10	Theta value (0-180 degrees). Phi value (-180 to +180 degrees). Source level at this band column in centibels.

Note: The radius line (1) need not match that in the .INP file line (9). Bullwink will scale this .DAT file data according to pure geometric spreading from this input source data R (in the .DAT file) to the output requested NetCDF file data R (in the .INP file).

Table 4-32 includes a description of the nonlinear acoustic correction (.NLC) An example file is provided in Figure 4-5.

```
mil
34    = num bands
31    = num range
NLgain   OA   10   11   12   13   14   15  ...   37   38   39   40   41   42   43
Rfeet  **** **** **** **** **** **** ****  ... **** **** **** **** **** **** ****
1000   1190    0    0    0    0    0    0  ...    0    0    0    0    0    0    0
1100   1180    0   -2    0    0    0    0  ...   20   33   54   82  121  177  266
1200   1172    1   -5    0   -1    0   -1  ...   36   58   94  143  211  311  450
1300   1163    1   -7    0   -1    0   -1  ...   50   80  130  197  290  428  614
1400   1156    1   -9    0   -2    0   -1  ...   63  101  163  246  365  540  770
1500   1149    2  -11    0   -2    0   -1  ...   75  120  195  294  436  649  923
1600   1142    2  -13    1   -3    0   -2  ...   87  140  227  343  508  758 1077
```

Figure 4-5. Example Nonlinear Acoustic Correction (.NLC) File

Table 4-33. Bullwink Nonlinear Acoustic Correction File Description

Line	Position	Max Length	Description
1	1	A256	Condition description (not used)
2	1	I5	Number of frequency bands
3	1	I5	Number of ranges (distances)
4	1	A256	Column labels (not used)
5	1	A256	Column labels (not used)
6	1 2 3-end	I5 I5 nI5	Range for correction (feet) Overall SPL from waveform (not used) Nonlinear correction for one frequency (dB)

Notes: (1) Line 6, position 3 is repeated for each frequency specified on line 2.
(2) Line 6 is repeated once for each range specified on line 3.

4.5 DeDopplerizer (Creation of Stationary Source Data .NC Files)

Wyle DeDopplerizer is a stand alone executable that will remove the inherent Doppler shift from microphone data of an aircraft overpass. This program prepares source noise from measured data for use in ART for the creation of source sphere representative of a stationary source. One of the inherent problems with the current method for characterization of aircraft noise sources is that it is impossible to directly record an aircraft flying through a microphone array without also recording changes in frequency commonly referred to as a Doppler shift. In order to know what the equivalent signal would be from a stationary source (with the same noise characteristics as a moving source), the signal must be manipulated to remove the Doppler shift.

4.5.1 De-Dopplerization

The Doppler effect is a perceived change in the frequency content of a source noise due to a difference in relative velocity between the source and the receiver. This effect exists in all recorded data when the source moves past the receiver. The net result of the Doppler shift is to increase frequencies for sources that are approaching a receiver, and to decrease frequencies for sources that are moving away from a receiver. The frequency shift is defined by:

$$f' = f\left[\frac{1}{1+\frac{u}{c}}\right] \qquad (16)$$

In general, unless data will always be applied for the same vehicle speed as it was collected, a Doppler correction will be needed. This can be accomplished within a noise model, with the model using a difference based on Equation (16) applied to the flight test and the modeled airspeed. Often it is desirable to "de-Dopplerize" the data to zero airspeed, equivalent to shifting the frame of reference to aircraft coordinates. This is particularly useful when there are tonal characteristics. The following discussion describes this full de-Dopplerization process.

To accurately remove the Doppler shift from a recorded sound it is crucial to have accurate tracking of the aircraft as it flies through the microphone array. The tracking data and the microphone data must have the exact same time stamp indicators so that they can be synchronized. From this data it is possible to determine the frequency shift caused by the aircraft's motion and remove it from the recorded data.

The first step in removing the Doppler shift is to calculate the frequency shift needed at each time step in the time history. This is accomplished by analyzing the tracking data and calculating the closing speed between the source and the receiver and using that in Equation (16).

Next, the time waveform from the microphone is processed into spectra at each of the desired time steps. With digital recordings, this is generally accomplished via Fast Fourier Transform (FFT) analysis, with the results converted into power spectra with units of decibels. The width of each bin from the FFT is determined by the sampling rate of the recording device and the number of FFT points. (Bin width = number of FFT points divided by sampling rate.) This sample rate can be considered as the base sample rate for a stationary source.

As the aircraft approaches, each wave crest from the noise passes the receiver at intervals that are less than what would be expected of a stationary source. For example, with a sample rate of 10,000 samples per second and a static 100 Hz signal, a wave crest will be picked up every 100 samples: once every 0.01 second. If the aircraft is moving forward there is a Doppler shift such that the resulting wave crests will be picked up by a microphone less often than every 100 samples. For this example, consider a wave crest that is picked up by the microphone every 80 samples (every 0.008 second). This shows up as a signal recorded as 125 Hz (increased from the actual, stationary frequency of 100 Hz). If the sample rate is reduced to 8,000 samples per second, we will again have the 100 Hz signal frequency.

An equivalent, and more direct, way of examining this process is to consider the edge frequencies of each bin. For the example of a 10,000 samples per second and a 1000 point FFT, the power spectrum of the recorded signal will have a sequence of lines at 10 Hz intervals. Each line may be

considered to be a bin 10 Hz wide. When the Doppler shift is applied, each frequency is multiplied by (in this example) 0.8. The bin width (and its center frequency) is thus reduced by the exact amount determined by Equation (16).

As the aircraft passes, the frequency shift multiplier for this example will change from 0.8 to 1.25, in accordance with Equation (16). A significant issue associated with this change is that, for each time step, there will be a different frequency resolution. It is impractical to have so many different resolutions if one wants to analyze the data throughout a flight because it would be almost impossible to track a frequency through the time history. It is therefore desirable to redistribute the data into bins with a standard fixed width.

This re-binning process is accomplished by assuming that the energy in each bin is evenly distributed throughout the bin. This way it is possible to simply apportion energy from bins with various width into bins of a standard width based on the stationary sample rate. Figure 4-6 illustrates this process.

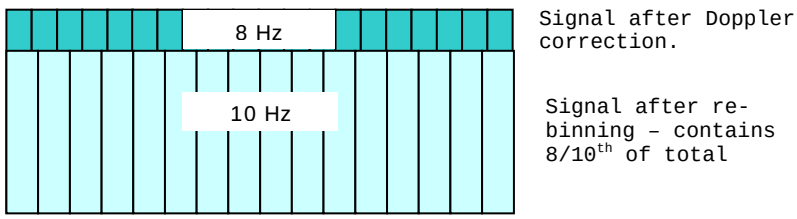

Figure 4-6. Re-binning Process

A problem that occurs when this process is employed is the unavoidable loss of information. This occurs in two ways. One is that the number of points in each final frequency bin is different than the original data. In the example, data that was recorded at an 8 Hz resolution is now diluted to a 10 Hz resolution. The second is that the frequency range itself changes. If the original recording had a range from 10 Hz to 10 kHz, the de-Dopplerized signal has a range from 8 Hz to 8 kHz. Apportioning to the original range, de-Dopplered data from 8 Hz to 10 Hz will be discarded, and de-Dopplered data from 8 kHz to 10 kHz will not be present. Behind the aircraft, the opposite shift will cause original high frequency data to be discarded and for data at the lowest frequencies to not be present. A solution to this second issue is to ensure that the original recording has a wide enough frequency range so that what remains will cover requirements. Note that, for conventional aircraft, which always have a forward velocity, less data will be lost at either end if de-Dopplerization is performed within the noise model, using a difference shift rather than first fully shifting to zero velocity.

For aircraft that can have zero forward velocity, such as rotorcraft or VTOL aircraft, de-Dopplerization to zero velocity is inevitable. When there are pure tones of interest, the clarity of fully de-Dopplerizing the data is invaluable: pure tones from the aircraft stay constant throughout the entire fly-by.

Figure 4-7 shows spectral time histories from a real aircraft flying past a microphone. The X-axis shows time while the Y-axis shows frequency. Several pure tones can be seen as streaks that run from the left to the right. In the first image, these pure tones change as the aircraft passes by the microphone array, following the classic Doppler shift from high frequency to a lower frequency. In the second image, the de-Dopplerization algorithm has been applied. In this case, the pure

tone streaks remain flat throughout the entire time history. In this case the tones have been corrected to represent an equivalent static noise source.

4.5.2 DeDopplerizer Input File Description

DeDopplerizer is a stand alone executable that will remove the inherent Doppler shift from recorded microphone data of a moving flight vehicle. The software requires a set of microphone files in the NASA narrow band microphone file NetCDF format, and an associate .TH file that describes the flight path and geometric parameters of the vehicle with respect to the microphone locations. It is crucial that the NetCDF files and the .TH file are synchronized with a common time reference to ensure that the Doppler shift is centered on the moment when the aircraft is directly above the microphones.

A required control file contains all of the program information needed to run the DeDopplerizer. Information is entered to the program via keywords. An example control file is provided in Figure 4-8 and a listing of the keywords is given in Table 4-32.

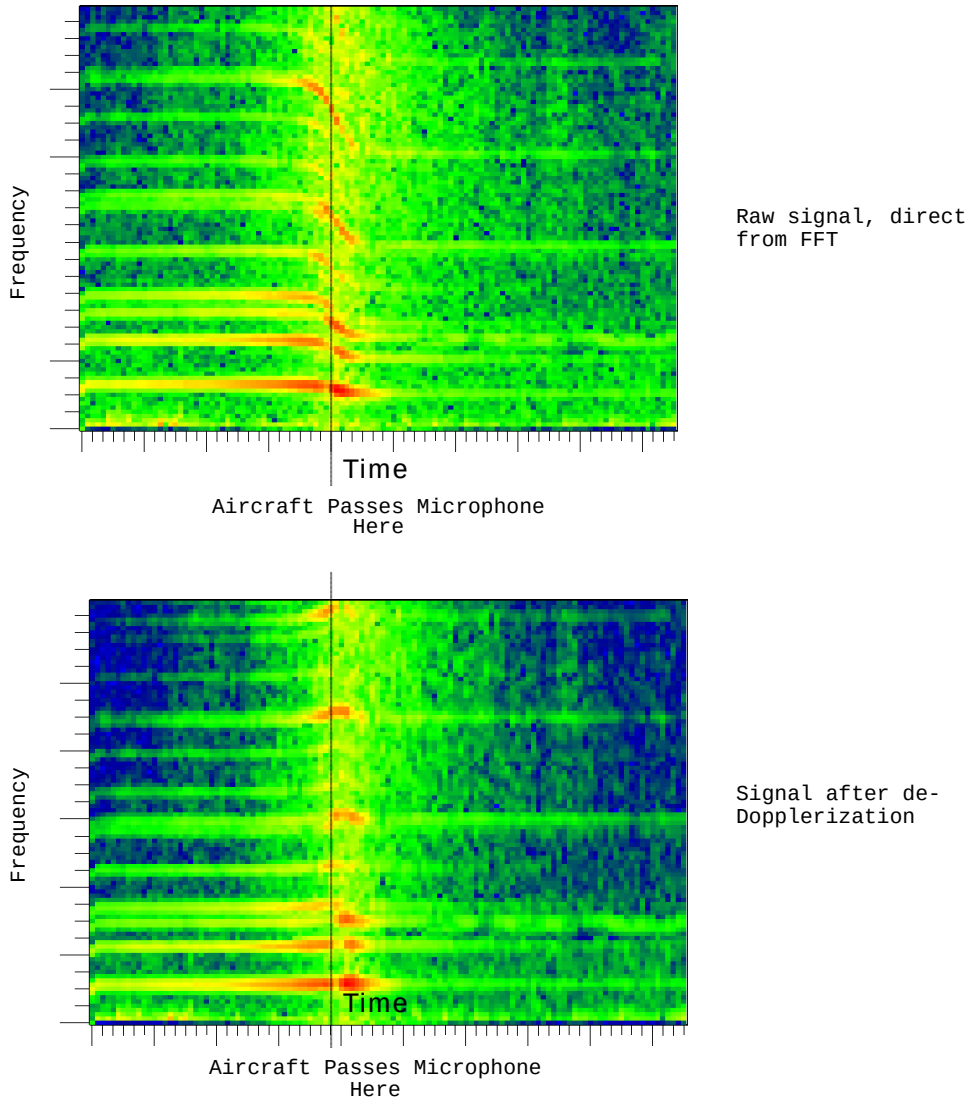

Figure 4-7. Spectral Time Histories, Before and After de-Dopplerization

```
C:\data\Doppler\DataFiles\000001.TH
C:\data\Doppler\Output\
001 C:\data\Doppler\DataFiles\000001_01_BIN.NC
002 C:\data\Doppler\DataFiles\000001_02_BIN.NC
003 C:\data\Doppler\DataFiles\000001_03_BIN.NC
004 C:\data\Doppler\DataFiles\000001_04_BIN.NC
005 C:\data\Doppler\DataFiles\000001_05_BIN.NC
006 C:\data\Doppler\DataFiles\000001_06_BIN.NC
007 C:\data\Doppler\DataFiles\000001_07_BIN.NC
008 C:\data\Doppler\DataFiles\000001_08_BIN.NC
009 C:\data\Doppler\DataFiles\000001_09_BIN.NC
010 C:\data\Doppler\DataFiles\000001_10_BIN.NC
011 C:\data\Doppler\DataFiles\000001_11_BIN.NC
012 C:\data\Doppler\DataFiles\000001_12_BIN.NC
013 C:\data\Doppler\DataFiles\000001_13_BIN.NC
014 C:\data\Doppler\DataFiles\000001_14_BIN.NC
015 C:\data\Doppler\DataFiles\000001_15_BIN.NC
016 C:\data\Doppler\DataFiles\000001_16_BIN.NC
017 C:\data\Doppler\DataFiles\000001_17_BIN.NC
018 C:\data\Doppler\DataFiles\000001_18_BIN.NC
019 C:\data\Doppler\DataFiles\000001_19_BIN.NC
020 C:\data\Doppler\DataFiles\000001_20_BIN.NC
WINDOW hamming
TIMESTEP 0.5
NUMSAMPLES 4096
```

Figure 4-8. Sample DeDopplerizer Control File

Table 4-34. DeDopplerizer Control File Keyword List

Keyword	Description
NUMSAMPLES	Requested output sample rate. Must be value of 2^n.
OVERLAP	Amount of overlap to be used in the FFT. Valid: 0.0-1.0 Default is 0.5
TIMESTEP	Requested output time step (sec) in deDopplerized spectral time history file
WINDOW	FFT window type: hann, hamming, rectangle

Control File Description – *No Keyword* (mandatory section)

Table 4-35. DeDopplerizer Control File Structure

Line	Position	Max Length	Description
1	1	A256	.TH file and path associated with this case
2	1	A256	Output directory for DeDopplerizer results
3	1	A3	NetCDFfile 3-character ID There should be one NetCDF file listed for each microphone contained in the .TH file. This ID is used to associate the .TH file and NetCDF files
	2	A256	Path and filename of the NetCDF file associated with the microphone ID in columns 1-3

Notes: (1) Include the trailing backslash on line 2.
(2) If there are twenty microphones listed in the .TH file then there should be twenty lines of microphone data in the control file.
(3) Filenames and paths may NOT contain spaces.

Keyword **WINDOW**

WINDOW determines the type of window to be used by the FFT. A hamming window is recommended and is the default if no window is listed.

Values: hanning, hamming, rectangle

Table 4-36. WINDOW Keyword Format

Line	Position	Max Length	Description
1	1 2	A6 A9	WINDOW Keyword Window Type: hann (default), hamming, rectangle

Keyword **TIMESTEP**

TIMESTEP This is the time history time increment in seconds that the resulting files will output. A reasonable time history should be selected. The default value is 0.5 (secs). Any floating value may be used.

Table 4-37. TIMESTEP Keyword Format

Line	Position	Max Length	Description
1	1 2	A8 F38	TIMESTEP Keyword Floating value of time increment (sec) Default = 0.5

Keyword **NUMSAMPLES** (required keyword)

NUMSAMPLES, combined with the sample rate, will give the band width. By increasing this value you may need to decrease the number of averages or the overlap of the averages. The default value is 4096. Allowable values must be an integer value of.

Table 4-38. NUMSAMPLES Keyword Format

Line	Position	Max Length	Description
1	1 2	A10 I10	NUMSAMPLES Keyword Samples per time step. Must be an integer value of 2^n. Default = 4096

Keyword **OVERLAP** (required keyword)

OVERLAP specifies the signal overlap in determining the results of the FFT. Default is 0.5, or 50%.

Table 4-39. OVERLAP Keyword Format

Line	Position	Max Length	Description
1	1 2	A7 F38	OVERLAP Keyword Signal overlap in decimal format. Valid 0.0 – 1.0

The output from this process will be a set of spectral time history files and a log (.LOG) file in the output directory. The spectral time history files will all be named with the same root as the corresponding NetCDF microphone file but with the .STH suffix. The log file will list any errors that occurred and will also delineate some of the particulars of the Fast Fourier Transform. Additional information contained in the log file includes the band width of the output bins, the number of averages, and the time step.

4.6 ELV2PLT

The Elevation file is a binary file which is not easily viewed. The ELV2PLT utility converts an .ELV file into an ASCII Tecplot -formatted file. The Elv2PLT utility may be accessed from the command prompt using the following command:

Elv2PLT input.ELV output.PLT

Input.ELV is the input elevation (.ELV) file and may include the path.

Output.PLT is the output (.PLT) file in Tecplot format and may include the path.

4.7 ELVBuilder (Elevation and Impedance Builder)

AAM has the ability to include the effects of topography on the acoustic propagation. A discussion of the physics may be found in Chapter 2. The terrain is described in two parts: elevation and ground impedance. The file formats are consistent with NOISEMAP[6] and NMSIM[3] and use the .ELV extension for the altitude grid and .IMP extension for ground impedance files.

ELVBuilder is an interactive graphical program, that builds .ELV and .IMP files. A discussion of the various topographical file formats and data sources is included here. The ELVBuilder software permits the creation of both elevation and impedance files from topographic digital data. Two standard impedance files (hard and soft) are distributed with the software.

The impedance file stores information about the ground impedance of the study area in a grid identical in size and resolution to the elevation grid. Ground impedance is basically a measure of the reflectivity of the ground. In the propagation module, the ground impedance is quantified by the flow resistivity (in MKS RAYLS) of the ground. The better the ground is at reflecting the sound the higher the impedance and flow resistivity. For example, asphalt is acoustically very hard and has a resistivity of about 30,000 RAYLs (Pa•s/m). Table 3-17 lists some typical impedance values.

4.7.1 Topography Data

AAM requires topographic elevation data when performing acoustic propagation over varying terrain. The NMSIM ELVBuilder, will accept data from a variety of sources, including United States Geological Survey (USGS) Digital Line Graph (DLG) hypsography layers, USGS Digital Elevation Model (DEMs), ESRI ASCII grid files, Digital Terrain Elevation Data (DTED), and Digital Feature Attribute Data (DFAD). DLGs and DEMs are freely available for most of the United States at no cost (USGS web site: http://edc.usgs.gov/geodata) or nominal cost (direct order).

Building the elevation file requires input data which describes the topography of the study area. Before discussing the process of building an elevation file it is important to understand what input files are available and the impact they have on the analysis.

Before building an elevation file it is important to collect all the necessary input files. To do this it is also necessary to know exactly where the study area is and what its extent is. Once this has been determined you can go about the process of collecting the necessary files.

ELVBuilder can accept input terrain files in the following formats:

- Digital Line Graphs (DLG).
- Digital Elevation Model (DEM).
- ESRI ASCII exchange format.

- Military DTED format.
- National Elevation Dataset (NED).

4.7.1.1 Digital Line Graph (DLG) Files

Digital Line Graph files are generated from currently available maps that USGS possesses. To quote from the DLG user's manual, "Digital Line Graph data are currently derived by digitizing map features as line graph elements from cartographic source materials." In other words, they are direct digital representation of the USGS maps. This means that the files store the roads, power lines, municipal boundaries, elevation lines, water, etc., that are on the map. To reduce the clutter inherent in this system, each different kind of data set is stored in its own file.

There are a total of eleven different file types used to store all of the data on a map, although not every area will have every file type. The files are denoted with a two-letter abbreviation in the name. Table 4-39 lists the file types with a brief description of the contents of the file. For the purposes of generating an elevation file, only the hypsography files are used.

Table 4-40. DLG Category Names and Abbreviations

Long Form	Abbreviation	Prominent Features
Hypsography	HP	Elevation Lines.
Hydrography	HY	All bodies of water from oceans to streams.
Vegetative Surface Cover	SC	Trees, scrub, farms, grass lands, etc.
Non-Vegetative Features	NV	Lava, sand, gravel, etc.
Boundaries	BD	Civil boundaries, including the following: State, commonwealth, and territory; county, parish, borough, and municipal; township or minor civil division; city or incorporated place; Federal reservation; other reservation; large parks and small parks.
Survey Control and Markers	SM	Survey markers.
Roads and Trails	RD	All roads and trails.
Railroads	RR	All railroads.
Pipeline, Transmission Lines, and Miscellaneous Transportation	MT	All remaining transportation features, including airports.
Man Made Features	MS	Forts, mines, waterworks, buildings, etc.
U.S. Public Land Survey System	PL	Many individual features are recorded here including local subdivisions, survey corners, lines, and areas within public domain States.

The abbreviation for each file is a two letter code that is inserted into the filename. The rest of the filename is generally a coded set of numbers. For example, a typical hydrography file for the Fort Ticonderoga area is named 445064.HY.OPT, and a boundary file for the same area is named gs1bdf03.DO. ELV builder makes use of these abbreviations in determining what type a particular DLG file is, so you are discouraged from renaming these files.

DLG files come in a variety of scales:

- 1:24,000 scale.
- 1:62,500 scale.
- 1:63,360 scale.
- 1:100,000 scale.
- 1:2,000,000 scale.

USGS stores these data files in two different formats, the Optional format and the Spatial Data Transfer Standard (SDTS).

If the 1:100,000 Optional format DLG files are used, they may be downloaded free from the USGS website address given above. The other scale files can be purchased from the same website. The 1:100,000 files are organized into quadrangles that are 30 minutes in latitude and 60 minutes in longitude. The quadrangles are generally named after the predominant city within that quadrangle and are indexed on the USGS webs site alphabetically and by the state they are in.

The quadrangles themselves are subdivided into an East and West half. Within each half quadrangle the DLG files are once again subdivided into types. Generally there will be four files of any given type in a half of a quadrangle but some instances, where there is a large amount of data, there may be sixteen files.

4.7.1.2 Digital Elevation Model (DEM) Files

The DEM files are generated by sampling elevations at regular intervals to generate a grid of elevations. The shape and style of these grids depends on the scale of the map. The original data used for the sampling may be the physical maps (the same as those used for the DLG files), it may be from DLG files, and it may be from satellite data.

The DEM files come in a range of scales:

- 1:24,000 scale.
- 1:63,360 scale.
- 1:100,000 scale.
- 1:250,000 scale.

USGS stores these data files in two different formats. The Spatial Data Transfer Standard (SDTS) format is currently not supported by the AAM suite of tools. The other format is known as the "Optional" format. Only the 1:250,000-scale files are available from USGS for free, but all scale versions of these files are available for a nominal fee.

If the 1:250,000 DEM files are used, they may be downloaded directly from the USGS website address given above. Each file covers an area 1 degree of latitude by one degree of longitude in extent. They are generally named after the predominant city within that area and are indexed on the USGS webs site alphabetically and by the state they are in.

4.7.1.3 ESRI ASCII Files

ESRI ASCII format files are ASCII files that can be used to export data out of an ESRI product, such as ArcInfo. The file has no scale identification in it and great care must be taken when using these types of files.

The ESRI ASCII format stores data in a regular grid where the height and width of each grid cell is the same. The lower left corner of the study area is the only coordinate given in the file and all subsequent locations are based on that corner.

For AAM, the ESRI ASCII file must store the lower left corner and the grid cell size in decimal degrees. The altitude must be stored in meters relative to the mean sea level (MSL). Also, the

longitude should be negative for the southern sphere and the latitude should be negative for the western sphere.

4.7.1.4 Digital Terrain Elevation (DTED) Files

DTED files are created by the National Imagery and Mapping Agency (NIMA), part of the DOD. DTED files store elevation data in regular grids based on a geographic (Latitude and Longitude) system. The data is used by the elevation-file builder by first converting it to UTM 84. For a more detailed description of DTED files and the levels of detail available, consult the NIMA online documentation at http://www.nima.mil/publications/ specs/printed/DTED/ DTED_1-2.html.

4.7.1.5 USGS National Elevation Dataset (NED) Files

The USGS National Elevation Dataset consists of a high- resolution, merged, seamless set of raster format elevation data files with 1:24,000 scale Digital Elevation data. The data is based on the NAD 83 horizontal datum. NED is updated bimonthly incorporating the best available information. Currently this dataset contains seamless coverage for the continental U.S. in 1 arc-second resolution with some areas of 1/3 arc-second resolution.

4.7.1.6 Digital Feature Attribute Data (DFAD) File

The attribute data file is a comma separated values file which contains the ground resistivity for various types of ground cover found in military Digital Feature Attribute Data (DFAD) files. An itemization of the assigned standard values is given in Table 4-38.

If the user desires to modify the impedance data file, the format is very simple. The first line lists the column headings (Code, Flow Resistivity, Description, Notes). This is followed by a blank line, followed by the data. The Code represents the DFAD feature code, the Flow Resistivity is an estimate of that type of feature, the Description is the text description of the feature, and the Notes are simply a way for the user to add additional information.

This file may be edited by adding, changing, or subtracting elements from it, but it must maintain the same format and filename.

4.7.2 Coordinate Systems

The data stored in these files comes in a variety of formats. The ELVBuilder is designed to deal with all of the different formats, but it is useful to understand how the data can be stored and what impact it can have on the case.

One of the ever-present difficulties in dealing with maps is that the maps must project a round object (the earth) onto a flat piece of paper. Identifying where a point is on the globe requires that everyone interested in that location understands exactly how that projection was implemented.

There are several ways to represent the globe in two dimensions, and two of the most commonly used ones are Geographic (latitude and longitude) and Universal Transverse Mercator (UTM).

4.7.2.1 Latitude and Longitude

The most commonly used coordinate system today is the Geographic system (latitude and longitude). Lines of constant latitude run parallel to the equator from north to south while lines of constant longitude (call meridians) run perpendicular to the latitude lines and converge at the poles.

Overall, latitude and longitude is a coordinate system composed of parallels of latitude and meridians of longitude. Both divide the circumference of the Earth into 360 degrees, which are further subdivided into minutes and seconds. In geographic coordinate systems like latitude and longitude, the distance covered by a degree of longitude differs as you move towards the poles. Therefore, calculations used to measure distance and calculate area using latitude and longitude coordinates can become quite involved. In order to make analysis easier to use a projected Cartesian coordinate system such as Universal Transverse Mercator is often used.

Table 4-41. DFAD Attributes and Impedances

Code	Flow Resistivity	DFAD Description	Notes
325	225	Athletic Field	Grass
334	30000	Artificial Mountain	Concrete
706	30000	Airport Runways and Taxiways	Concrete
707	30000	Aircraft Parking Area	Concrete
830	30000	Open Storage	Concrete
862	30000	Vehicle Storage Area	Concrete
863	30000	Vehicle Parking Area	Concrete
864	650	Aircraft Storage Area	Dirt
865	225	Ship Storage Area	Water or Dirt
901	650	Ground surface	Dirt
902	650	Soil	Dirt
906	1650	Sand/Desert	Sand
907	1650	Sand Dunes	Sand
908	90000	Marsh/Swamp	Water/Dirt
909	100000	Rice Paddies	Water
910	30000	Smooth, Solid Rock	Rock
911	30000	Boulder Field/Lava	Rock
912	30000	Rocky, Rough Surface	Rock
913	5000	Dry Lake	Packed Dirt
914	90000	Mud/Tidal Flats	Water/Dirt
915	1650	Islands	Sand
930	1000000	Salt Water	Water
931	1000000	Salt Water, Sea State	Water
932	1000000	Salt Water, Sea State, Subject to Ice	Water
933	1000000	Salt Water, Subject to Ice	Water
934	100000	Salt Pans	Water
940	1000000	Fresh Water (General)	Water
941	10000000	Fresh Water, Sea State	Water
942	1000000	Fresh Water, Sea State, subject to Ice	Water
943	1000000	Fresh Water, Subject to Ice	Water
950	40	Vegetation (General)	
951	50	Orchards/Hedgerows	Trees
952	60	Deciduous Tress	Trees
953	60	Evergreen Trees (Including Nipa Palm and Mangrove)	Trees
954	60	Mixed Trees (Deciduous and Evergreen)	Trees
955	225	Tundra	Grass
956	200	Vineyards	
960	20000	Snow/Ice Areas (General)	Packed Snow
961	20000	Permanent Snow	Packed Snow
962	90000	Permanent Snow, Glacier/Ice Cap	Ice
963	90000	Pack Ice (Temporary)	Ice or Water
964	90000	Polar Ice Pack (Permanent)	Ice
965	90000	Pack Ice (Temporary)	Ice or Water
966	90000	Pack Ice (Temporary)	Ice or Water
967	90000	Pack Ice (Temporary)	Ice or Water

4.7.2.2 Universal Transverse Mercator (UTM)

The Universal Transverse Mercator (UTM) grid system divides the earth into 60 zones, each covering 6 degrees of longitude. Each zone is represented by a rectangular grid. Points in the zone are represented by Cartesian coordinates referenced to an origin at the intersection of the central longitude line (called the central meridian) and the equator. UTM zones are numbered 1 through 60, starting at the International Date Line, and proceed eastward. The zones extend from 80° S to 84° N. There are special UTM zones between 0 degrees and 36 degrees longitude above 72 degrees north latitude and a special zone 32 between 56 degrees and 64 degrees north latitude.

Each UTM zone is based upon the Transverse Mercator projection. This is a type of cylindrical projection that can be placed to intersect at a chosen central meridian. The strength of a Transverse Mercator projection lies in its ability to minimize distortion of scale and distance, and with a separate projection for each UTM zone, a high degree of accuracy is possible.

UTM grid coordinates are expressed as a distance in meters to the east, referred to as the "easting," and a distance in meters to the north, referred to as the "northing." Easting values are measured from the central meridian. The central meridian, the middle longitude line in the zone, is assigned an easting value, called a false easting, of 500,000 meters. This assures that there are no negative coordinate values in a zone. Grid values to the west of the central meridian are less than 500,000 meters and to the east, more than 500,000 meters. If an area of interest extends beyond the boundaries of a given zone, the coordinates of one zone can be transposed and represented in another zone, up to half the width of a zone (3 degrees of longitude).

Northing values are measured from the equator. For locations north of the equator the equator is assigned the northing value of 0 meters. To avoid negative numbers, locations south of the equator are made with the equator assigned a value, called false northing, of 10,000,000 meters.

Whenever the coordinate system and projection of a map are cited its datum must also be specified. A datum is a set of constants that specify the coordinate system used for calculating coordinates of points on the Earth. There is no perfect projection or datum. All map projections represent tradeoffs between different types of distortion. Selecting a projection requires consideration of several factors, one of which is the intended use of the map. Some distortions of shape, distance, direction, scale, and area always result from the type of projection and datum chosen.

- Universal Transverse Mercator in the World Geodetic System (WGS) 84 datum has been chosen as the default system.
- This system is widely used, often built into commercial navigation systems, and has a one-to-one correspondence to latitude and longitude. It provides a local cartesian system.

Regardless of what format the input files may have, ELVBuilder converts all coordinates into UTM84. For example, many DEM maps store the elevation data in a Geographic coordinate system based on an earlier data (called NAD 27). It is important to understand this for exportation of data or if data files are used which do not have an explicit reference (like ESRI ASCII files).

4.7.3 Ground Elevation and Impedance File Format

Both .ELV and .IMP files are in NMBGF 1.0 format.[15] Keywords listed in Table 4-41 are recognized. Each keyword must be followed by the appropriate user data. Metric MTRC types Zalt and Flow and the associated keywords ZALT and FLOW are used in the .ELV and .IMP files, respectively. The ZALT keyword indicates a grid of terrain elevation data, and the units must correspond to the signal unit keyword contained in the file (FEET and METR). Flow Resistance grid values are expected to be input in CGS Rayls as itemized in Table 3-17. Acoustically soft ground has a normal value of 200 and acoustically hard ground, 10,000 or greater. Additional detail regarding the NMBGF format may be found in Reference 15.

Table 4-42. .ELV and .IMP Keyword Usage

Keyword	ELV	IMP
TITL	•	•
CASE	•	•
DECM	•	
FLOT	•	•
UTMZ	•	•
USER	•	•
NINJ	•	•
FEET	•	•
METR	•	•
DIDJ	•	•
IRJR	•	•
MTRC	•	•
ZALT	•	
FLOW		•
XRYR	•	
ENDF	•	•

Note: MTRC must be followed by Zalt for terrain files and Flow for impedance files.

Sample .IMP files are provided for uniform soft and hard ground. These .IMP files can be used with any .ELV file. It is not necessary, therefore, to prepare .IMP files unless ground impedance varies.

4.8 FlattenELV

The FlattenELV program reduces all of the terrain data in a specified .ELV file to a user-specified uniform height. The user specifies the desired ground altitude. The default is 100.0 ft MSL. The grid size, spacing and dimensions are not modified. To run FlattenELV from the command prompt:

FlattenELV controlfile.FE

The control file format is described in Table 4-42.

Table 4-43. FlattenELV Control File Format

Line	Position	Max Length	Description
1	1	A1024	Input filename
2	1	F10.5	Desired output elevation

4.9 IMPchanger

The IMPchanger program reads in a user-specified impedance (.IMP) file and creates a new output (.IMP) file with a uniform impedance (flow resistivity) value as defined in the input control file. To run IMPchanger from the command line:

IMPchanger controlfile.IC

The content of the control file (.IC) is defined in Table 4-43.

Table 4-44. IMPchanger Control File Format

Line	Position	Max Length	Description
1	1	A1024	Input filename
2	1	F10.5	Desired output elevation

4.10 NCDUMP

The NCDUMP utility outputs an ASCII file representation of the NetCDF file to the standard output device. The output is organized so that the user can browse the names, dimensional size, attributes, and the data values for all of the variables. NCDUMP is a utility that comes with the standard distribution of the NetCDF software provided by the Unidata Program Center[26]. The executable module is included with the software distribution.

To use NCDUMP type the program name followed by the name of the NetCDF file. For example

NCDUMP CH53E004.nc

will display on the console terminal the contents of the CH53E004.nc file. The contents of the file may be redirected to a file by typing

NCDUMP CH53E004.nc > CH53E004_NC.TXT

where CH53E004_NC.TXT is the name of an output text file and may include the path. The default format used for each type of variable can be overridden by invoking one of several optional switches.

NCDUMP [-c | -h] [-v var1,…] [-b lang] [-f lang] [input filename]

where:

-c Shows the values of the variables (XYZ, PHI, THETA, and FREQUENCY) as well as the declaration of all dimensions, variables, and attribute values. Data values are not included with the output.

-h Shows only the header information in the output. The output will contain the declaration of the NetCDF dimensions, variables, and attributes of the input file. Data values are not included with the output.

-v Outputs the values of the variables, in addition to the header information. The variable name must be included with the optional switch.

-b lang Output contains the data for multidimensional variables (pressure and phase) in a form that shows the indices used for storing and retrieving the data. If the "-b F" switch is invoked, the output follows the FORTRAN convention (indices starting at 1, first dimension varying fastest) and if the "-b C" switch is specified the output follows the C language convention (indices starting at zero, last dimension varying fastest).

-f lang Similar to the -b switch with the exception that there is full annotation of the variable indices. If the "-b F" switch is invoked the output follows the FORTRAN convention (one-based indices, first dimension varying fastest) and if the "-b C" switch is specified the output follows the C language convention (zero-based indices, last dimension varying fastest).

4.11 PLT2ELV

PLT2ELV takes an ASCII Tecplot file and builds a binary elevation (.ELV) file or impedance (.IMP) file. To run from the comman line:

PLT2ELV filename.P2E

where filename.P2E is the PLT2ELV control file containing the information in Table 4-44.

Table 4-45. PLT2ELV Control File Format

Line	Position	Max Length	Description
1	1	A1024	Input filename
2	1	A1024	Output filename
3	1	I1	Operation mode (0 = .ELV output, I = .ELV input)

4.12 POI2MIC

The POI2MIC program reads in a specific point of interest (.POI) time history file containing multiple receiver points, and creates a single time history file in the microphone format specified by the ART program. This utility facilitates circular analysis and the analytical creation of microphone files. To run POI2MIC from the command line:

POI2MIC controlfile.P2M

The control file (.P2M) contents and structure are defined in Table 4-45.

Table 4-46. POI2MIC Control File Format

Line	Position	Max Length	Description
1	1	A1024	POI input filename
2	1	A1024	MIC filename root
3	1	I3	MIC filename 3-digit run number extension

4.13 RAZ2PLT

The RAZ2PLT utility is a tool which reads in a binary weather .RAZ file and creates an ASCII Tecplot output file. These results include, for each receiver mesh point and for each source height, the spectral propagation result (dB as a function of frequency). To run RAZ2PLT from the command line:

RAZ2PLT controlfile.R2P

The control file (.R2P) contents and structure are defined in Table 4-46.

Table 4-47. RAZ2PLT Control File Format

Line	Position	Max Length	Description
1	1	A1024	Input .RAZ filename
2	1	A1024	Output .PLT filename

4.14 RAZSUBTRACT

The RAZSUBTRACT utility allows one to determine the difference between two .RAZ weather grid files. Both files must contain the same grid dimensions, grid spacing, receiver height, and source heights. These are contained in the .RAZ file header and are verified by the program. The difference between the two files is calculated and put in an output ASCII Tecplot file. To execute RAZSUBTRACT from the command line:

RAZSUBTRACT controlfile.R2S

The format of the control file (.R2S) is given in Table 4-47.

Table 4-48. RAZSUBTRACT Control File Format

Line	Position	Max Length	Description
1	1	A1024	Input .RAZ filename
2	1	A1024	Input .RAZ file to be subtracted
3	1	A1024	Output .PLT filename

4.15 RNMwea

AAM includes an atmospheric pre-processor module, RNMwea, which contains algorithms to compute the effects of a horizontally stratified atmosphere with winds on atmospheric sound propagation.[11,12] The computational model, in turn, applies the RNMwea to calculated spectral (one-third octave band or narrow band) variation at each receiver point. The detailed curved ray propagation is performed in the RNMwea pre-processor over a mesh of receiver points for a range of source heights and a specified atmosphere. The gridded ground mesh of interest is used along with an omnidirectional source, to determine the effect of the atmosphere at each mesh point.

During execution this weather effect is applied to the individual receiver points for the particular geometric combination. This allows for rapid inclusion of weather effects including zones of silence without a significant increase in computational run time. At present the curved ray weather algorithms apply only over flat terrain, for single event analyses and for one-third octave band or narrow band sources. A technical description of the physics contained in this RNMwea module can be found in Chapter 2.

4.15.1 RNMwea Input File Description

The weather module (RNMwea pre-processor) is a program run from the command line using an ASCII input deck, in much the same manner as AAM is executed. The following sections describe the structure of the input and output files and the meaning of the various parameters.

Two input files are referred by the weather module, RNMwea. The first is an input file which describes grid and analysis related parameters. The second is a weather file which describes the atmospheric information, such as altitude, temperature, pressure, and winds.

The weather module is run from the Windows command prompt, similar to the manner in which AAM is executed. The input parameter filename specified on the command line:

RNMwea filename.INP

Filename.INP is the 256-character input parameter file and pathname. Included in this input file is the name of the output atmospheric profile file.

The output created by RNMwea will be a binary atmosphere file with the .RAZ extension. The name of the output file will be the same prefix as the weather (.WEA) file identified on the first line of the .INP file.

A sample file is pictured in Figure 4-9, and the structure of the weather parameter input file is described in Table 4-48.

```
RNOavg.WEA          Weather profile definition input file xxxxxxxx.WEA
16000.              rangegrid (Ft)
250.                gridresol (Ft)
250.                resolution (Ft)
5.000               hr (Ft)
31                  Number of frequencies (use 31=standard 1/3 OB # 10-40)
200.                flores (Chessel)
1                   letsbounce (1=yes, 0=None)
0.                  turbcst (ground turbublence, Chessell, 0=none)
2                   nalt (number of altitudes to consider, list follows, minimum=2)
32.8                hs (Ft) List of nalt source heights
100.
```

Figure 4-9. Weather Parameter Input File

Table 4-49. Weather Parameter Input File Structure

Line	Position	Max Length	Description
1	1	A256	Path and filename of the atmospheric profile file.
2	1	F38	Grid range in ft. This distance on each side of the source will be the final mesh size.
3	1	F38	Grid resolution (ft) to be used for the ground mesh.
4	1	F38	Resolution. X-Y plane separation interval (ft) between ray impacts on the ground. Should be approximately equal to grid resolution.
5	1	F38	Receiver height (ft).
6	1	I10	Number of frequencies to be calculated. If the standard frequencies are to be used, set this to 31 and bands 10-40 (10 Hz – 10,000 Hz inclusive) will be calculated. For any other value, repeat line 7 once for each frequency. These must match the AAM source frequency bands.
7	1	F38	Frequency (Hz).
8	1	F38	Flow resistivity – specific flow resistance per unit thickness for the ground (based on Chessell).
9	1	I10	Letsbounce flag to control multiple reflections of rays at the ground (0 = no bounce, 1 = bounces calculated).
10	1	I10	Turbcast. Constant measure of the turbulence level near the ground (see Chessell).
11	1	I10	Number of source heights to calculate weather effects.
12	1	F38	Source height (ft). Repeat this line once for each height specified on line #11.

Notes: (1) Line 7 should be repeated once for each frequency stated in line 6.
(2) Line 12 should be repeated once for each source height stated in line 11. Although RNMwea will create an output .RAZ file containing only one output source height altitude. AAM requires a minimum of two for interpolation.
(3) Source heights must monotonically increase.

The RNMwea input file (.INP) specifies on the first line an atmospheric profile to be used. An example .WEA file is shown in Figure 4-10 and itemized in Table 4-49. The metric weather profile units are used instead of the standard AAM units to facilitate the use of typical weather station reports.

```
Weather average from rno 1 to 8760
    1             25
   0.0  86.73 284.110.00637152    0.00000    0.00000    1.06495
  24.0  86.23 284.520.00626900    0.47977   -0.42978    1.05717
  46.0  85.98 284.620.00611488    0.30075   -0.36209    1.05375
 225.0  83.97 283.260.00525749    1.64414   -1.11102    1.03391
 430.0  81.71 281.580.00462496    2.38024   -1.55440    1.01211
 533.0  80.59 280.770.00438725    2.76852   -1.80765    1.00117
 872.0  77.02 278.350.00382468    3.51573   -2.40815    0.96509
 981.0  75.90 277.600.00368442    3.71447   -2.63397    0.95366
1046.0  75.24 277.160.00360395    3.84395   -2.79594    0.94688
1117.0  74.53 276.680.00352312    3.95379   -2.99848    0.93954
1169.0  74.02 276.330.00346618    4.02527   -3.15510    0.93418
1299.0  72.74 275.470.00333020    4.14683   -3.51295    0.92092
1598.0  69.89 273.480.00303081    4.32736   -4.41064    0.89117
1881.0  67.28 271.600.00274990    4.43038   -5.33022    0.86385
2190.0  64.55 269.550.00244640    4.42798   -6.25751    0.83502
2383.0  62.90 268.270.00225927    4.43972   -6.89792    0.81752
2434.0  62.46 267.930.00221039    4.44344   -7.06675    0.81290
2487.0  62.02 267.580.00215949    4.44103   -7.22253    0.80824
2825.0  59.27 265.340.00183578    4.45046   -8.17849    0.77888
2834.0  59.20 265.280.00182717    4.45350   -8.20166    0.77812
3207.0  56.31 262.800.00147286    4.57655   -9.18507    0.74703
3407.0  54.81 261.480.00128420    4.62120   -9.73637    0.73084
3505.0  54.10 260.820.00119236    4.62124  -10.02323    0.72310
4058.0  50.22 257.170.00067902    4.93655  -11.44348    0.68078
4238.0  49.00 255.970.00051446    5.23311  -11.84146    0.66746
```

Figure 4-10. Weather Module (.INP) Sample Atmosphere File

Table 4-50. Weather Module (.WEA) Atmospheric Profile File Description

Line	Position	Max Length	Description
1	1	A7	Weather – These first 7 characters must appear. The remainder of the line may be used for documentation.
2	1 2	I 10 I 10	Time frag (not used). Number of altitudes in the specified profile.
3	1 2 3 4 5 6 7	F38 F38 F38 F38 F38 F38 F38	Altitude (meters). Pressure (kPa). Temperature (°K) Water mole fraction. Wind speed in X (m/s). Wind speed in Y (m/s). Density (kg/m^3).

Note: (1) Line 3 must be repeated once for each altitude specified on line (2).
(2) Altitudes must monotonically increase.

4.16 SPHERE

The SPHERE program outputs an ASCII text file that may be used by Tecplot to display a three-dimensional perspective of the sound sphere.

SPHERE may be run from a Windows command line by specifying the name and path of the .NC file to be formatted:

SPHERE filename.NC

The SPHERE program will automatically create or overwrite an output file with the specified filename.NC and a .PLT extension.

Figure 4-11 is a portion of a Tecplot ASCII file output by the SPHERE computer program.

```
TITLE = "SOUND SPHERE FOR CH146, Run120 Delta ART Moose Jaw Can 6 14 98 170 10    "
VARIABLES = "X" "Y" "Z" "Overall" "A-Weighted" "C-weighted" "Phi" "Theta" "010Hz" "012Hz" "016Hz"
ZONE I=     37 J=     37
  -100.000    0.000    0.000   95.74   91.29   94.05  -90.00    0.00  73.50   75.20   70.40
   -99.619   -8.716    0.000   94.91   89.63   92.98  -90.00    5.00  73.80   74.80   69.80
   -98.481  -17.365    0.000   94.22   88.12   92.09  -90.00   10.00  74.10   74.40   69.20
```

Figure 4-11. Sample Tecplot Input Data File Format

The file header begins with the name of the sound sphere. In this example, the filename is CH146120.NC. Following the title is a list of variables. The variables X, Y and Z define the surface of a sound sphere in body fixed coordinates. Overall, A-weighted, C-weighted are the corresponding X, Y and Z sound levels. This is then followed by a listing of the one-third octave band data. The user may plot individual one-third octave bands in Tecplot. The keyword ZONE signals Tecplot that the data is (I, J) ordered.

Figure 4-12 is an example of a portion of a Tecplot ASCII file from an omnidirectional narrow band source.

```
TITLE = "SOUND HEMISPHERE Narrow band Hemisphere Data at 20 low frequencies &#0;
VARIABLES = "X" "Y" "Z" "Olvl" "dBA" "dBC" "Phi" "Theta" " 27.5Hz" " 30.5Hz" " 33.6Hz" " 36.6Hz"
ZONE I= 37 J= 37
-100.00   0.00 0.00 113.01 86.69 111.73 -90.00  0.00 100.00 100.00 100.00 100.00 ...
- 99.62 - 8.72 0.00 113.01 86.69 111.73 -90.00  5.00 100.00 100.00 100.00 100.00 ...
- 98.48 -17.36 0.00 113.01 86.69 111.73 -90.00 10.00 100.00 100.00 100.00 100.00 ...
- 96.59 -25.88 0.00 113.01 86.69 111.73 -90.00 15.00 100.00 100.00 100.00 100.00 ...
- 93.97 -34.20 0.00 113.01 86.69 111.73 -90.00 20.00 100.00 100.00 100.00 100.00 ...
```

Figure 4-12. Sample Tecplot File from an Omnidirectional Narrow Band Source

4.17 TH2MIC

The TH2MIC program reads in a spectral time history (.TH) file created by AAM run with ART keyword-enabled, and creates an ASCII output file in the ART microphone format. This utility facilitates circular analysis and the analytical creation of microphone files.

To run TH2MIC from the command line:

TH2MIC_controlfile.T2M

The format of the control file (.T2M) is given in Table 4-50.

Table 4-51. TH2MIC Control File Format

Line	Position	Max Length	Description
1	1	A1024	.TH input filename
2	1	A1024	Output microphone filename root
3	1	I3	Output microphone 3-digit filename extension (usually the run number)

4.18 TRJresampler

The computational module creates a trajectory (.TRJ) file when the VIDEO or AUDIB keywords are in use. This file contains the internal vehicle trajectory that was analyzed when creating the .TIG file output. The 3D Acoustic Visualizer requires definition of the flight trajectory in order to synchronize the vehicle motion with the sound on the receiver mesh. When video animation is created, it is the trajectory file which drives the source motion in the animation. Under certain circumstances the user might want to render a different time spacing of the flight trajectory. This may be accomplished by changing the spacing in the .TRJ file. Caution must be exercised since the acoustic calculations are not updated using the revised trajectory file. Within the animation rendering, a linear (in energy) interpolation is performed in time to obtain the receiver mesh acoustic levels. When refining the trajectory to finer time spacing without redoing the propagation calculations the visualizer results could be misleading. This utility should be used with caution.

4.19 3DVisualizer

The 3D Visualizer is a powerful tool for animating in color over 3D terrain the sound levels at the receiver points. It will display the motion of the source along the prescribed trajectory and in a synchronized time fashion based on the time history render the sound levels in color. The user has the ability to control the viewing angles and display area of interest. Options are provided to capture still images and animation videos in .AVI format. The following sections describe the various menu options available in 3DVisualizer.

4.19.1 Load a File

To load a new file for viewing, select File → Open and choose a .TIG file. The Load a File Dialog will prompt metric selections for viewing with the 3DVisualizer (Figure 4-13).

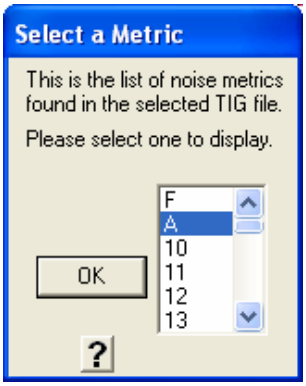

Figure 4-13. 3DVisualizer Load a File Dialog

The metrics listed are based on information contained in the .TIG file and represent different aspects of the noise. Select the metric or band of interest and press OK.

If there is a 3D model file (.3DS) study file and path specified in the .TIG file heading, it will load automatically. Then the program will render the .3DS graphic in the visualizer and animate its motion and orientation along the flight track as specified by the data contained in the trajectory (.TRJ) file.

4.19.2 Controls

The user may control the display via mouse or keyboard. For mouse control, the left button controls the position of the scene while the right button controls the rotation. For keyboard control, refer to Figure 4-14. The Shift key increases the rate of change for each of these controls.

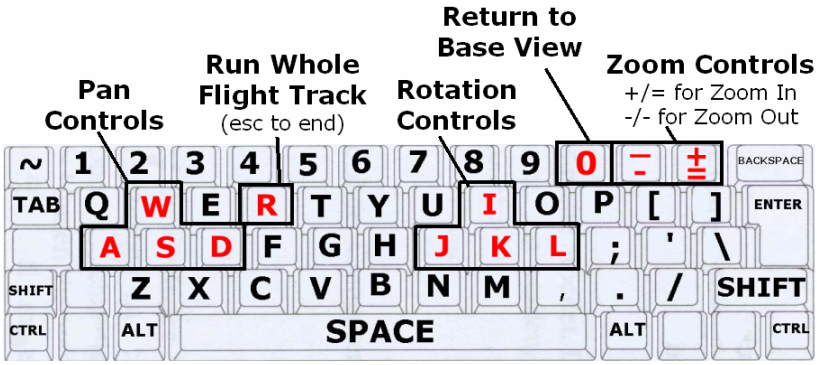

Figure 4-14. Keyboard Control Diagram

4.19.3 Contour Levels and Terrain Scale

A pop-up window contains the legend for the contour levels, as shown in Figure 4-15. To vary the color rendering, enter new levels for the upper or lower bounds (the midpoint is calculated from them), and then press Update. A second pop-up window contains a sliding terrain scale. Raising the bar increases the level of terrain magnification while lowering the bar reduces it.

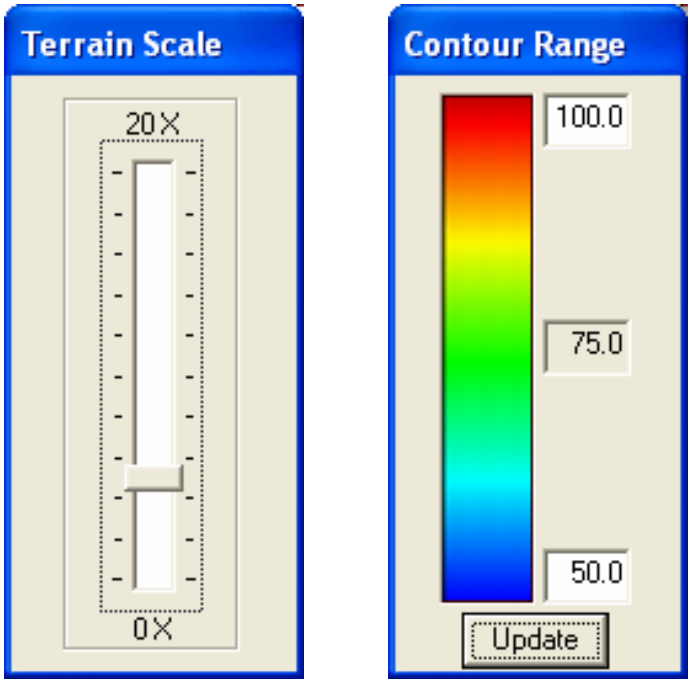

Figure 4-15. Terrain Scale and Contour Range Dialogs

4.19.4 Options

There are three different drawing options available from the menu item Options, as shown in the dialog in Figure 4-16. With this menu, the user may choose to display or hide the flight track, aircraft, or receiver sites.

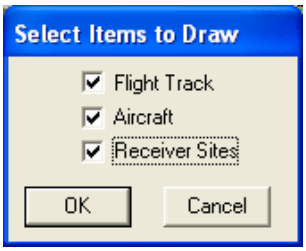

Figure 4-16. Drawing Options Dialog

The Vehicle Scale menu (Figure 4-17) allows the user to change the relative size of the vehicle as it is drawn. All of the models are stored with a size of unity, consistent with the terrain and grid units. It is often necessary to increase this size to be able to visualize the flight vehicle. The Receiver Site Size menu (Figure 4-17) allows the user to change the size of the rendered spheres located at the specific point measurement sites.

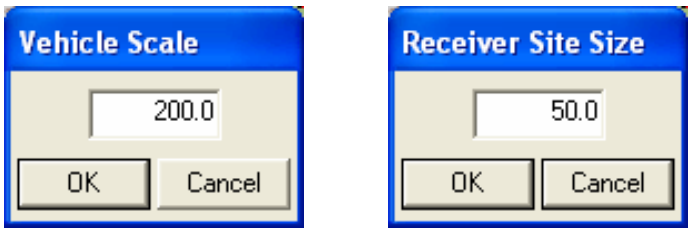

Figure 4-17. Vehicle Scale and Receiver Site Size Dialogs

4.19.5 Capturing Images and Video

The user has the option to capture either a full video or just a screen capture. The Capture → Still menu item will bring up a standard windows file select dialog. Select the file type (.BMP, .PCX, or .PNG) and specify the filename and the currently shown image will be saved to that file. The Capture → Video menu item (Figure 4-18) allows the user to select frames and frame rate of the output video file. The user will be prompted with a standard Windows dialog box to select an output video directory for the video file (.AVI). A subdirctory called *Vidcaps* will be created to store the individual phot frames used to generate the video. After the video has been created, these images are no longer needed and can be deleted.

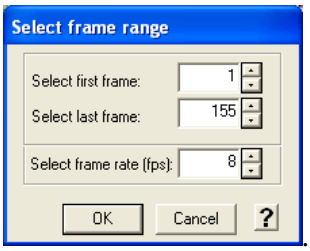

Figure 4-18. Capture Video/Select Frame Range Dialog

5.0 User Manual and Tutorials

This section contains a collection of tutorials which have been designed to help users become familiar with the basic features and capabilities of AAM. Each tutorial targets a specific analysis and function. For example a user may need to generate a time history at a point of interest, or the user may need to create an annual noise contour for a multitude of operations, or the user may need to create noise spheres from measurement data. All the files used in examples presented in the tutorials are included with the distribution software. Each tutorial is structured to include examples and additional information about the use of specific keywords and details germane to the task at hand.

The user is expected to be familiar with running programs from the Windows command prompt and be familiar with the basic functionality of a text editor such as Notepad or WordPad for Windows based systems, or VI or pico for Linux systems. SinceAAM is a collection of programs, most of which are run from the command line, all users are encourage to start with the tutorial "Basic Setup of the Environment" (Section 5.1).

5.1 Basic Setup of the AAM Environment

To run these examples, the env.bat file provided in the tutorial directory must be edited so that the location of the bin directory is set in PATH and the NCFILES directory is indicated in the ROTOR_NOISE and FWING_NOISE keyword of the command-prompt session.

If installation was to the default directory, then the env.bat file should look like this:

```
Set PATH=c:\AAM\bin;%path%
Set ROTOR_NOISE=c:\AAM\NCFILES
```

To launch a command-prompt session, which sets the environment variables on a PC, double-click on the Cmd.EXE file. It contains the following command line which launches a command-prompt session that runs the env.bat file.

```
Cmd /k env.bat
```

An alternative method is to create a batch file that contains the environment settings, applicable to the current program execution only. A sample listing of such elements that may be added to the top of a batch file is given below.

```
Set rotor_Noise=c:\AAM\ NCFILES
Set path = c:\AAM\bin;%path%
```

In order for AAM to run, it must first have a noise file located in the directory that has been designated with the ROTOR_NOISE or FWING_NOISE keyword.

5.2 NMPlot Single Event Noise Contour (noisecon.INP)

The section listed below provides detailed instructions for running a sample input case for obtaining a noise contour for a single event. The contour calculated in the following section is A-weighted sound exposure level (SELA). The Figure 5-1 below shows a NMPlot single event noise grid as calculated for a single helicopter operation. The basic steps involve creating an input file with the COMPUTEGRD keyword. The example input file is shown below in Figure 5-2. The helicopter is flying in a southwesterly direction, accelerating from 40 knots to 116 knots.

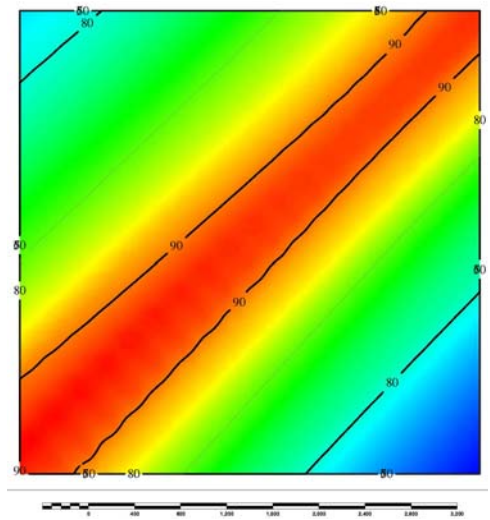

Figure 5-1. NMPlot Single Event Noise Contour (SELA) as Calculated by AAM (noisecon)

COMPUTEGRD signals signals the creation of an output GRD file in NMBGF20 format. Possible metrics are created by including any of following in the input deck (SEL, SELA, SELC, LMAX, EPNL, DNL, CNEL, NEF, and WECPNL). Multiple metrics may be included, one per line if needed. For this particular example The grid spacing and extent are defined and input via the keyword SETUP PARA

```
REM  Tutorial noisecon.inp Single event .GRD contour file
COMPUTEGRD
SELA
SETUP PARA
       100       100        5.
     -2000     -2000        0.
      2000      2000
        90     50000       200
CH146
1
      0.00      0.00      0.00
0
0
ONE TRACK
Southwesterly Accelerating flight
2
   7000.00   7000.00     750.     0.00     0.00      40.0     0.00     0.00     0.00    90.00
  -7000.00  -7000.00     750.     0.00     0.00     116.0     0.00     0.00     0.00    90.00
END
```

Figure 5-2. COMPUTEGRD Keyword Input File (noisecon.INP)

To obtain the noise contour, run AAM from command prompt.

C:\AAM\Projects\Tutorials>AAM noisecon.inp

AAM will create an output with a same prefix as the input file with a .GRD extension in the same directory as the input file. This grid file (.GRD) may be displayed using NMPlot as shown in Figure 5-1. Additional output generated includes the primary .TXT file. Itemized in this file is a listing of the source noise data files that were used in the contour calculations. A portion of the primary output (.TXT) file is given in Figure 5-3.

```
NETCDF FILES USED IN THE CALCULATIONS
Number Filename      Flight-   Pylon     Speed
                     Path-     Angle    (Knots)
                     Angle    (Degrees)
                    (Degrees)
11       ch146120      0.0      90.0       78.
12       ch146105      0.0      90.0       98.
13       ch146101      0.0      90.0       99.
14       ch146170      0.0      90.0      100.
15       ch146104      0.0      90.0      102.
16       ch146194      0.0      90.0      102.
17       ch146117      0.0      90.0      119.
```

Figure 5-3. "NETCDF FILES USED" Segment of Primary Output (.TXT) File

5.3 Tecplot ASCII Grid File (.PLT) Single Event Noise Contour

This section provides detailed instructions for running a sample input case for the purpose of obtaining a Tecplot ASCII Grid file for a single event. The LMAXA contour is shown in Figure 5-4 below. The critical keyword for creating a Tecplot ASCII Grid file single event noise contour is COMPUTEPLT (Figure 5-5). An illustration of the flight track is given in Figure 5-6. Also illustrated in the example is the DIAGNOSTICS keyword. This triggers generation of additional output in the .TXT file, including the detailed trajectory with time increments, as shown in Figures 5-7 and 5-8.

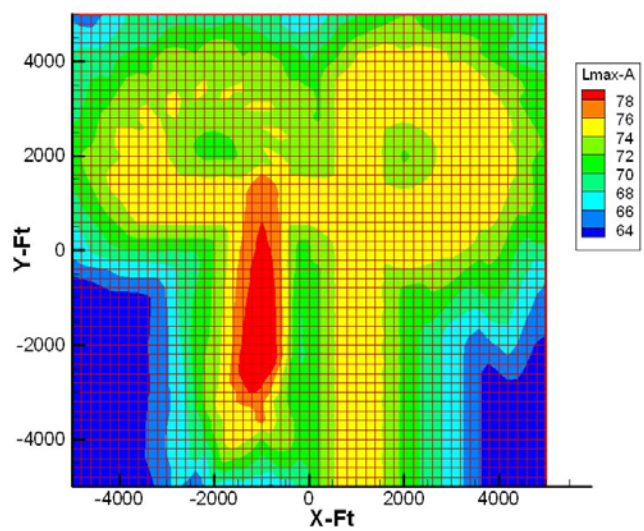

Figure 5-4. LMAXA Single Event Noise Contour

```
COMPUTEPLT
DIAGNOSTICS
SETUP PARA
       200       200       500
     -5000     -5000         5
      5000      5000
        60     30000    100000
CH146
1
   0.00   0.00  0.00
0
0
ONE TRACK
Run 001

   1000.00  -9000.00   1000.00     0.00      0.00   100.00    0.00     0.00     0.00     90.00
   1000.00  -8000.00   1000.00     0.00      0.00    90.00    0.00     0.00     0.00     90.00
   1000.00   2000.00   1000.00   270.00   1000.00    90.00    0.00     0.00     0.00     90.00
   2000.00   1000.00   1000.00     0.00   1000.00    90.00    0.00     0.00     0.00     90.00
  -2000.00   1000.00   1000.00   270.00   1000.00    90.00    0.00     0.00     0.00     90.00
  -1000.00   2000.00   1000.00     0.00      0.00    50.00    0.00     0.00     0.00     90.00
  -1000.00  -2000.00    600.00     0.00      0.00    50.00    0.00     0.00     0.00     90.00
END
```

Figure 5-5. COMPUTEPLT and DIAGNOSTICS Keyword Input File (pretzel.INP)

To create a noise contour from the command prompt:

C:\AAM\Projects\Tutorials> AAM pretzel.inp

This will create an output with a same prefix as the input file with a .PLT extension in the same directory as the input file. COMPUTEPLT signals the creation of a Tecplot format output file containing a grid of equally spaced points. At each (x,y,z) point in the earth-fixed coordinate system, the A-weighted SEL, the C-weighted SEL, the A-weighted maximum sound level and the EPNL are output. The output file will have the same prefix as the input filename with the .PLT extension. Open the .PLT file in Tecplot and select the desired level to view. Figure 5-4 shows a 2-D view of a LMAXA. A portion of the .PLT file is shown in Figure 5-8.

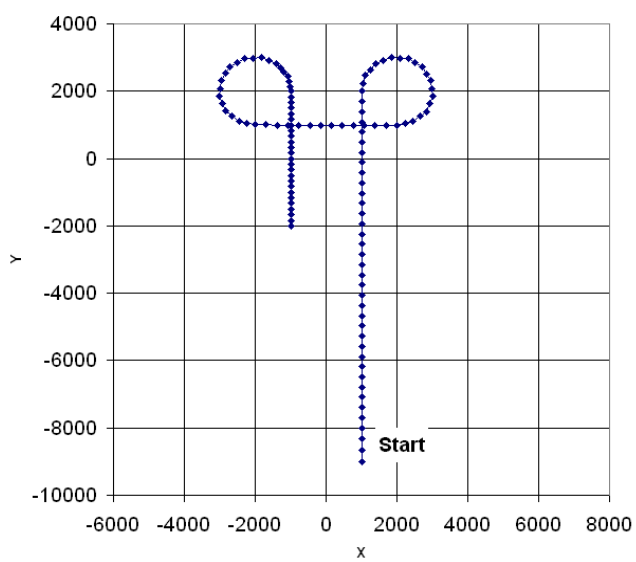

Figure 5-6. Example Flight Track (pretzel)

Interpolated Track for analysis 116 points

time	Xft	Yft	Z-MSL	ang	rad	spd	yaw	attack	roll	nacl	beta	gamma	EulCalc	QSAM
0.0000	1000.00	-9000.00	1000.00	0.00	0.00	100.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
2.0789	1000.00	-8654.97	1000.00	0.00	0.00	96.67	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
4.1579	1000.00	-8321.64	1000.00	0.00	0.00	93.33	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
6.2368	1000.00	-8000.00	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
8.2317	1000.00	-7696.97	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
10.2267	1000.00	-7393.94	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
12.2216	1000.00	-7090.91	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
14.2165	1000.00	-6787.88	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
16.2115	1000.00	-6484.85	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
18.2064	1000.00	-6181.82	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
20.2013	1000.00	-5878.79	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
22.1963	1000.00	-5575.76	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
24.1912	1000.00	-5272.73	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
26.1861	1000.00	-4969.70	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
28.1811	1000.00	-4666.67	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
30.1760	1000.00	-4363.64	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
32.1709	1000.00	-4060.61	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
34.1659	1000.00	-3757.58	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
36.1608	1000.00	-3454.55	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
38.1557	1000.00	-3151.51	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
40.1507	1000.00	-2848.49	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
42.1456	1000.00	-2545.45	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
44.1405	1000.00	-2242.42	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
46.1354	1000.00	-1939.39	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
48.1304	1000.00	-1636.36	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
50.1253	1000.00	-1333.33	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
52.1202	1000.00	-1030.30	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
54.1152	1000.00	-727.27	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
56.1101	1000.00	-424.24	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
58.1050	1000.00	-121.21	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
60.1000	1000.00	181.82	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
62.0949	1000.00	484.85	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
64.0898	1000.00	787.88	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00
66.0848	1000.00	1090.91	1000.00	0.00	0.00	90.00	0.00	0.00	0.00	90.00	90.00	0.00	0	0.00

Figure 5-7. "Interpolated Track for Analysis" Segment of Primary Output (.TXT) File

```
TITLE = "Integrated Noise Metrics  pretzel.inp"
VARIABLES = "X-Ft" "Y-Ft" "Z-Ft-MSL" "SEL-unwt"     "SEL-A"      "SEL-C"         "Lmax-A"      "EPNL"
ZONE I=     51 J=     51
           -5000.   -5000.        0.       88.59       74.96        87.03          57.69       77.37
           -4800.   -5000.        0.       88.76       75.42        87.18          58.36       77.72
           -4600.   -5000.        0.       88.95       75.88        87.35          59.07       78.00
           -4400.   -5000.        0.       89.15       76.36        87.54          59.82       78.57
           -4200.   -5000.        0.       89.37       76.86        87.74          60.57       79.25
           -4000.   -5000.        0.       89.58       77.31        87.94          61.37       79.71
           -3800.   -5000.        0.       89.80       77.73        88.14          62.05       80.01
           -3600.   -5000.        0.       90.01       78.11        88.34          62.76       80.36
           -3400.   -5000.        0.       90.24       78.46        88.55          63.44       80.68
           -3200.   -5000.        0.       90.47       78.78        88.77          64.30       80.96
           -3000.   -5000.        0.       90.71       78.99        88.98          65.46       80.99
```

Figure 5-8. Portion of Tecplot ASCII (.PLT) File (pretzel)

5.4 Detailed Time History at Points of Interest (poitime)

This section provides instructions for obtaining a detailed time history at Points of Interest for a single event. Figure 5-9 below shows a Time History plotted in Tecplot. The keyword required to create a time history at points of interest is COMPUTEPOI. A helicopter is flying in southwest direction while accelerating.

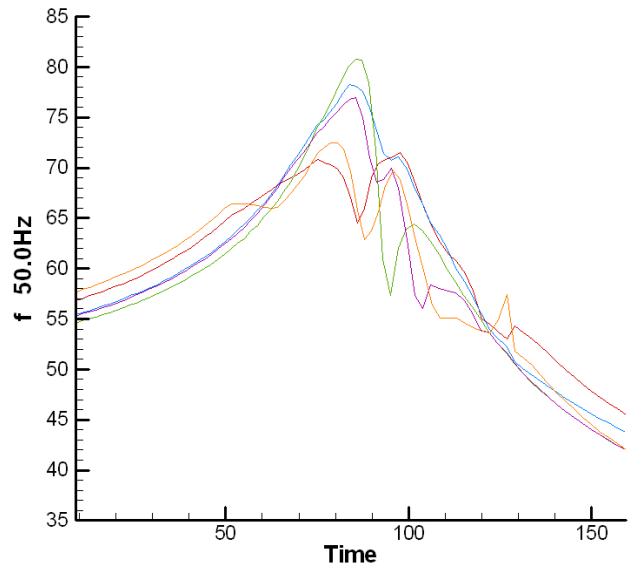

Figure 5-9. Spectral Time History (50 Hz) for Five Points of Interest (poitime)

The input file (Figure 5-10) illustrates the use of the COMPUTEPOI keyword for creation of detailed time history data at five microphone locations. COMPUTEPOI triggers the creation of a detailed time history Tecplot file as well as series of sound rankings at points of interest for multiple flight track analyses.

```
REM  AAM Tutorial poitime.inp Single event .POI time history file
COMPUTEPOI
SETUP PARA
       100       100       5.
     -2000     -2000       0.
      2000      2000
        90     50000       200
CH146
1
      0.00      0.00      0.00
0
0
ONE TRACK
Southwesterly Accelerating flight
2
   7000.00   7000.00     750.     0.00     0.00      40.0     0.00     0.00     0.00    90.00
  -7000.00  -7000.00     750.     0.00     0.00     116.0     0.00     0.00     0.00    90.00
POI
5
Mic1 -1000.0   1000.0      5.0
Mic2  -500.0    500.0      5.0
Mic3     0.0      0.0      5.0
Mic4   500.0   -500.0      5.0
Mic5  1000.0  -1000.0      5.0
END
```

Figure 5-10. COMPUTEPOI Keyword Sample Input File (poitime)

Run AAM from the command prompt:

C:\AAM\Projects\Tutorials> AAM poi.inp

This will create output in the same directory as the input file. Contained within the main text output file will be an ASCII graphic of the time history at the points of interest (See Figure 5-11). The time history detailed output file will have the same prefix as the input file and a .POI extension. This .POI file is ASCII and may be viewed with a text editor (Figure 5-12). One should note that the detailed spectral time history is included in this file.

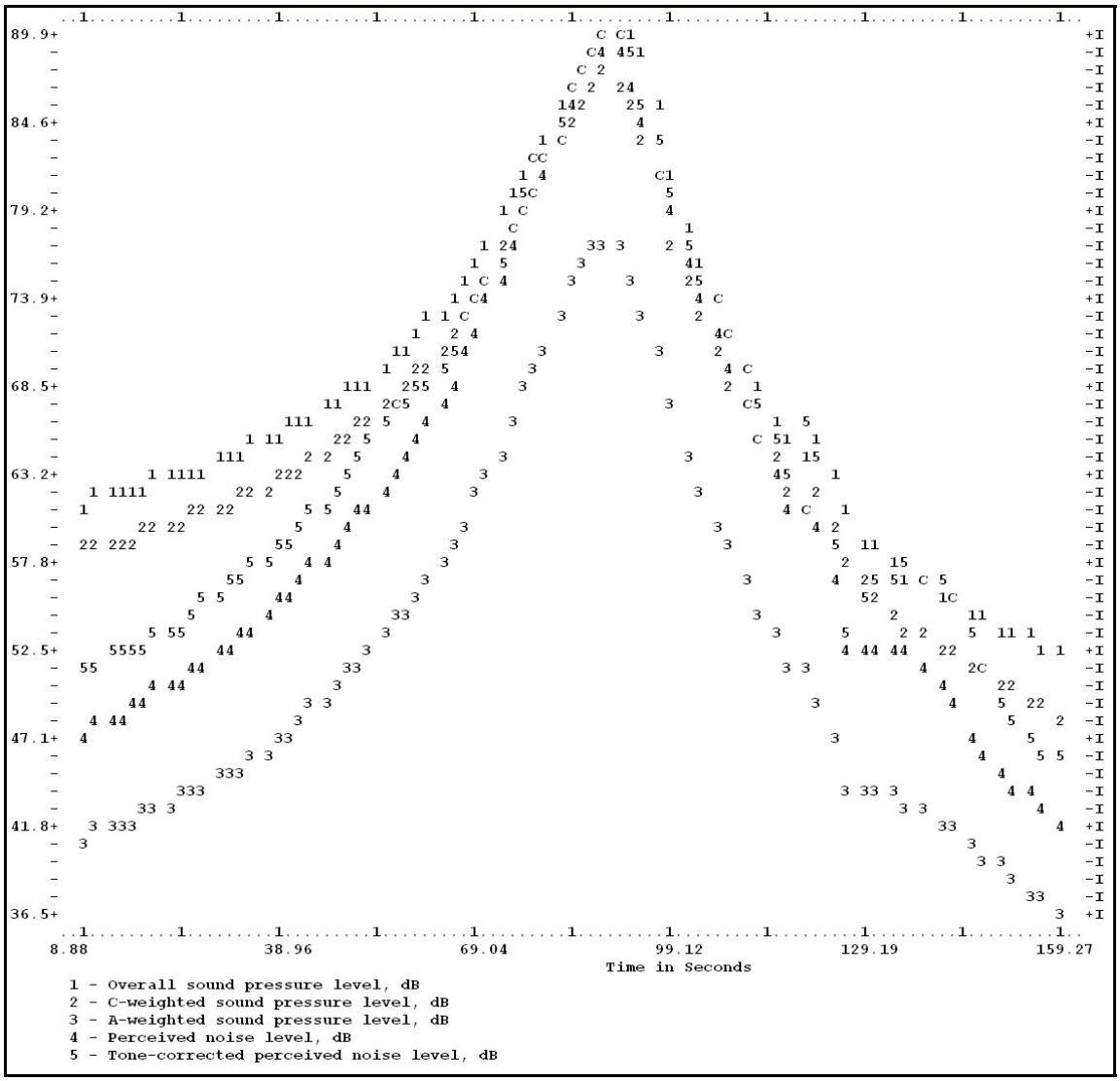

Figure 5-11. Example of AAM ASCII Time-History Output

```
TITLE = "Points of Interest Time History"
VARIABLES = "Time" "SPL" "dBC"   "dBA"   "PNL"   "PNLT"  "f  10.0Hz" "f  12.5Hz" "f  16.0Hz" "f 20.0Hz"
ZONE I=  76 F=POINT
     8.97     62.74     59.96    43.26    50.67    54.15       30.7      30.6      31.6      47.4    ...
    10.85     62.94     60.17    43.62    51.13    54.37       30.7      30.6      31.6      47.5    ...
    12.73     63.15     60.40    43.97    51.57    54.59       30.7      30.6      31.7      47.7    ...
    14.61     63.38     60.63    44.34    52.01    54.97       30.7      30.6      31.8      47.8    ...
    16.49     63.61     60.88    44.73    52.48    55.47       30.8      30.5      31.8      48.0    ...
    18.36     63.85     61.14    45.14    52.97    55.97       30.8      30.5      31.9      48.2    ...
    20.23     64.10     61.40    45.56    53.47    56.45       30.7      30.5      32.0      48.4    ...
    22.10     64.37     61.69    46.01    53.99    56.91       30.7      30.4      32.1      48.6    ...
    23.96     64.64     61.98    46.47    54.53    57.35       30.7      30.4      32.1      48.8    ...
    25.82     64.93     62.29    46.96    55.09    57.80       30.7      30.4      32.2      49.0    ...
```

Figure 5-12. Example of Time History (.POI) Detailed Output (poitime)

5.5 Creating a 3D Audibility Sound Animation Video (paxvideo)

This section provides detailed instructions for creating a 3D sound animation video (.AVI) for a single event which displays human audibility (D-prime). In this example, a helicopter performs a surveillance mission Calvert Cliffs State Park. This animation helps the user to view the audibility (D-prime) at various locations on the ground. While creating this animation, terrain files were used; the terrain files used in this example are provided. Figure 5-13 shows an image depicting the audibility at an instant in time, calculated by AAM. To create an animation, one must use the keyword VIDEO in the input file as shown in Figure 5-14. In order to calculate human audibility, one must also use the DPRIME keyword.

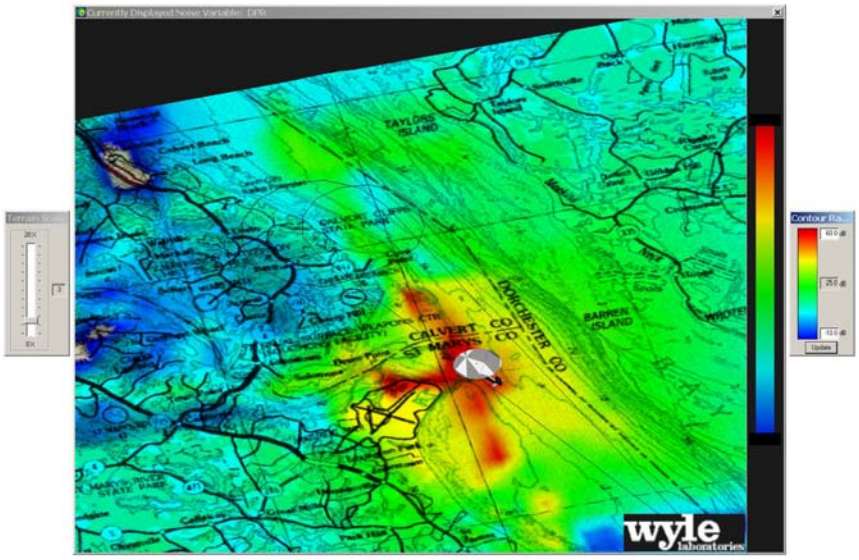

Figure 5-13. Sound Animation

The VIDEO keyword triggers the generation of a time history file. VIDEO generation capability is only permitted with the COMPUTEGRD keyword and is not compatible with the COMPUTEPOI and AUBID keywords.

For this example, the keyword TERRAIN is used in the input file to specify an elevation and impedance file of the geographical area under consideration. For this particular example terrain and impedance files are provided. The coordinates of the computational domain in the SETUP PARA keyword section must exactly match the corners of the .ELV grid. These values may

be obtained by using ELV2PLT and reading the first and last points in the ASCII .PLT file. The PaxVideo.INP file is shown in Figure 5-14.

```
REM45678901234567890123456789012345678901234567890123456789012345678901234567890
REM      11-20     21-30     31-40     41-50     51-60     61-70     71-80
VIDEO
patuxent.tig
TERRAIN
patuxent.elv
patuxent.imp
UTM
SETUP PARA
1000      1000      20.0
1176378.2 13837664. 5.0
1281364.8 13921653.
  90     500000     200
TH57B
1
00.00000   00.0000 0.000
0
0
REM  X        Y         Z      dang     radius    spd(kts)    yaw     pitch    roll     nacAng
ONE TRACK
Direct approach
     6
  1274062. 13904761.      70.        0.      0.      40.      0.       0.       0.       90.
  1259430. 13865475.    1500.   139.13    3079.     110.      0.       0.       0.       90.
  1253660. 13865475.    1000.     0.00       0.      80.      0.       0.       0.       90.
  1241482. 13898144.    1500.   107.83    3604.      40.      0.       0.       0.       90.
  1244695. 13903003.    1000.     0.00       0.      40.      0.       0.       0.       90.
  1274165. 13904349.      70.     0.00       0.      40.      0.       0.       0.       90.
END
```

Figure 5-14. VIDEO Keyword Input File (paxvideo.INP)

To create an animation, run AAM using the command.

C:\AAM\Projects\Tutorials> AAM paxvideo.INP

This will output a time history (.TIG) file using the name provided in the input file. Figure 5-15 shows a portion of the .TIG file created by this example. The time is in seconds in the same reference frame as the input flight track (or with the first point in the flight track assigned *t=0* if keyword TIMETRAJ is not used). A companion file containing the interpolated trajectory (.TRJ) is also created. This file will bear the input filename prefix with a .TRJ extension. 3DVisualizer is a post-processor which reads the trajectory files and time history files and time history files, and interpolates temporally into uniformly spaced arrival time increments for the purpose of creating graphical sound animations.

```
Filename: paxrivervideo.tig
pax1.elv
pax1.imp



ii:    1   51   51
jj:    1   35   35
Fig8.TRJ
heli.SRC
---End File Header---
Site: 00010001
Integ:                    Spec: 105
Lat: 0.0000000 Long: 0.0000000  User X: 333186.  User Y: 4224258. Grnd Z: 91.12  Recv Z: 96.12
UTM Zone:  18    Easting:   333186.    Northing: 4224258.
31-03-2006
Echo
SP#    TIME       F     A    10   11   12   13   ...   40      DOPPLER
*** ************ **** **** **** **** **** ****   ... **** ************
  0 AMBIENT      -990 -990 -990 -990 -990 -990   ... -990
  1      152.701  358  118 -407  319  308  284   ... -999    1.0000000
  2      172.658  353  118 -411  314  303  276   ... -999    1.0000000
  3      192.637  304  118 -461  265  255  225   ... -999    1.0000000
  4      212.639  301  118 -463  262  253  219   ... -999    1.0000000
  5      232.666  296  117 -467  258  249  212   ... -999    1.0000000
  6      252.720  291  117 -471  253  245  204   ... -999    1.0000000 …
```

Figure 5-15. Sample .TIG File

3DVisualizer is used to view the acoustic results. It gives the user the capability to render in color over 3D terrain the sound levels at the receiver points.

To view the acoustic results open paxvideo.TIG in 3DVisualizer. Select File→Open and highlight the paxvideo.TIG file from the directory. If the 3DVisualizer didn't automatically locate the trajectory file, it will prompt the user to browse for the file. The program then has the user select a metric to view with the 3DVisualizer Load a File Dialog shown in Figure 5-16.

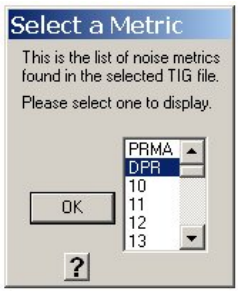

Figure 5-16. 3DVisualizer Load a File Dialog

For this example, select the DPRMX metric. The listed metric are taken from the .TIG file header and represent different noise variables available for display.

If there is a 3D model file (.3DS) associated with the aircraft used in the study it will load automatically. If the file is not located in the same directory, the user will be asked to find the file, or select Cancel to not load the aircraft model. The program will load the data into memory and display it on the screen in 3D.

To build an .AVI file in the 3DVisualizer use the menu item Capture→Video. This will bring up dialog box shown in Figure 5-17.

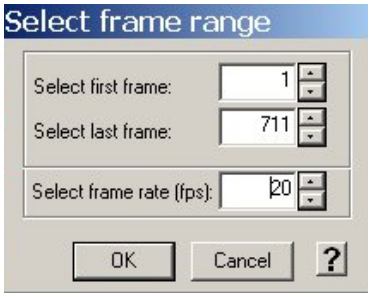

Figure 5-17. Capture Video/Select Frame Range Dialog

This dialog allows the user to select the frames and frame rate of the video to be created. It prompts the user to select a directory for the video files. After selecting the directory 3DVisualizer will create that directory, and put the video file (.AVI) of that name in that directory. It also creates a subdirectory called *Vidcaps* where all the individual frames from the video are stored.

5.6 Creating Noise Contours using the Multiple-Operations Input Format (multops)

This tutorial section describes the creation of noise contours using the multiple-operations format input (Figure 5-18). NMPlot may be used to display the contours (heavy grey lines in Figure 5-18) along with a host of other geographical information and operations information such as ground tracks (thin black lines in Figure 5-18).

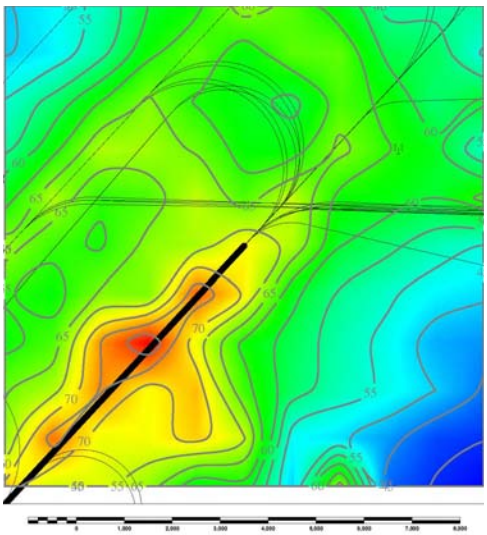

Figure 5-18. Multiple-Operations DNL Noise Contour (multops.GRD)

Running the acoustic module with multiple operations requires two input files (.RUN and .OPS), consistent with other Department of Defense noise tools such as BaseOps, RNM and NOISEMAP. The .RUN file is, in essence, a control file which specifies paths to operations and terrain files as well as identifying the desired calculations, grid domain and resolution. The operations (.OPS) file

contains operational information including tracks, profiles, number of flight operations and general base information such as airfield data, runways, navigational aids and specific points.

Figure 5-19 contains the multops .RUN file listing which demonstrates the use of the COMPUTEGRD keyword for calculation of a noise contour grid (.GRD) file.

```
RUN
multops.run               7.0 10-Feb-2007 12:00:00        1
This is run file for Sample AAM 7 MultOps case

multops.ops
not_used.log
IGNOREPOI           multops.poi              DAILY         0
IGNORETOP
COMPUTEGRD          multops.grd               DNL
    -05000    -05000     05000     05000
      1000      1000         0     W
ENDRUN
```

Figure 5-19. Multiple-Operations Format Control File (multops.RUN)

As indicated in Figure 5-20, the operations data is contained in the multops.OPS file. The operations file may be created manually using a text editor, or it can be generated by using the BaseOps user interface available from Wasmer Consulting (www.wasmerconsulting.com). At the time of publication of this report, a specialized AAM specific version of BaseOps was not yet available online but may be obtained from Wyle. Portions of the .OPS file are highlighted here. Figure 5-20 itemizes the specific points (POINT keyword), the navigational aids (NAVAID keyword) and the runway coordinates (RUNWAY keyword).

```
POINT              7
S1             -1922      2956         5    81.422362420068W    30.406941704652N S1
S2             10395     -5145         5    81.383191411754W    30.384720396774N S2
S3              5678    -14765         5    81.398192600860W    30.358332422230N S3
S4              4892      8526         5    81.400692269004W    30.422220396774N S4
S5              9871    -20335         5    81.384857857183W    30.343053730108N S5
S6              5590    -10613         5    81.398472461924W    30.369721493987N S6
S7             -1660     20273         5    81.421529197353W    30.454442801865N S7
NAVAID             5
SGJ            29905   -154900        17    81.321144941655W    29.973937535242N SGJ
SSI            -3980    243351        17    81.428907352691W    31.066353049835N SSI
CRG           -24094    -16092        17    81.492874687369W    30.354692417841N CRG
HEG          -118145    -38765        17    81.791979380312W    30.292499637503N HEG
NRB             3225      2051        17    81.405993728033W    30.404459260061N NRB
RUNWAY             4
23                 0         0        17     -5372     -5772        17
    81.416250000000W    30.398833300000N    81.433333300000W    30.383000000000N300
05             -5372     -5772        17         0         0        17
    81.433333300000W    30.383000000000N    81.416250000000W    30.398833300000N300
3H1            -5232     -5623        17     -5372     -5772        17
    81.432888100000W    30.383408900000N    81.433333300000W    30.383000000000N300
5H1            -5372     -5772        17     -5232     -5623        17
    81.433333300000W    30.383000000000N    81.432888100000W    30.383408900000N300
```

Figure 5-20. Airfield Portion of the Multiple-Operations Format File (multops.OPS)

When using the multiple-operations formatted inputs, operations are defined as separate ground tracks and profiles. Within the module the tracks and profiles are integrated together and time assignments made using a nominal 2-second increment, to form three-dimensional flight trajectories. Figure 5-21 illustrates two of the 35 ground tracks defined in the TRACK keyword section of the multops.OPS example input file.

```
TRACK             35
23D2             DEP23                          0.00         2         5
          East Departure Hanna Lane

                 8050      0.0       8050      8050
                 1125   -105.0L      2061     10111
                14300      0.0      14300     24411
                 1125     55.0R      1079     25490
               300000      0.0     300000    325490
05G1             PAT05        05               0.00         2         9
          GCA Box

                 8000      0.0       8000      8000
                 1250     60.0R      1308      9308
                18000      0.0      18000     27308
                 1250    120.0R      2617     29925
                43494      0.0      43494     73419
                 1250     90.0R      1963     75382
                15588      0.0      15588     90970
                 1250     90.0R      1963     92933
                26494      0.0      26494    119427
```

Figure 5-21. Ground Track Portion of the Multiple-Operations Format File (multops.OPS)

Profiles are defined separately along with the operational information in the ROTARYWINGPROF and keyword sections. In the example shown in Figure 5-22 the CH-146 vehicle uses profile 114 assigned FIXEDWINGPROF to track 05A1 with 1.45 daily daytime operations and 0.09 daily nighttime operations.

```
ROTARYWINGAC       1
CH146     CH-146
ROTARYWINGPROF    33                                        % RPM
 114      HELICOPTER CH146
05A1               0      2430      1.45      0.00      0.09         0         7
                   0         0        50         0        +7         0        90
                  50       150        50         0       +12         0        90
                5800       500        80         0        -1       +25        90
               20660       500        80         0         0         0        90
               24500       800       100         0         0       -25        90
               30000      1000       100         0         0         0        90
              200000      1000       100         0         0         0        90
 116      HELICOPTER CH146
05A3               0      2430      1.45      0.00      0.09         0         6
                   0         0        50         0        +7         0        90
                  50       150        50         0       +12         0        90
                4500       500        80         0        -1       -25        90
               19700       800       100         0         0         0        90
               25000      1000       100         0         0         0        90
              200000      1000       100         0         0         0        90
```

Figure 5-22. Flight Profile Portion of the Multiple-Operations Format File (multops.OPS)

5.7 Elevation File Creation Process

An elevation file is created using the interactive graphical ELVBuilder program. ELVBuilder is an interactive Windows program. To run ELVBuilder, double-click on the executable icon. You will then be presented with the Elevation File Case Building Dialog (Figure 5-23). The elevation file contains the information defining the ground altitude in the analysis region.

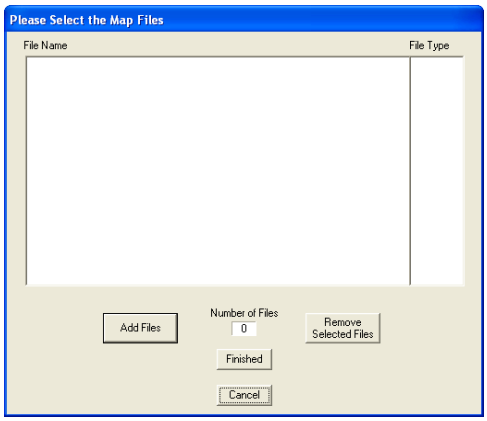

Figure 5-23. Elevation File Case Building Dialog

Terrain files in DLG, DEM, ASCII, DTED, or NED format may be used to create an .ELV file for AAM.

Add a file by using the Add Files button. This will bring up a standard windows file selection dialog. The default file type is .DLG, but other elevation file types can be selected with the File Types pull down menu.

As files are added they will appear in the dialog, along with their description on the right hand side. The total number of files is tallied at the bottom of the dialog. If a file is added by mistake it can be removed by first selecting it, then clicking the Remove Selected Files button. Once a complete set of files has been added, press Finished and enter the main UTM zone as shown in Figure 5-24. This is useful if the study area crosses over two UTM zones and all the data needs to be represented in one specific zone. If zero (0) is selected as the zone then all of the data will be transposed to the zone of the first data file listed.

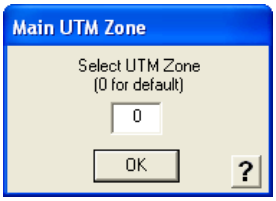

Figure 5-24. Select UTM Zone Dialog

With a main zone selected the elevation builder processes all of the input files. Once the data files have been processed, Figure 5-25, the main window for building a new elevation file, will appear. To the left of the window is the combined elevation contours from all of the input files. On the menu bar below are the current coordinates of the mouse, and to the right is the dialog box that contains all of the crucial study area information used to generate the elevation file.

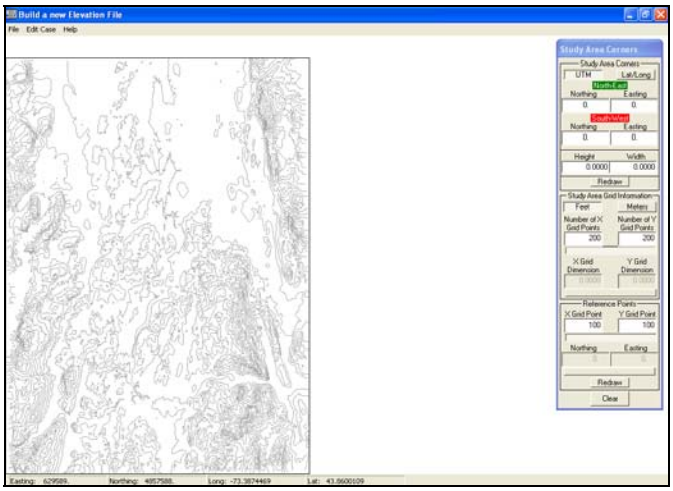

Figure 5-25. Elevation Builder Main Screen

At this point it is possible to generate a new elevation file. However, to better orient the study area, one may add a layer of details to the map showing the roads, trails, airports, and other data of interest.

To define a study area, click the left mouse button on one corner of the measurement area and drag the marquee to cover the whole study area. Clicking the left mouse button again will drop the marquee and define the area. In the graphical view, one will see a box placed over the map that covers the measurement area. The southwest corner of the box has a red square and the northeast corner has a green circle. The coordinates of these corners correspond to the upper portion of the Study Area dialog box (Figure 5-26).

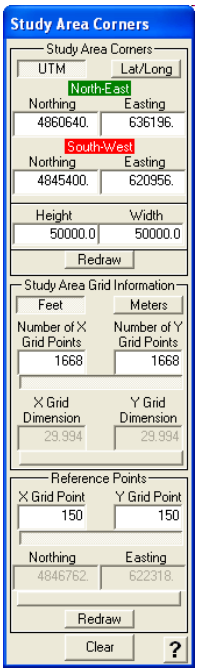

Figure 5-26. Study Area Dialog Box

This dialog has three main sections. The upper section shows the corners and the height and width of the study area. The middle section describes the final size of the output grid, and the lower section defines the coordinates of the study area's reference point.

The upper section, called Study Area Corners (Figure 5-27), has three buttons. The Lat/Long and UTM buttons will change the view of the corner coordinates (the depressed button is the selected coordinate system). The Redraw button will redraw the frame around the study area. The units of height and width are shown in the next section of the dialog box.

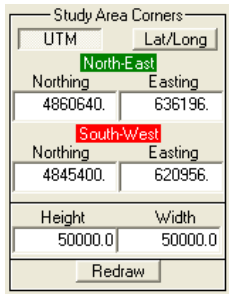

Figure 5-27. Study Area Corners Dialog

The second section of the Study Area Grid Information dialog box (Figure 5-28) contains two buttons: Feet or Meters. These units will be used to create the .ELV file.

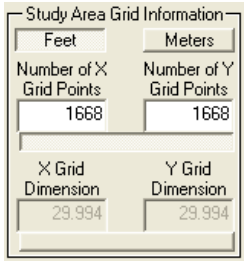

Figure 5-28. Study Area Grid Information Dialog

The default value for the number of grid points in both the X and Y direction is 200 points. The actual size of each grid point (and therefore the resolution of the grid) is displayed in the X Grid Dimension and Y Grid Dimension fields of the dialog box. The higher the resolution of the grid, the better the topographical features of the map are resolved. In general the resolution should be set so that the individual cells are no greater than the smallest topographical feature of importance.

If the study area covers relatively flat terrain and there are few topographical features, improving the grid resolution will provide little increase in accuracy. If, on the other hand, the study area covers extreme terrain, a change in the grid spacing can mean a dramatic change in elevation, and hence, a change in the propagation results.

You may edit either the number of grid points or the size of each grid point. However, only one element can be changed with the other elements updating automatically by moving the mouse off of the dialog. By default the number of grid points is initially editable. Clicking the long bar just beneath grid dimension fields changes the editable parameters, allowing you to choose the dimensions rather than the number. When dimensions are chosen, ELVBuilder will round the dimension size down to obtain an integer number of grid points over the study area.

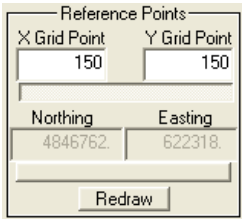

Figure 5-29. Reference Points Dialog

The lower section of this dialog box, called Reference Points (Figure 5-29), is important for users who want to see values in different orthogonal coordinate systems. The reference point is used to link this alternate reference coordinate system to the native UTM 84 coordinate system of the elevation file.

This reference point is located on one of the grid points as shown in the fields X Grid Point and Y Grid Point, and is displayed inside of the study area with the "+" sign. Changing the grid point values of the reference point changes the location of the reference point, and pressing Redraw will update the map.

It is also possible to select the location of the reference point directly by entering its location into the coordinate fields below the grid location. As with the grid resolution, however, first click the large bar below these fields to unlock these fields. Entering a coordinate directly will only provide a nominal location since the reference point must be co-located with one of the grid points. Once the mouse is moved off the dialog these coordinates automatically update to the nearest grid point. If a specific reference coordinate is desired, design the study area and grid size such that a grid point will lie exactly at that location.

Once you are satisfied with the study area, select the menu item Open → Save Elevation File. This allows you to save the elevation file. If the area selected is near the edge of the contour map the program may warn you that some of the data may be extrapolated, because the data may not encompass all of the area shown on the screen.

Whether or not you chose to define a user-defined coordinate system, you will be asked to select an elevation filename. Once a filename is selected, the elevation file is generated. When the program is finished making the file it will signal you with a Finished! dialog.

5.8 Creating an Impedance File

ELVBuilder is a Windows-based program that may be used to create an impedance file from DLG hydrography files, DFAD files, or NED files. Double-clicking the executable will result in the Impedance File Build Dialog (Figure 5-30).

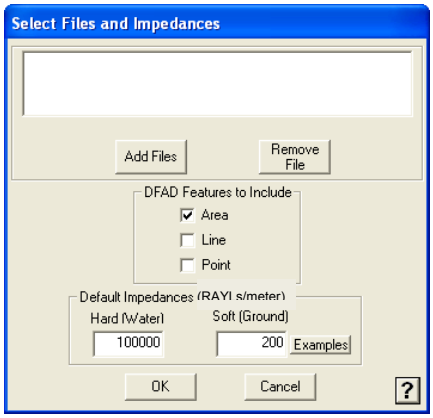

Figure 5-30. Impedance File Build Dialog

In the case of DLG hydrography files, the impedance builder will make areas of water defined in those files as hard and all other areas as soft. In the case of the DFAD and NED files, the impedance builder will create differing impedance values based upon the feature attributes. The various values of terrain features and related impedance values are stored in a comma separated values file called ImpAttrib.csv in the RND directory.

If DFAD terrain data is used, select the features of interest (Area, Line, or Point). Examples of area features are lakes, fields, deserts, etc. Examples of line features are roads, bridges, rivers, etc. Examples of point features include transmission towers, water towers, billboards, and other small features. Generally speaking, the Area features will provide the bulk of the ground surface-type data. Some line features my be beneficial.

After the terrain files have been selected, ensure that the default impedance values are appropriate. Generally speaking, 100,000 RAYLs is appropriate for water (Hard) and 200 RAYLs is appropriate for ground (Soft). Pressing the Examples button will bring up the impedance table shown in Figure 5-31.

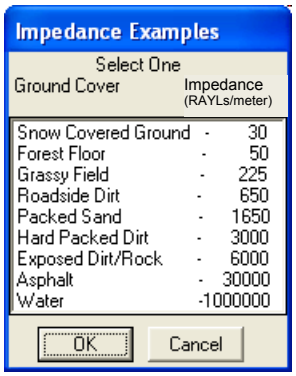

Figure 5-31. Impedance Value Examples Dialog

Selecting one of the typical values will automatically update the Soft Impedance file building dialog.

After the terrain files have been selected, click the OK button to define a filename and build the impedance file.

5.9 Editing an Existing Elevation File

After an elevation file is built, a control file is also built with an .ELB extension. This is the elevation build file, which allows one to edit an existing elevation file. If no build file is found the program will automatically build a new case.

Once the ELVBuilder has been launched, select the menu item File → Open. This will open a standard windows file select dialog allowing the selection of the elevation build file (.ELB). In either case, the Elevation File Case Building dialog will appear and be automatically populated with the files used to build the original elevation file, provided that the build file is in the same directory as the elevation file.

You can change the input files here, or accept the original set can continue by pressing the Finished button. The elevation file builder will reprocess the files and bring up the Elevation Builder main screen. This time, however, the study area and all settings are automatically set. Changes can be made exactly the same as if a new case were being generated.

5.10 Visualizing Source Data (.NC Files)

A convenient way to visualize the contents of an .NC file is to view it using Tecplot (Figures 5-32 and 5-33). Type, on the command line:

Sphere ch146105.nc

This will create a file called ch1461053.plt. The "3" will always be added to the .NC root name and the .PLT extension is for Tecplot.

Open this file in Tecplot. A dialog box will open asking for which variables to use for the axes. Click OK. The resulting plot will be a circle overlayed by a mesh. To format the plot and show a contour of the data, go to the Frame menu and click on the Paste Style from File. In the resulting dialog box, select the 3DSphere.sty or FlatSphere.sty file provided with this tutorial. This will assign theta to the X-axis and phi to the Y-axis and display it in three dimensions.

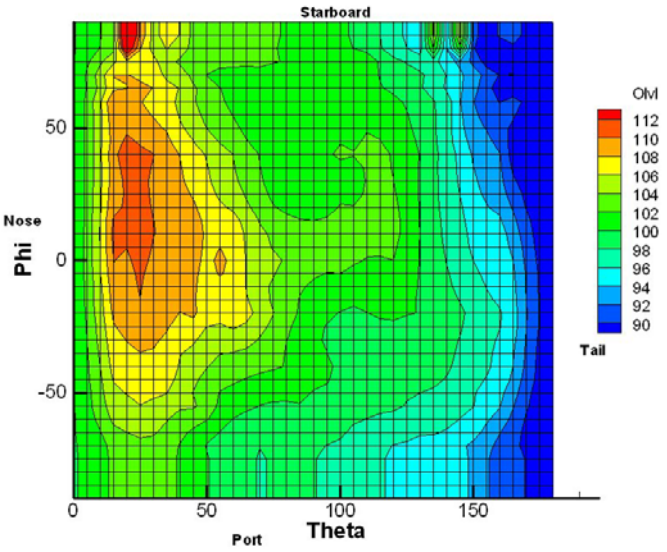

Figure 5-32. Flat Source Data

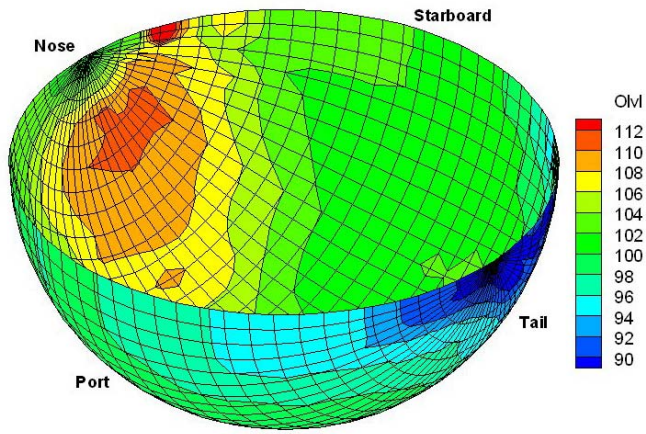

Figure 5-33. Three-Dimensional Source Data

5.11 Creating Source Data (.NC) Files from Measured Data

Acoustic flight tests are conducted using a combination of ground and elevated microphones oriented in a "U" shaped array as illustrated in Figure 5-34, part 1. Elevated microphones are not always used. That limits the θ measurement range, but does not change the process. The vehicle is then flown through the array, where synchronized microphone and GPS data is collected. Time and geometric based analysis allows one to go from a ground based frame of reference (Figure 5-34, part 2) to a moving frame of reference (Figure 5-34, part 3) while accounting for propagation and ground effects, in order to obtain source characteristics (Figure 5-34, part 4).

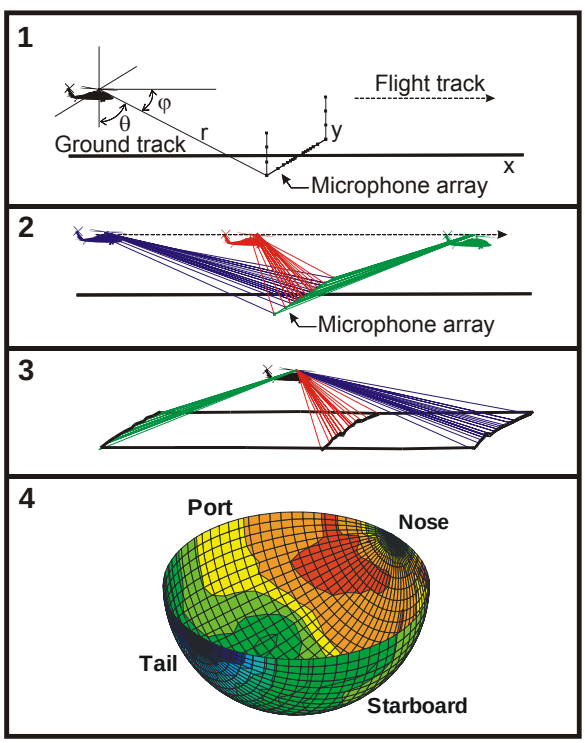

Figure 5-34. Typical Procedure for Obtaining Acoustic Measurement Data

Source data (.NC) files are built in two steps:

1. AAM is used to calculate the propagation physics and geometric relationship between the source and microphones.
2. ART is used to apply those propagation corrections to the measured microphone spectral time histories and map the results onto a three-dimensional sphere.

In this example (run_33), flight test data (GPS, acoustic and weather) from a Bell206 helicopter will be analyzed to create a sound sphere. Uniform soft flat terrain will be assumed. A portion of the input file (run_33.inp) is given in Figure 5-35.

The salient features of this file include the "U" shaped array microphone locations as points of interest, the current local atmospheric parameters, and the time synchronized GPS flight tracking data. The TIMETRAJ keyword indicates that the first column of the ONE TRACK keyword data section specifies the time in seconds after midnight. Since AAM is a simulation program and internally requires assignment of time to each trajectory point and resulting arrival time at the receiver, it is important to define the time with the same time reference as the microphone data. This will ensure the proper temporal linking of the physical propagation characteristics and helicopter orientation with the measured spectral time history.

If onboard flight data recorder information is available to specify the vehicle orientation (roll, pitch, yaw) this may be included in the ONE TRACK definition. One purpose of the analysis (step 1) is to determine, for each input trajectory point, the relative geometric relationship between the flight vehicle (accounting for orientation) with the microphone locations. The information reported to the output (.TH) file will include mapped relationship (ϕ, θ) on the sphere for each trajectory point. The TIMESPACING keyword may be used to adjust the fidelity and resolution of this information. A nominal spacing of 0.5 seconds is recommended.

Additional features included in RNM Version 7 and AAM are the user specification of the final orientation of the vehicle with respect to the ground based coordinate system (thereby bypassing the calculated source orientation) and the user specification of a constant mast tilt angle which will be applied as a uniform change in pitch for all trajectory points. To access these capabilities use the ABSANGLES and MAST TILT keywords. Additional information about these keywords is included in Section 3.5.1.3.

Numerous sphere control parameters for heating atomospheric absorption and handling nonlinear propagation were developed for fixed wing aircract. These keywords (EXTEND45, ALTHFSHAPE, NOABSCAP, NOSETAIL10, POWER, SYMMETICAL, THRUSTANGLE, WRAPAROUND) are described in detail in section 4.1.3.

```
REM456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789
0
REM  B206 input file for ART5, February 2005  100dB BB Onmidirectional Source
DIAGNOSTIC
COMPUTEPOI
ART
TOFORMAT
31
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
SETUP PARA
       200       200       200
     -5000     -5000         0
      5000      5000
        60     30000       200
ArtBB
1
         0         0         0
0
0
ATMOS
2
      FEET         F        MB
        00        77       757        55
      5000        77       757        55
POI
20
1             -46.62    397.41    173.54
2             -46.62    397.41    149.88
3             -46.62    397.41     99.54
4             -46.62    397.41     50.29
5             -41.80    372.64      0.00
6             -30.65    273.29      0.00
7             -19.52    174.01      0.00
8             -11.15     99.39      0.00
9              -5.58     49.79      0.00
10              0.00      0.00      0.00
11              5.59    -49.81      0.00
12             11.14    -99.34      0.00
13             16.73   -149.14      0.00
14             22.29   -198.74      0.00
15             30.65   -273.28      0.00
16             41.82   -372.80      0.00
17             42.66   -395.02     50.29
18             42.66   -395.02     99.54
19             42.66   -395.02    149.85
20             42.66   -395.02    168.50
TIMESPACING
0.5
TIMETRAJ
ONE TRACK
GPS tracking B206
216
  54981.00  -6246.00    59.40    62.90    0.00    0.00    101.04    0.00    0.00    0.00   90.00
  54982.00  -6075.70    57.60    65.40    0.00    0.00    101.04    0.00    0.00    0.00   90.00
  54983.00  -5905.00    54.90    67.70    0.00    0.00    101.22    0.00    0.00    0.00   90.00
  54984.00  -5734.10    50.90    69.30    0.00    0.00    101.35    0.00    0.00    0.00   90.00
  54985.00  -5563.00    46.10    70.40    0.00    0.00    101.45    0.00    0.00    0.00   90.00
  54986.00  -5391.80    41.20    71.40    0.00    0.00    101.53    0.00    0.00    0.00   90.00
  54987.00  -5220.40    36.60    73.30    0.00    0.00    101.59    0.00    0.00    0.00   90.00
  54988.00  -5049.00    32.40    75.50    0.00    0.00    101.62    0.00    0.00    0.00   90.00
  54989.00  -4877.50    29.10    77.80    0.00    0.00    101.78    0.00    0.00    0.00   90.00
  54990.00  -4705.50    26.30    80.00    0.00    0.00    101.93    0.00    0.00    0.00   90.00
  54991.00  -4533.50    24.50    82.00    0.00    0.00    101.86    0.00    0.00    0.00   90.00
```

Figure 5-35. Portion of the Input File Featuring the ART Keyword (run_33.inp)

5.11.1 Step One – Obtaining the Propagation and Geometric Relationship

Run AAM from the command line:

AAM run_33.inp

The primary AAM output when using the ART keyword is a time history (.TH) file containing spectral propagation details at each of the points of interest (microphone locations). A time history file may also be generated for any source by using the SPECTRUM and COMPUTEPOI keywords. A portion of the time history file isgiven in Figures 5-36 through 5-38. Selected highlights from the wide, structured ASCII time history file are included below and cited in *italics*. Additional details about the .TH file format may be found with the SPECTRUM keyword explanation in Section 3.5.1.3.

- Position of the source (*Xsource*, *Ysource*, *Zsource*) and receiver (*Xrecvr*, *Yrecvr*, *ZrAGL*) (Figure 5-36).
- Time of the source location (*Tsource*) and the time at which sound generated at *Tsource* will arrive at the microphone location (*Trecvr*) (Figure 5-36).
- For each frequency *(#, FreqNC*) the resultant free-field level at the receiver (*FreeF*), the unweighted level including ground effect (*BBlev*) (Figure 5-37).
- The slant range between source and receiver in Feet (*slant*) (Figure 5-36).
- The mapped sphere location (*Theta*, *Phi*) pointing to the receiver at time *Tsource* (Figure 5-38).
- Spherical spreading adjustment (*Spread*), air absorption (*AirAB*) and ground effect (*gOut*) (Figure 5-38).
- The level as a function of frequency at the receiver point accounting for all propagation effects (*Receiv*) (Figure 5-38).
- The overall (sum of *Receiv*) unweighted sound pressure level (*Rec_dB*) (Figure 5-38).

```
TITLE = "1/3 Octave HemiSphere Individual & S ummed Unweighted dB Output run_33.TH   "
VARIABLES="F1" "F2" "F3" "F4" "Xsource" "Ysource" "Zsource" "Tsource" "Xrecvr" "Yrecvr" "ZrAGL" "Trecvr" "#"
ZONE I=0031 J=0274 F=POINT
AUXDATA  TEMP  = "     298.150 K"
AUXDATA  HUMID = "      55.000 %"
AUXDATA  NMICS = "020"
AUXDATA  THISMIC = "001"
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 10
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 11
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 12
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 13
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 14
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 15
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 16
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 17
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 18
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 19
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 20
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 21
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 22
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 23
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 24
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 25
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 26
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 27
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 28
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 29
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 30
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 31
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 32
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 33
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 34
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 35
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 36
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 37
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 38
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 39
           01   01   01   01   -6246.00     59.40   62.90 54981.000000 -46.62 397.41 173.54  54986.459548 40
           01   01   01   01   -6160.75     58.50   64.15 54981.500000 -46.62 397.41 173.54  54986.884742 10
           01   01   01   01   -6160.75     58.50   64.15 54981.500000 -46.62 397.41 173.54  54986.884742 11
           01   01   01   01   -6160.75     58.50   64.15 54981.500000 -46.62 397.41 173.54  54986.884742 12
```

Figure 5-36. Portion of Time History (.TH) File – Source Location

"#"	"SLev"	"FreqNC"	"FrqDop"	"FreeF"	"WeaTer"	"BBlev"	"cB01"	"cB02"	"cB03"	"Slant"
10	200.000	10.00	10.00	164.130	0.000	169.765	1697	-3700	-3700	6209.57
11	200.000	12.50	12.50	164.126	0.000	169.571	1695	-3700	-3700	6209.57
12	200.000	16.00	16.00	164.118	0.000	169.248	1692	-3700	-3700	6209.57
13	200.000	20.00	20.00	164.106	0.000	168.808	1688	-3700	-3700	6209.57
14	200.000	25.00	25.00	164.087	0.000	168.160	1681	-3700	-3700	6209.57
15	200.000	31.50	31.50	164.057	0.000	167.161	1671	-3700	-3700	6209.57
16	200.000	40.00	40.00	164.008	0.000	165.598	1655	-3700	-3700	6209.57
17	200.000	50.00	50.00	163.937	0.000	163.396	1633	-3700	-3700	6209.57
18	200.000	63.00	63.00	163.824	0.000	160.036	1600	-3700	-3700	6209.57
19	200.000	80.00	80.00	163.645	0.000	156.524	1565	-3700	-3700	6209.57
20	200.000	100.00	100.00	163.397	0.000	158.526	1585	-3700	-3700	6209.57
21	200.000	125.00	125.00	163.046	0.000	162.292	1622	-3700	-3700	6209.57
22	200.000	160.00	160.00	162.511	0.000	164.910	1649	-3700	-3700	6209.57
23	200.000	200.00	200.00	161.887	0.000	165.591	1655	-3700	-3700	6209.57
24	200.000	250.00	250.00	161.145	0.000	164.082	1640	-3700	-3700	6209.57
25	200.000	315.00	315.00	160.288	0.000	158.009	1580	-3700	-3700	6209.57
26	200.000	400.00	400.00	159.351	0.000	158.278	1582	-3700	-3700	6209.57
27	200.000	500.00	500.00	158.434	0.000	162.438	1624	-3700	-3700	6209.57
28	200.000	630.00	630.00	157.386	0.000	155.928	1559	-3700	-3700	6209.57
29	200.000	800.00	800.00	156.059	0.000	159.597	1595	-3700	-3700	6209.57
30	200.000	1000.00	1000.00	154.376	0.000	154.755	1547	-3700	-3700	6209.57
31	200.000	1250.00	1250.00	151.945	0.000	153.710	1537	-3700	-3700	6209.57
32	200.000	1600.00	1600.00	147.800	0.000	150.419	1504	-3700	-3700	6209.57
33	200.000	2000.00	2000.00	141.925	0.000	144.465	1444	-3700	-3700	6209.57
34	200.000	2500.00	2500.00	132.837	0.000	135.145	1351	-3700	-3700	6209.57
35	200.000	3150.00	3150.00	118.129	0.000	120.407	1204	-3700	-3700	6209.57
36	200.000	4000.00	4000.00	94.048	0.000	96.632	966	-3700	-3700	6209.57
37	200.000	5000.00	5000.00	58.919	0.000	60.993	609	-3700	-3700	6209.57
38	200.000	6300.00	6300.00	2.876	0.000	5.618	56	-3700	-3700	6209.57
39	200.000	8000.00	8000.00	-86.535	0.000	-83.888	-838	-3700	-3700	6209.57
40	200.000	10000.00	10000.00	-211.889	0.000	-209.270	-2092	-3700	-3700	6209.57
10	200.000	10.00	10.00	-370.000	0.000	169.879	1698	-3700	-3700	6124.49
11	200.000	12.50	12.50	-370.000	0.000	169.684	1696	-3700	-3700	6124.49
12	200.000	16.00	16.00	-370.000	0.000	169.357	1693	-3700	-3700	6124.49

Figure 5-37. Portion of Time History (.TH) File – Propagation Effects

"Beta"	"Gamma"	"Theta"	"ACspd"	"Phi"	"Receiv"	"Free"	"Spread"	"AirAb"	"gOut"	"Rec_dB"
-0.61	0.84	3.73	101.04	-92.79	169.76	175.81	-35.86	-0.01	5.63	178.47
-0.61	0.84	3.73	101.04	-92.79	169.57	175.81	-35.86	-0.01	5.45	178.47
-0.61	0.84	3.73	101.04	-92.79	169.25	175.81	-35.86	-0.02	5.13	178.47
-0.61	0.84	3.73	101.04	-92.79	168.81	175.81	-35.86	-0.03	4.70	178.47
-0.61	0.84	3.73	101.04	-92.79	168.16	175.81	-35.86	-0.05	4.07	178.47
-0.61	0.84	3.73	101.04	-92.79	167.16	175.81	-35.86	-0.08	3.10	178.47
-0.61	0.84	3.73	101.04	-92.79	165.60	175.81	-35.86	-0.13	1.59	178.47
-0.61	0.84	3.73	101.04	-92.79	163.40	175.81	-35.86	-0.20	-0.54	178.47
-0.61	0.84	3.73	101.04	-92.79	160.04	175.81	-35.86	-0.31	-3.79	178.47
-0.61	0.84	3.73	101.04	-92.79	156.52	175.81	-35.86	-0.49	-7.12	178.47
-0.61	0.84	3.73	101.04	-92.79	158.53	175.81	-35.86	-0.74	-4.87	178.47
-0.61	0.84	3.73	101.04	-92.79	162.29	175.81	-35.86	-1.09	-0.75	178.47
-0.61	0.84	3.73	101.04	-92.79	164.91	175.81	-35.86	-1.63	2.40	178.47
-0.61	0.84	3.73	101.04	-92.79	165.59	175.81	-35.86	-2.25	3.70	178.47
-0.61	0.84	3.73	101.04	-92.79	164.08	175.81	-35.86	-2.99	2.94	178.47
-0.61	0.84	3.73	101.04	-92.79	158.01	175.81	-35.86	-3.85	-2.28	178.47
-0.61	0.84	3.73	101.04	-92.79	158.28	175.81	-35.86	-4.79	-1.07	178.47
-0.61	0.84	3.73	101.04	-92.79	162.44	175.81	-35.86	-5.71	4.00	178.47
-0.61	0.84	3.73	101.04	-92.79	155.93	175.81	-35.86	-6.75	-1.46	178.47
-0.61	0.84	3.73	101.04	-92.79	159.60	175.81	-35.86	-8.08	3.54	178.47
-0.61	0.84	3.73	101.04	-92.79	154.75	175.81	-35.86	-9.76	0.38	178.47
-0.61	0.84	3.73	101.04	-92.79	153.71	175.81	-35.86	-12.19	1.76	178.47
-0.61	0.84	3.73	101.04	-92.79	150.42	175.81	-35.86	-16.34	2.62	178.47
-0.61	0.84	3.73	101.04	-92.79	144.47	175.81	-35.86	-22.21	2.54	178.47
-0.61	0.84	3.73	101.04	-92.79	135.15	175.81	-35.86	-31.30	2.31	178.47
-0.61	0.84	3.73	101.04	-92.79	120.41	175.81	-35.86	-46.01	2.28	178.47
-0.61	0.84	3.73	101.04	-92.79	96.63	175.81	-35.86	-70.09	2.58	178.47
-0.61	0.84	3.73	101.04	-92.79	60.99	175.81	-35.86	-105.22	2.07	178.47
-0.61	0.84	3.73	101.04	-92.79	5.62	175.81	-35.86	-161.26	2.74	178.47
-0.61	0.84	3.73	101.04	-92.79	-83.89	175.81	-35.86	-250.67	2.65	178.47
-0.61	0.84	3.73	101.04	-92.79	-209.27	175.81	-35.86	-376.03	2.62	178.47
-0.61	0.84	3.78	101.04	-92.79	169.88	175.94	-35.74	-0.01	5.63	178.59
-0.61	0.84	3.78	101.04	-92.79	169.68	175.94	-35.74	-0.01	5.44	178.59
-0.61	0.84	3.78	101.04	-92.79	169.36	175.94	-35.74	-0.02	5.12	178.59

Figure 5-38. Portion of Time History (.TH) File – Receiver Information

The computational module will also automatically generate a 200 dB omni directional full sphere with 5 degree resolution to use in the determination of the propagation losses, if one does not already exist. This sphere will be called OMNI_200.NC and will be placed in the NCFiles directory as indicated by the ROTOR_NOISE parameter. One may view the details of this sphere by using the NCDUMP utility from the command prompt in the NCFILES directory:

NCDUMP omni_200.NC >OMNI_200.txt

Portions of this NCDUMP output text file is listed in Figure 5-39 and 5-40. The *variables* section indicates the units while the *data* section indicates the values of the sphere coordinates, frequency and level.

```
variables:
        float BB ;
                BB:unit = "" ;
        float NB ;
                NB:unit = "" ;
        float PT ;
                PT:unit = "" ;
        float DOPPLER_SHIFT_REMOVED ;
                DOPPLER_SHIFT_REMOVED:unit = "" ;
        float EMPTY_WEIGHT ;
                EMPTY_WEIGHT:unit = "POUNDS" ;
        float FUEL_WEIGHT ;
                FUEL_WEIGHT:unit = "POUNDS" ;
        float LOAD_WEIGHT ;
                LOAD_WEIGHT:unit = "POUNDS" ;
        float RADIUS ;
                RADIUS:unit = "FEET S" ;
        float FLIGHT_PATH_ANGLE ;
                FLIGHT_PATH_ANGLE:unit = "DEGREE" ;
        float PYLON_ANGLE ;
                PYLON_ANGLE:unit = "DEGREE" ;
        float SPEED ;
                SPEED:unit = "KNOTS" ;
        float XYZ(XYZ) ;
                XYZ:unit = "FEET" ;
        float PHI(PHI) ;
                PHI:unit = "DEGREE" ;
        float THETA(THETA) ;
                THETA:unit = "DEGREE" ;
        float FREQUENCY(FREQUENCY) ;
                FREQUENCY:unit = "HERTZ" ;
        float AMPLITUDE(PHI, THETA, FREQUENCY) ;
                AMPLITUDE:unit = "DECIBEL" ;
```

Figure 5-39. Variables Portion of the Omnidirectional Sphere File (OMNI_200.NC)

```
// global attributes:
                :title = "200dB Omnidirectional Sphere Auto Generated by AAM            " ;
data:
 BB = 1  ;
 NB = 0  ;
 PT = 0  ;
 DOPPLER_SHIFT_REMOVED = 0  ;
 EMPTY_WEIGHT = 5000  ;
 FUEL_WEIGHT = 0  ;
 LOAD_WEIGHT = 0  ;
 RADIUS = 100  ;
 FLIGHT_PATH_ANGLE = 0  ;
 PYLON_ANGLE = 90  ;
 SPEED = 0  ;
 XYZ = 0 , 0 , 0  ;
 PHI = -180 , -175 , -170 , -165 , -160 , -155 , -150 , -145 , -140 , -135 ,
    -130 , -125 , -120 , -115 , -110 , -105 , -100 , -95 , -90 , -85 , -80 ,
    -75 , -70 , -65 , -60 , -55 , -50 , -45 , -40 , -35 , -30 , -25 , -20 ,
    -15 , -10 , -5 , 0 , 5 , 10 , 15 , 20 , 25 , 30 , 35 , 40 , 45 , 50 ,
    55 , 60 , 65 , 70 , 75 , 80 , 85 , 90 , 95 , 100 , 105 , 110 , 115 ,
    120 , 125 , 130 , 135 , 140 , 145 , 150 , 155 , 160 , 165 , 170 , 175 ,
    180  ;
 THETA = 0 , 5 , 10 , 15 , 20 , 25 , 30 , 35 , 40 , 45 , 50 , 55 , 60 , 65 ,
    70 , 75 , 80 , 85 , 90 , 95 , 100 , 105 , 110 , 115 , 120 , 125 , 130 ,
    135 , 140 , 145 , 150 , 155 , 160 , 165 , 170 , 175 , 180  ;
 FREQUENCY = 10 , 12.5 , 16 , 20 , 25 , 31.5 , 40 , 50 , 63 , 80 , 100 ,
    125 , 160 , 200 , 250 , 315 , 400 , 500 , 630 , 800 , 1000 , 1250 ,
    1600 , 2000 , 2500 , 3150 , 4000 , 5000 , 6300 , 8000 , 10000  ;
 AMPLITUDE =
  200 , 200 , 200 , 200 , 200 , 200 , 200 , 200 , 200 , 200 , 200 , 200 ,
    200 , 200 , 200 , 200 , 200 , 200 , 200 , 200 , 200 , 200 , 200 , 200 ,
    200 , 200 , 200 , 200 , 200 , 200 , 200 ,
  200 , 200 , 200 , 200 , 200 , 200 , 200 , 200 , 200 , 200 , 200 , 200 ,
    200 , 200 , 200 , 200 , 200 , 200 , 200 , 200 , 200 , 200 , 200 , 200 ,
```

Figure 5-40. Data Portion of the Omnidirectional Sphere File (OMNI_200.NC)

5.11.2 Step Two - Applying and Mapping a Three-Dimensional Source Sphere

Using the time history (.TH) file (generated by using a 200 dB omnidirectional sphere), one can create a .RUN file for ART (Figure 5-41) and create the source sphere file (.NC). Key information in the .RUN file includes the vehicle parameters, location and names of the microphone time history files, spectral and grid resolution information about the desired source data file and some analysis control features.

```
REM  B206 input file for ART5, February 2005
THFILE
Run_33.TH
REM.............X.............Y.............Z......... FloRes.....Acoustic Data File & Path
MICROPHONE
20
01        -46.6200       397.4100       173.5400            200.     Run_33_Mic_01.txt
02        -46.6200       397.4100       149.8800            200.     Run_33_Mic_02.txt
03        -46.6200       397.4100        99.5400            200.     Run_33_Mic_03.txt
...

TOFORMAT
  30
11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
30 31 32 33 34 35 36 37 38 39 40 41
SPHERE
5          Theta Delta
0          Theta Min
180        Theta Max
5          Phi Delta
-90        Phi Min
90         Phi Max
40000.     Slant Max
GRIDOPTIONS
2           NRNG
0           CAY
NCFILE
B206_033.NC
SOUND HEMISPHERE FOR B206_, Run 033 Eglin Florida 9.19.03 ART3:01/12/04
2475       EW
0          FW
0          LW
100.       RadBB
90         pylon ang
ALL MESSAGES
END
```

Figure 5-41. Portion of an ART Input (.RUN) File

Examining the microphone broad band spectral time history data (Figure 5-42) one can see that there is zero data only in band 10 (10Hz) and valid data in the higher bands. Only a portion of the data is displayed in Figure 5-42. The ART input file (Figure 5-41) therefore specifies, with the TOFORMAT keyword, analysis of bands 11-40. ART has the capability to create sparsely populated spheres. This feature is especially useful when considering narrow band data and only a limited number of discrete bins need to be analyzed. The ALL MESSAGES keyword echoes the microphone spectral time history details in the log file.

```
Filename: Run_33_Mic_12.txt
LogFile:    Mic:12  Run:33
Integ:  .5000 SPLin Flat Spec:0176 Corr:   .00 Cal:   .00
Description: TH57 Noise Measurements
Location: Eglin, Florida
Date: 09/19/03

SP#    TIME       F     A    10   11   12   13   14   15   16
*** ************ **** **** **** **** **** **** **** **** ****
    AMBIENT         0    0    0    0    0    0    0    0    0
  1 15:15:58.600  560  348    0  512  468  438  423  321  334
  2 15:15:59.100  584  362    0  532  496  457  451  325  358
  3 15:15:59.600  595  358    0  549  518  479  474  378  366
  4 15:16: 0.100  584  341    0  544  514  467  474  374  386
  5 15:16: 0.600  586  357    0  548  519  459  475  378  397
  6 15:16: 1.100  588  360    0  535  512  462  485  362  411
  7 15:16: 1.600  579  358    0  504  485  433  465  356  418
  8 15:16: 2.100  571  353    0  519  500  395  424  334  390
```

Figure 5-42. Portion of a Microphone One-third Octave Band File (Run_33_Mic_12.txt)

Run ART from the command line:

ART run_33.run

ART generates a log file which contains details about the acoustic processing. Figure 5-43 contains some of the information written to the log file including:

- The number of control points used to generate the sphere for each band;
- The average noise level for each band;
- The average tail level for each band;
- The smoothing band levels;
- The average airspeed assigned to the noise data (.NC) file; and
- The average flight path angle assigned to the noise data (.NC) file.

```
 Band           1  Passing control points into ZGRID:        5122
 Band           2  Passing control points into ZGRID:        5202
 Band           3  Passing control points into ZGRID:        5212
...
...
 Applying nose averages band            1   82.48970      0.0000000E+00
 Applying tail averages band            1   76.23493      0.0000000E+00
 Applying nose smoothing band           1   80.51517
 Applying nose smoothing band           1   81.57966
  Nose / Tail averaging
  Calculated average Conditions
  airspeed=   100.5469     kts
  flight path angle =  0.1614393     deg
```

Figure 5-43. Portion of the ART Log File Processing Details

In addition to the log file ART creates the specified sound sphere file (.NC) and the Tecplot (.PLT) file as shown in Figure 5-44.

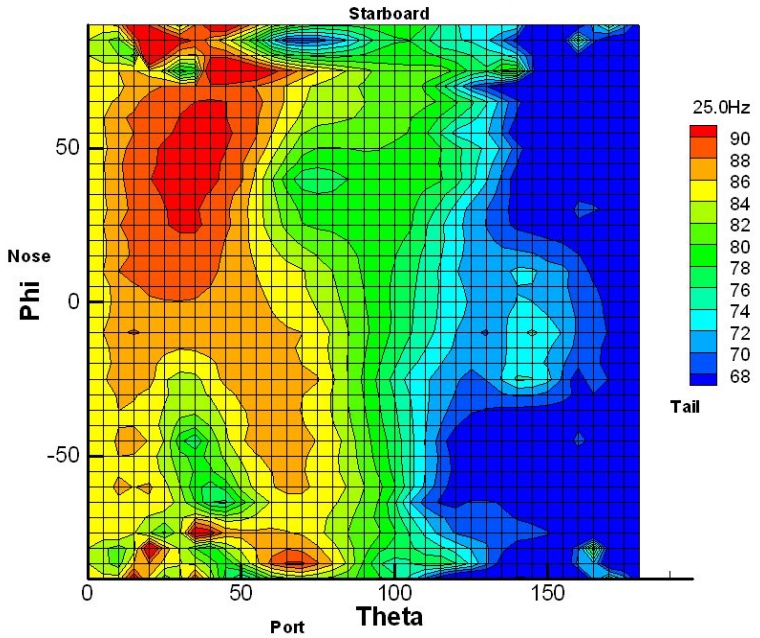

Figure 5-44. Resultant Sound Sphere (.NC) File

5.12 Creating a One-Third Octave Band .NC File from Text with Bullwink

The Bullwink program reads in an ASCII input file containing general vehicle characteristics, spectral and geometric data and creates a NetCDF .NC file. Bullwink can be operated in one-third octave band, narrow band or pure tone and phase modes. See Section 4.4 for more details about using Bullwink in narrow band and pure tone with phase modes. For this example, a sphere with six distinctly different levels in each of the six primary directions will be created. The sphere produced will have 20 dB uniformly in every direction except for a 10° x 10° region in the region and direction of the primary axes: Top=150 dB, Right=180 dB, Left=120 dB, NPole=210 dB, SPole=90 dB, Bottom=60 dB, Rest=20 dB. The header information for the source data file is contained in the input file (Figure 5-45). Further details about the Bullwink input files may be found in Section 4.4. Bullwink is run from the command line

Bullwink 6nodes.BLW

This will generate the output file, 6node000.NC, which may be graphically illustrated (Figure 5-46) by creating a Tecplot .PLT file with the command:

Sphere 6node000.NC

```
Six Nodes.  Top=150 Right=180 Left=120 NPole=210 SPole=90 Bottom=60 Rest=20....
1          BB
0          NB
0          PT
0          DS
5000       EW
0          FW
0          LW
100.       R
0          Elev
90         pylon ang
100.0      Airspeed
0.0,0.0,0.0     XYZ
```

Figure 5-45. Bullwink

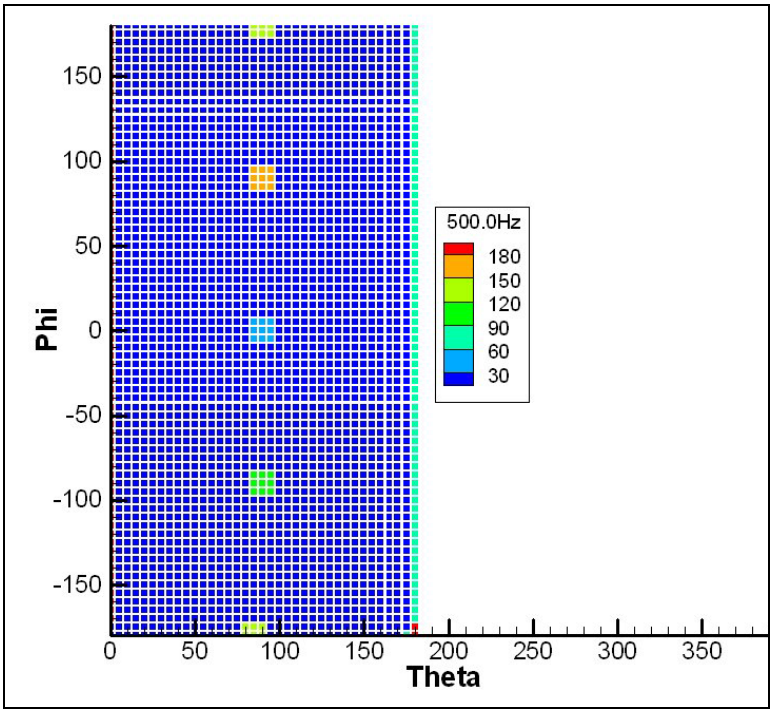

Figure 5-46. Bullwink 6node Example NetCDF Sphere

5.13 Creating Stationary Source Spheres from Measurement Data (DeDopplerizer)

This tutorial will demonstrate how to create a stationary source sphere (.NC file) from measurement data using the deDopplerizer module. A single narrow band source sphere will be created from measurement data that contains a Doppler shift.

The basic procedure is:

- Calculate the Doppler effects based on the vehicle trajectory and microphone orientation;
- Apply the frequency corrections to the recorded spectral time history (.TH) microphone files creating stationary spectral time histories; and
- Use ART to assemble a narrow band source sphere using the stationary microphone files.

For this example, a narrow band source file is created automatically when one uses the ART keyword.

One can also generate a .TH file by using the SPECTRUM keyword in conjunction with any source (.NC) file. A portion of the AAM input deck is provided in Figure 5-47.

```
REM  Input file for ART, February 2007  DeDopplerized case
NBFORMAT
  20
27.46582    30.51758    33.56934    36.62109  ...

SPHERE
5          Theta Delta
0          Theta Min
180        Theta Max
5          Phi Delta
-90        Phi Min
90         Phi Max
40000.     Slant Max
SNRATIO
-500.0
REM
GRIDOPTIONS
2           NRNG
0           CAY
NCFILE
NBDeD001.NC
DeDopplerized (Stationary) Source file run 006003.NB
1000       EW
0          FW
0          LW
100.       RadBB
90         pylon ang
DOPPLERSTATE
1          Doppler Shift (1=Stationary, 0=Moving Source)
THFILE
006003NB.TH
MICROPHONE
20
01    -46.6200   397.4100   173.5400   200. \data\006003_01_BIN.nbd
02    -46.6200   397.4100   149.8800   200. \data\006003_02_BIN.nbd
...
```

Figure 5-47. Input for Creating Doppler Effect Time History (.TH) File

Key parameters which control the analysis are:

- Specification of narrow band format and the discrete frequencies to be considered (NBFORMAT keyword). These frequencies match specific data available in the input microphone files, which contain the Doppler shift due to the vehicle motion.
- Location of the microphone positions as points of interest (POI keyword).
- Measured .OPS time synchronized trajectory (TIMETRAJ and ONE TRACK keywords).
- Identification of the source sphere as narrow band (SETUP PARA keyword).

Run AAM from the command line as follows:

AAM DeDoppNM.inp

This creates a narrow band source file (.NC), a point of interest one-third octave band file (.POI) and a spectral time history (.TH) file.

Using NCDUMP to view the details of the OMNI_200.NC file created by AAM indicates the DOPPLER SHIFT_REMOVED parameter in the .NC file has been set to 1 (Figure 5-48).

```
// global attributes:
                :title = "200dB Omnidirectional Sphere Auto Generated by AAM                " ;
data:
 BB = 0  ;
 NB = 1  ;
 PT = 0  ;
 DOPPLER_SHIFT_REMOVED = 1  ;
 EMPTY_WEIGHT = 5000  ;
 FUEL_WEIGHT = 0  ;
 LOAD_WEIGHT = 0  ;
 RADIUS = 100  ;
 FLIGHT_PATH_ANGLE = 0  ;
 PYLON_ANGLE = 90  ;
 SPEED = 0  ;
 XYZ = 0 , 0 , 0  ;
 PHI = -180 , -175 , -170 , -165 , ...
 THETA = 0 , 5 , 10 , 15 , 20 , 25 ,...
 FREQUENCY = 27.46582 , 30.51758 , 33.56934 , 36.62109 , 39.67285 ,
    42.72461 , 45.77637 , 48.82812 , 51.87988 , 54.93164 , 57.9834 ,
    61.03516 , 64.08691 , 67.13867 , 70.19043 , 73.24219 , 76.29395 ,
    79.3457 , 82.39746 , 85.44922  ;
 AMPLITUDE =
  200 , 200 , 200 , 200 , 200 , ...
```

Figure 5-48. Stationary Omnidirectional Source (.NC) File Header

The resulting .POI file (Figure 5-49) shows the spectral time histories at the points of interest in terms of one-third octave bands. Upon editing the omni.POI file, one sees that the non-zero data begins in the 6th one-third octave band (31.5 Hz). The other bands have -370 because there is no energy in those bands even though the source .NC file contained data at 27.4 Hz. This is because the source is moving towards the POI, and the Doppler shift increases the received frequency.

```
TITLE = "Points of Interest Time History"
VARIABLES =
"f  10.0Hz" "f  12.5Hz" "f  16.0Hz" "f  20.0Hz" "f  25.0Hz" "f  31.5Hz" "f  40.0Hz"  "f 50.0Hz"
    -370.0      -370.0      -370.0      -370.0      -370.0       160.2       168.6       174.8
    -370.0      -370.0      -370.0      -370.0      -370.0       160.1       168.7       174.9
    -370.0      -370.0      -370.0      -370.0      -370.0       160.0       168.9       174.9
    -370.0      -370.0      -370.0      -370.0      -370.0       159.9       169.0       175.0
    -370.0      -370.0      -370.0      -370.0      -370.0       159.8       169.1       175.1
    -370.0      -370.0      -370.0      -370.0      -370.0       159.7       169.3       175.2
    -370.0      -370.0      -370.0      -370.0      -370.0       159.6       169.4       175.3
    -370.0      -370.0      -370.0      -370.0      -370.0       159.5       169.6       175.4
    -370.0      -370.0      -370.0      -370.0      -370.0       159.4       169.8       175.5
    -370.0      -370.0      -370.0      -370.0      -370.0       159.3       169.9       175.6
```

Figure 5-49. Point of Interest One-Third Octave Band Portion

In order to see evidence of a Doppler shift, one must scan down the .POI file to where the one-third octave band containing a level changes from the 31.5 Hz to the 25 Hz one-third octave band. The corresponding information may be found at the discrete narrow band frequencies by looking at the time history (.TH) file (Figure 5-50). In this, the *FreqNC* column indicates the source frequency (stationary source data from the .NC file) while the *FreDop* column indicates the Doppler-shifted frequency due to the vehicle motion. As you scan down the file, you will see the change in the received frequency gradually decrease as the vehicle passes by the microphone location.

```
    "Trecvr"    "#"  "SLev" "FreqNC" "FreDop" "FreeNB" "



45284.757138    1   200.000    27.47    30.76  168.483
45284.757138    2   200.000    30.52    34.18  168.478
45284.757138    3   200.000    33.57    37.60  168.472
45284.757138    4   200.000    36.62    41.02  168.465
45284.757138    5   200.000    39.67    44.43  168.458
45284.757138    6   200.000    42.72    47.85  168.451
45284.757138    7   200.000    45.78    51.27  168.442
45284.757138    8   200.000    48.83    54.69  168.434
45284.757138    9   200.000    51.88    58.11  168.424
45284.757138   10   200.000    54.93    61.52  168.415
45284.757138   11   200.000    57.98    64.94  168.405
45284.757138   12   200.000    61.04    68.36  168.394
45284.757138   13   200.000    64.09    71.78  168.383
45284.757138   14   200.000    67.14    75.20  168.371
45284.757138   15   200.000    70.19    78.61  168.359
45284.757138   16   200.000    73.24    82.03  168.346
45284.757138   17   200.000    76.29    85.45  168.333
45284.757138   18   200.000    79.35    88.87  168.320
45284.757138   19   200.000    82.40    92.29  168.306
45284.757138   20   200.000    85.45    95.70  168.292
```

Figure 5-50. Portion of the Narrow Band Time History (.TH) File

The next part in the process is to adjust the measured spectral time history data to eliminate the effect of the Doppler shift and represent a stationary source. Figure 5-51 is the control file used with the DeDopplerizer. To run the DeDopplerizer from the command prompt:

DeDopplerizer DeDoppControl.txt

```
DeDoppNB.TH

001 Data\006003_01_BIN.NC
002 Data\006003_02_BIN.NC
003 Data\006003_03_BIN.NC
004 Data\006003_04_BIN.NC
005 Data\006003_05_BIN.NC
006 Data\006003_06_BIN.NC
007 Data\006003_07_BIN.NC
008 Data\006003_08_BIN.NC
009 Data\006003_09_BIN.NC
010 Data\006003_10_BIN.NC
011 Data\006003_11_BIN.NC
012 Data\006003_12_BIN.NC
013 Data\006003_13_BIN.NC
014 Data\006003_14_BIN.NC
015 Data\006003_15_BIN.NC
016 Data\006003_16_BIN.NC
017 Data\006003_17_BIN.NC
018 Data\006003_18_BIN.NC
019 Data\006003_19_BIN.NC
020 Data\006003_20_BIN.NC
WINDOW hanning
OVERLAP 0.5
TIMESTEP 0.5
NUMSAMPLES 8192
```

Figure 5-51. DeDopplerizer Control File

Next, run ART from the command line:

ART nb_dedop.run

Figure 5-52 displays a portion of the ART input file used in the analysis. The NBFORMAT keyword specifies the particular frequencies of narrow band data which are to be included in the resultant noise sphere. The frequencies are a subset (within 0.1 Hz) of the spectral data contained in the stationary microphone files (.NBD) and the time history (.TH) file. Figure 5-53 shows the final stationary noise sphere results for the 67.1 Hz band.

```
REM  Input file for ART, February 2007  DeDopplerized case
NBFORMAT
  20
27.46582    30.51758    33.56934    36.62109  ...

SPHERE
5          Theta Delta
0          Theta Min
180        Theta Max
5          Phi Delta
-90        Phi Min
90         Phi Max
40000.     Slant Max
SNRATIO
-500.0
REM
GRIDOPTIONS
2           NRNG
0           CAY
NCFILE
NBDeD001.NC
DeDopplerized (Stationary) Source file run 006003.NB
1000       EW
0          FW
0          LW
100.       RadBB
90         pylon ang
DOPPLERSTATE
1          Doppler Shift (1=Stationary, 0=Moving Source)
THFILE
006003NB.TH
MICROPHONE
20
01    -46.6200   397.4100   173.5400   200. \data\006003_01_BIN.nbd
02    -46.6200   397.4100   149.8800   200. \data\006003_02_BIN.nbd
...
```

Figure 5-52. Partial ART Input File for a Stationary Source

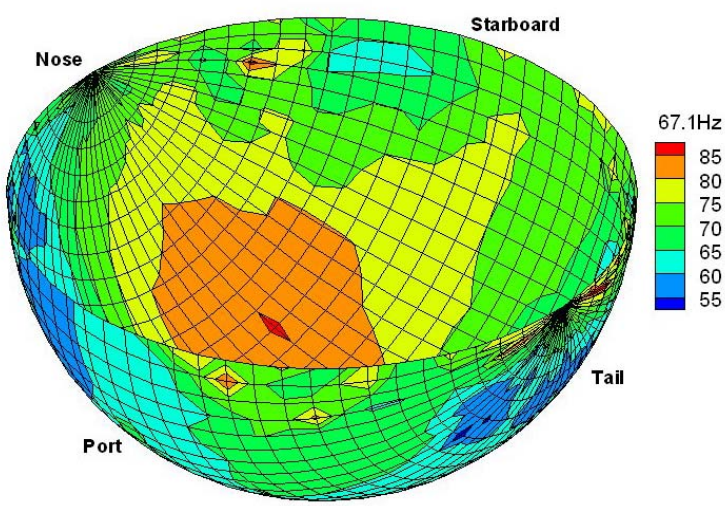

Figure 5-53. Resultant 67.1 Hz Stationary Source

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Glossary

This section describes the terminology used in this document. The terms are arranged in alphabetical order.

A-weighting - A measurement of loudness based on ANSI S1.4-1985[56], which accounts for the frequency sensitivity of the human ear. Sound in each one-third octave band is A-weighted and summed.

Airspeed - The actual speed of the aircraft relative to the air.

Angle of Attack - The angle inscribed between the flight path and the X-axis of the body-fixed coordinate system (Figure 2-11).

Atmospheric Absorption - The propagation of sound through the atmosphere gradually converts sound into heat by a number of molecular processes resulting in a reduction of the sound energy. The rate at which the acoustic energy converts to heat energy is dependent on the relative amounts of nitrogen, oxygen, carbon dioxide, and water vapor. The amount of attenuation is greatest at large distances and at high frequencies.

Approach - A flight operation that begins in the terminal control area, descends, and lands on an airport runway or pad.

Body-fixed Coordinates - The origin is located at the vehicle center of gravity for fixed wing aircraft or the hub for rotary wing aircraft. X points in the positive direction from the bow to the stern. Y is positive on the starboard side and Z is positive vertically upwards (Figure 2-12).

C-weighting - Frequency weighted metric with relatively flat response between 50 and 5000 Hz.

Cutoff Distance - The slant range beyond which noise propagation is not computed. This point is user defined in single analysis mode, but is set to 30,000 ft for multiple operation mode.

Decibel (dB) - Twenty times the logarithm (base 10) of the ratio between two pressures The reference pressure is 20□*Pa* when referring to sound levels in dB.

Departure - A flight operation that begins on a runway or pad, proceeds down the runway or pad, and climbs to a designated altitude. Departures are defined in the input deck in the true direction of flight.

Earth-fixed Coordinate System - Orthogonal grid coordinate system, which defines the location of the observers positions, the runways and helicopter pads, the ground tracks, and terrain. It is centered at the airport reference point and oriented with the positive Z-axis increasing in altitude, and aligned with gravity.

Euler Angles - The orientation of the body-fixed coordinate system relative to the earth-fixed coordinate system.

Excess Ground Attenuation - See Ground Reflection and Attenuation.

Flight Profile - A set of points that model the geometrical and physical characteristics of a flight operation in the vertical plane. Each profile point contains (1) the cumulative distance traveled on the ground measured relative to the runway threshold; (2) the altitude above reference ground level; (3) the airspeed (4) the roll, angle of attack, and yaw angles; and (5) the nacelle tilt angle. At present, AAM does not account for the wind when determining airspeed and performing a source data look-up. Winds are taken into account by the RNMwea propagation module.

Flight Path Angle - Angle in degrees of the flight track segment measured relative to the earth-fixed coordinate system horizontal X-Y plane (Figure 2-11).

Flight Path-fixed Coordinate System - Figure 2-12 shows the flight path-fixed coordinate system. The origin is located on the flight track at the vehicle center of gravity. X points in the direction of travel. Y is positive on the port side and Z is positive upwards.

Flight Track Segment - A straight line segment between two endpoints, which are specified in three dimensions (X-Y-Z) relative to the earth-fixed coordinate system. Defined at the beginning and end of each segment are the X-Y-Z earth-fixed coordinates; the aircraft speed, the roll angle, angle of attack, yaw angle; and the nacelle tilt angle.

Gravity-Based Coordinate System - Same as earth-fixed coordinate system.

Ground-Fixed Coordinate System - Same as earth-fixed coordinate system.

Ground Reflection and Attenuation - The change in level that occurs due to the interaction between the acoustic ray that travels directly from the source to the receiver and the reflected ray that bounces off the ground while traveling from the source to the receiver.

Ground speed - Actual speed of the aircraft over ground. It is true airspeed adjusted for wind. A headwind decreases groundspeed, while a tailwind increases it. User inputs are relative to ground-based fixed references. At present, AAMdoes not account for winds when determining a simulation trajectory or performing a source data look-up. Winds are taken into account by the RNMwea propagation module.

Ground Track - The trace of the flight path on the horizontal (X-Y) earth-fixed coordinate system. Flight tracks are input as a series of connected line segments and curved segments.

Heading Angle - Direction the aircraft is pointed in the earth-fixed coordinate system as defined by the ground track segment (Figure 2-10). Internal to the program, East=0 degrees, North=90 degrees.

Level - In acoustics, the level of a power-like quantity (i.e., a parameter proportional to acoustic power such as pressure-squared or intensity) is ten times the common logarithm of the ratio of that quantity to a reference quantity of the same kind. The base of the logarithm, the reference quantity and the kind of level must be specified. In air applications, the reference pressure level is 20 micropascal $(20\mu PA)$. Sound pressure level in decibels is then written as $10 \log_{10}\left(p^2 / P^2_{ref}\right)$ or, $20\log_{10}\left(p / P_{ref}\right)$.

Nacelle Tilt Angle - The angle describing the position of the pylon. For helicopters, the nacelle tilt angle is equal to 90 degrees and for the tiltrotor in the airplane mode, the nacelle tilt angle is equal to 0 degrees (Figure 2-11).

Noise - Any disagreeable or unwanted sound.

Pitch - The angle between the body-fixed and earth-fixed coordinate systems. Summation of the angle of attack and the flight path angle (Figure 2-12). Positive pitch is nose up.

Roll - Orientation of the body-fixed coordinate system about the flight path coordinate system X-axis. Port side down is positive roll angle (Figure 2-12).

Slant Distance - The straight line distance in three dimensions between the source location and the observer position.

Spherical Loss Factor ($\Delta\beta$) - Parameter relative to 20 dB, which determines the maximum to minimum geometric slant range factor for which propagation analysis will occur. $R_{max} = R_{min} 10^{(\Delta\beta/20)}$. In multitrack mode $\Delta\beta = 40$ dB.

Spherical Angles - The angles (θ) and (ϕ) describe a point on the sound sphere (Figures 2-14 and 2-17), intersected by a line which connects the center of the sound sphere to the receiver location. (θ) describes the azimuth angle where zero is forward and positive is to starboard. (ϕ) describes the roll angle where zero is directly under the vehicle and positive to starboard.

Yaw - Orientation of the body-fixed coordinate system about the flight path-fixed coordinate system Z-axis. Left turn is positive yaw (Figure 2-12).

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