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Crows Landing Noise Measurement Study:

Summary of Measurements, Data and Analysis for the MD 600N Helicopter

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The U.S. Department of Transportation, John A. Volpe National Transportation Systems Center (Volpe Center), Environmental Measurement and Modeling Division, provided technical support to the Federal Aviation Administration, as a part of a National Rotorcraft Technology Center project to evaluate helicopter noise abatement approach procedures. In November 1996, the Volpe Center measured noise for MD Helicopters Inc.'s MD 600N helicopter. This document describes the planning and execution of the study at National Aeronautics and Space Administration Ames Crows Landing Test Facility in Crows Landing, California. Additionally, the data reduction procedures and data adjusted to standard conditions are presented.

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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

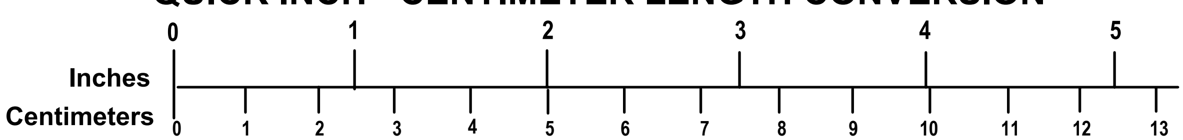
VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

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1.0 INTRODUCTION

As part of a National Rotorcraft Technology Center (NRTC) project to evaluate helicopter noise abatement approach procedures, an Acoustic Flight Test study was performed in October and November 1996, at National Aeronautics and Space Administration (NASA) Ames Crows Landing Test Facility in Crows Landing, California. This flight test program was a joint effort between Sikorsky Aircraft, MD Helicopters Inc., the NASA Langley and Ames Research Centers, the Federal Aviation Administration (FAA), and the Volpe National Transportation Systems Center's Acoustics Facility (VCAF).

This document summarizes measurements of the MD Helicopters Inc. MD 600N helicopter during the Crows Landing Acoustic Flight Test study. Section 1.0 provides a brief introduction to the Flight Test Study. Section 2.0 describes the test helicopter. Section 3.0 discusses the setup and instrumentation. Section 4.0 describes the test series performed. Section 5.0 describes the VCAF data reduction and analysis. Section 6.0 presents VCAF's analysis of the Flight Test Study results. Appendix A summarizes the meteorological data used in the data processing. Appendix B summarizes the tracking data used in the data processing. Appendix C provides complete helicopter noise-power-distance (NPD) data tables and plots of the helicopter L_{AE} NPD curves. Appendix D provides the spectral data used to assign the helicopter to a spectral class in the FAA's Integrated Noise Model (INM), along with the specific INM spectral class assignment. Appendix E provides the complete database files to be included in a future release of the INM. Appendix F provides a list of acronyms and abbreviations.

1.1 Objective

The Crows Landing NRTC flight test program encompassed several objectives, including: 1. Develop flight tests and demonstrate noise abatement flight procedures; and 2. acquire an extensive wide-area rotorcraft acoustics database for predictive model development and validation. The flight configurations described in Section 4.0 of this document consist of level flyover (LFO) events. All data were collected and processed in accordance with the basic procedures defined in Federal Aviation Regulation (FAR) Part 36 (Reference 1). The purpose of this paper is to document MD 600N LFO measurement data for use in the FAA's INM.

1.2 Schedule

A helicopter measurement schedule for the study is presented in Table 1.

Table 1. Study helicopter measurement schedule.

Date	Time Slot	Helicopter
November 4, 1996	7:00 – 9:00	MD 600N

2.0 TEST HELICOPTER DESCRIPTION

A brief description of the MD Helicopters Inc. MD 600N helicopter is provided below. Performance and acoustics data presented in this report are summarized in Appendix E in a table consistent with the INM.

2.1 MD 600N Helicopter

The MD 600N is marketed and supported by MD Helicopters Inc. of Mesa, Arizona. The helicopter is designed to carry two pilots and six passengers.

Selected operational characteristics, obtained from the manufacturer, are presented in Tables 2 and 3.

Table 2. Helicopter characteristics, MD 600N.

Helicopter Manufacturer	MD Helicopters Inc.
Helicopter Model	MD 600N
Helicopter Type	Single Rotor
Max. Gross Takeoff Weight [MGTW] (lb)	4,100
Number and Type of Engine(s)	1 Allison 250-C47[1]
Shaft Horsepower (hp)	600
Max. Continuous Power (hp)	530
Specific Fuel Consumption at Max. Power (lb/hr/hp)	0.48
Never Exceed Speed [V_{NE}] (kts)	155
Max. Speed in Level Flight with Max. Continuous Power [V_H] (kts)	134
Speed for Best Rate of Climb [V_Y] (kts)	85[1]
Best Rate of Climb [ROC] (FPM)	1,350

Table 3. Main and tail rotor specifications, MD 600N.

Characteristic	Main
Rotor Speed (max. RPM)	475
Diameter (in)	330
Chord (in)	6.75
Number of Blades	6
Fundamental Blade Passage Frequency (Hz)	47.5

The MD 600N is equipped with a main overhead rotor and Boeing's no tail rotor (NOTAR) system, which eliminates the need for an exposed tail rotor. The NOTAR system consists of an enclosed variable-pitch fan driven by the main transmission, a circulation control tailboom, a direct jet thruster, and vertical stabilizers. A photograph of the MD 600N is presented in Figure 1.

[1] Some MD600N component and performance specifications are known to have changed since the acoustic flight test in November 1996. In particular, Vy has been updated to a value of 80 kts and Type of Engine has been updated to a Rolls Royce 250-C47M. The values at the time of the flight test are reported above in Table 2.

Figure 1. MD Helicopters Inc. MD 600N test helicopter

3.0 SETUP

3.1 Measurement Facility

The NASA Ames Crows Landing Test Facility is located in Stanislaus County, California, approximately 80 miles southeast of San Francisco. It covers approximately 1,520 acres in the northwestern part of the San Joaquin Valley between the towns of Patterson and Crows Landing. An aerial view of Crows Landing Test Facility is provided in Figure 2.

Figure 2. Aerial view of Crows Landing Test Facility

Over the course of the multi-organizational study, acoustic data were acquired with an 8,000-ft-long by 3,000-ft-wide array consisting of 49 ground plane microphones and six 4-ft microphones. The microphone array covered an area of approximately 0.5 square miles. This microphone array is overlaid on a diagram of Crows Landing in Figure 3.

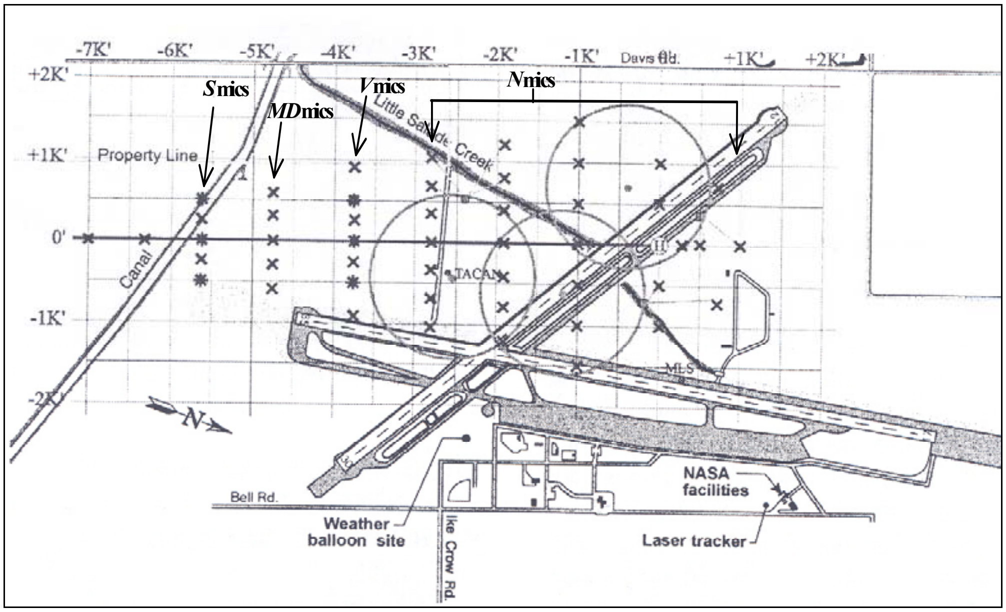

Figure 3. Crows Landing microphone array

In Figure 3, the microphone locations marked with an ✕ are equipped with a ground plane microphone, and the microphone locations marked with an ❋ are equipped with a ground plane microphone and a 4-ft microphone. Also, microphones labeled ***S*** were set up and monitored by Sikorsky; microphones labeled ***M D*** were set up and monitored by MD Helicopters Inc.; microphones labeled ***V*** were set up and monitored by VCAF and the FAA; and microphones labeled ***N*** were set up and monitored by NASA. The logistics of the flight test microphone array are covered in more detail in Reference 2.

3.2 Aircraft Positioning Instrumentation

During the Crows Landing Flight Test, NASA Ames Research Center tracked the flight path of the MD 600N using its Precision Automated Tracking System. This laser tracking system required the installation of a passive retroreflector on the helicopter at the Crows Landing Test Facility. The laser tracker site (identified in Figure 3 above) used an Nd:YAG laser to provide range with an accuracy of 1 ft and azimuth and elevation angles with an accuracy of 0.2 milliradians. The digital information stored in ASCII format included the following parameters: X-Y position, X-Z position, and helicopter speed. The specifics of the laser tracker system are covered in more detail in Reference 2.

3.3 Acoustic Instrumentation

The microphone array, pictured in Figure 3, consisted of 55 microphones, including 49 ground board-mounted microphones and six 4-ft tripod-mounted microphones. The data presented in this report were recorded by VCAF onto digital audio tape using 3 Brüel & Kjær Model 4155 ½-in-diameter microphones positioned at a height of 4 ft. The specific locations of these microphones are identified in Table 4, referenced to an arbitrary local coordinate system.

Table 4. Locations of VCAF 4-ft microphones at Crows Landing.

Microphone	X (ft)	Y (ft)	Z (ft)
V55	-3,750	492	0
V54	-3,750	0	0
V53	-3,750	-492	0

The specifics of the acoustic instrumentation and microphone array design are covered in more detail in Reference 2.

3.4 Meteorological Instrumentation

Weather information was acquired using a tethered weather balloon system. The weather balloon site, identified in Figure 3, consists of an electric winch-controlled, helium-filled balloon, an instrument/telemetry pod, a ground-based receiver/data-controller, and a ground-based support computer. Temperature, relative humidity, wind speed, and wind direction up to a 500-ft altitude were among the weather parameters collected during the Crows Landing Flight Test. The specifics of the weather balloon system are covered in more detail in Reference 2.

4.0 TEST SERIES DESCRIPTION

The data presented in this report represent eight LFO flight configuration events flown by the MD 600N. The reference conditions for each LFO event were: 492 ft altitude, 110 kts speed, and a descent angle of 0 degrees. The specifics of the LFO events are summarized in Table 5.

Table 5. MD 600N LFO reference conditions.

Series[2]	Description	Reference Altitude (ft)	Descent Angle (deg)	Reference Speed (kts)
L100	LFO	492	0	110

Meteorological and tracking data are presented for each of the eight LFO events in Appendices A and B, respectively.

[2] The eight LFO events were adjusted in VCAF's FAR 36 processing software and arithmetically averaged together to form one LFO test series.

5.0 DATA ANALYSIS

This section overviews the data reduction and analysis procedures. NPD data were generated for four different noise metrics: sound exposure level (SEL), denoted by the symbol L_{AE}; maximum, slow-scale, A-weighted sound level (MXSA), denoted by the symbol L_{ASmx}; effective perceived noise level (EPNL), denoted by the symbol L_{EPN}; and tone-adjusted, maximum, slow-scale, perceived noise level (MXSPNT), denoted by the symbol L_{PNTSmx}.

See Appendix C for MD 600N L_{AE}, L_{ASmx}, L_{EPN}, and L_{PNTSmx} NPD data in tabular form and L_{AE} NPD data in plotted form.

5.1 Data Reduction

Field data are collected in various formats, including DAT (acoustic data), ASCII files (laser tracking and meteorological data), and paper annotation (multiple field logs). These data were converted to a uniform digital format for processing by VCAF's analysis software.

5.2 Data Processing

Field data were reduced to a form usable by VCAF's analysis software, and the procedures discussed in FAR Part 36 (Reference 1) were followed.

- **FAR 36** The as-measured sound pressure level data, meteorological data, and tracking data were used by VCAF's processing suite to generate a set of sound level metrics derived using both simplified and integrated procedures. These metrics were derived for the three 4-ft VCAF microphones for each helicopter event. It is beyond the scope of this document to describe in detail the specifics of the FAR 36 data processing. However, a general processing flow diagram is presented in Figure 4. FAR 36 simplified metric data were used for diagnostic purposes only. Data derived using the more rigorous, FAR 36 integrated procedure are presented herein.

  – **Simplified Metrics** Simplified L_{AE}, L_{ASmx}, L_{EPN}, and L_{PNTSmx} metrics were generated using as-measured spectral and tracking data taken at helicopter overhead time. These metrics were strictly used for diagnostic purposes and will not be discussed further in this document.

  – **Integrated Metrics** Integrated L_{AE}, L_{ASmx}, L_{EPN}, and L_{PNTSmx} metrics were generated using the full, spectral, meteorological and tracking time-history data representative of helicopter sound levels within 10 dB of the maximum sound level. The integrated procedure adjusts the as-measured, ½-second spectral data for atmospheric and off-reference conditions to a single, reference condition. These integrated metrics have been assembled into NPDs and are presented in the noise data tables in Appendix C.

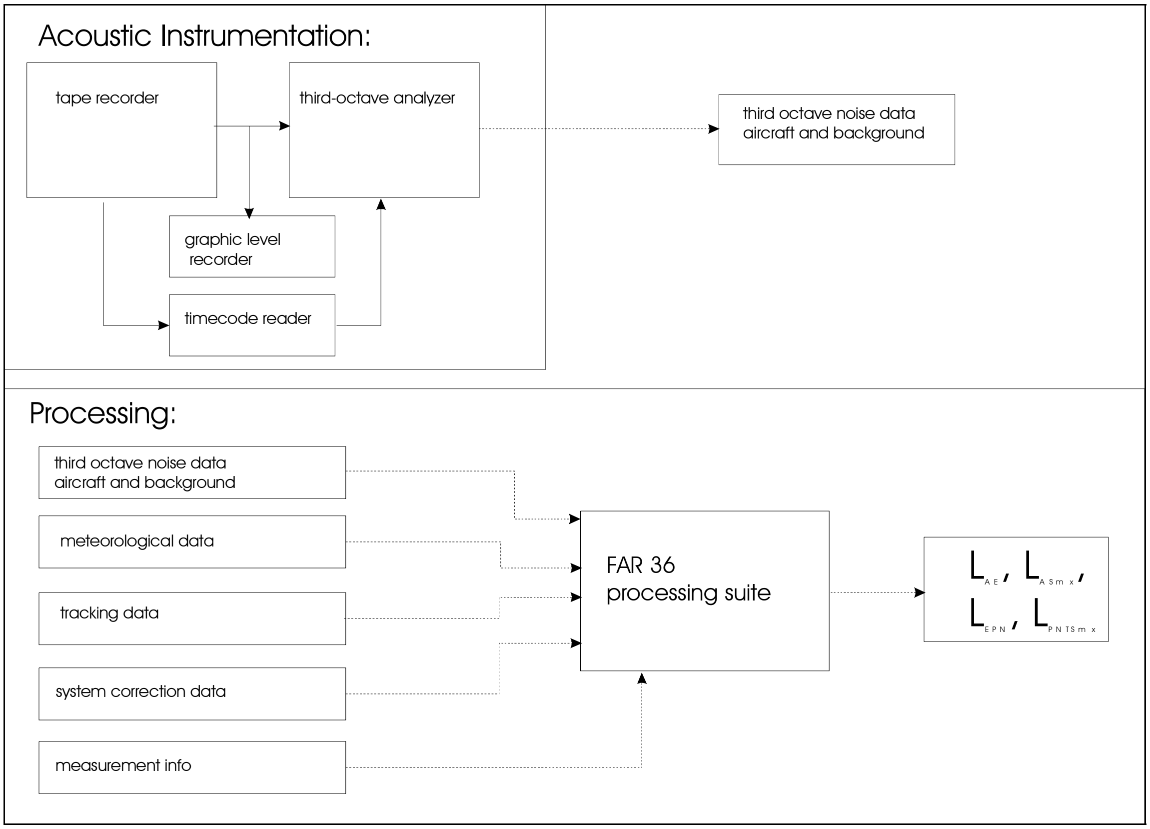

Figure 4. Data processing flow diagram

6.0 RESULTS

The measurement series NPDs presented in Appendix C were generated from noise data collected during eight LFO events which were adjusted in the VCAF's FAR 36 processing software and arithmetically averaged together.

Though the INM currently uses only centerline NPDs to calculate helicopter noise, a helicopter noise calculation methodology to be included in a future release of the INM is expected to utilize centerline and sideline NPDs. Therefore, centerline and sideline NPD data are presented in this report.

6.1 NPD Curves

Left-side, center, and right-side (relative to the direction of flight) noise data were collected for the MD 600N helicopter. The NPDs generated from these noise data, adjusted for reference speed, distance, temperature, and relative humidity and grouped into a LFO measurement series, are presented in tabular form in Appendix C. The L_{AE} NPDs are plotted in Figure C-1.

6.1.1 Reference Speed Duration Adjustment

All of the exposure-based NPD data in Section 6.0 and Appendix C were developed (according to the procedures documented in Section 5.0) using the MD 600N's reference speed of 110 kts. Consistent with SAE AIR 1845 ([Reference 3] which, along with FAR 36, is the foundation for processing data for inclusion in the INM [Reference 4]), NPDs for exposure-based helicopter noise metrics were adjusted to a reference speed of 160 kts. This was performed by applying a duration adjustment to the helicopter NPDs to account for the effect of time-varying helicopter speed. Since the L_{ASmx} and L_{PNTSmx} metrics are assumed to be independent of speed, no duration adjustment was applied to these metrics. The L_{AE} and L_{EPN} values in Appendix E of this report were adjusted prior to entering them into the INM's NPD_CURV.DBF database table, which is included in Appendix E. This duration adjustment was made using the following equation from Section 3.7 of the INM Technical Manual (Reference 5):

$$DUR_{ADJ} = 10 \log_{10}[160/AS_{seg}] \qquad [1]$$

where AS_{seg} is the helicopter reference speed at the closest point of approach between the flight path and the receiver.

All helicopter-specific reference speeds and the corresponding INM duration adjustments to 160 kts are provided in the tracking data tables in Appendix B of this report.

The NPD noise metric information contained in the NPD_CURV.DBF file described in Appendix G and found on the included CD-ROM have been adjusted to a reference speed of 160 kts. No other data presented in this report have been adjusted to 160 kts. Data reference speed information is summarized in Table 6.

Table 6. Helicopter data reference speed information.

Data Set	**Reference Speed**
Section 6.0	110 kts
Appendix B	110 kts
Appendix C	110 kts
Appendix E	160 kts

7.0 REFERENCES

1. Federal Aviation Regulations, Part 36, Noise Standards: Aircraft Type and Airworthiness Certification, Federal Aviation Administration: Washington, DC, September 1992.

2. Jacobs, et al., Acoustic Flight Testing of a Boeing MD Explorer and a Sikorsky S-76B Using a Large Area Microphone Array, American Helicopter Society Technical Specialists Meeting for Rotorcraft Acoustics and Aerodynamics, American Helicopter Society, Inc.: Williamsburg, VA, October 1997.

3. Society of Automotive Engineers, Committee A-21, Aircraft Noise, Procedure for the Calculation of Airplane Noise in the Vicinity of Airports, Aerospace Information Report No. 1845, Society of Automotive Engineers, Inc.: Warrendale, PA, March 1986.

4. Fleming, et al., Integrated Noise Model (INM) Version 6.0 User's Guide, FAA Report No. FAA-AEE-99-03, Federal Aviation Administration: Washington, DC, September 1999.

5. Fleming, et al., Integrated Noise Model (INM) Version 6.0 Technical Manual, FAA Report No. FAA-AEE-02-01, Federal Aviation Administration: Washington, DC, January 2002.

6. Spectral Classes for FAA's Integrated Noise Model Version 6.0, John A. Volpe National Transportation Systems Center Acoustics Facility: Cambridge, MA, December 1999.

APPENDIX A: METEOROLOGICAL DATA

This appendix presents the test day meteorological data used in the processing of all acoustic data. As noted in Section 3.4, temperature, percent relative humidity, wind speed, wind direction, and barometric pressure data were collected. Temperature in degrees Fahrenheit (^{o}F) and relative humidity in percent (%RH), taken at the helicopter's overhead time of day, are presented for each event in Table A-1. All meteorological data were measured with the weather balloon at a height of 10 m.

Changes in outdoor temperature and relative humidity are assumed to be negligible over short periods of time; accordingly, for the purpose of data processing, temperature and %RH were assumed to be constant over the 10-dB down period of each helicopter event.

All acoustic data presented herein were analyzed in accordance with wind speed and direction criteria as specified in FAR 36 (Reference 1).

Table A-1. MD 600N event 10-m meteorological data

Event #	Date	Time of Day	Air Temp (^{o}F)	Humidity (%RH)
L101	11/4/1996	08:28:29	53	80
L103	11/4/1996	08:34:08	54	78
L104	11/4/1996	08:37:27	54	79
L105	11/4/1996	08:40:24	54	77
L106	11/4/1996	08:43:26	55	76
L107	11/4/1996	08:46:30	55	77
L108	11/4/1996	08:49:22	56	76
L109	11/4/1996	08:52:05	56	74

APPENDIX B: TRACKING DATA

This appendix summarizes the laser tracking data used in the processing of the acoustic data measured for each helicopter event, including overhead time, helicopter test altitude (ft), test speed (kts), descent angle (deg), and reference speed (kts). Altitude data represent instantaneous altitude at the overhead time, whereas groundspeed and descent angle – the angle at which the helicopter approaches or departs relative to the ground – represent an average of data representing the sound level time history 10-dB-down duration. All of the helicopter LFO events discussed in this study involved a descent angle very close to 0 degrees. Note that while Table B-1 presents a summary of MD 600N tracking data at overhead time, the full, one-second time history tracking data were utilized in the FAR 36 software suite.

Data presented in Table B-1 include helicopter-specific test and reference conditions. For completeness, values of DUR_{ADJ}, used to adjust exposure-based metrics from these conditions to the 160-kts reference speed required for inclusion in the INM, are provided in the last column.

Table B-1. MD 600N event tracking data.

Event #	Overhead Time	Test Altitude (ft)	Test Speed (kts)	Test Descent angle (deg)	Reference Speed (kts)	DUR_{ADJ} (dB)
L101	08:28:29	514	111	0.1	110	1.6
L103	08:34:08	530	109	0.3	110	1.6
L104	08:37:27	512	103	-0.4	110	1.6
L105	08:40:24	514	111	-0.2	110	1.6
L106	08:43:26	525	105	-0.2	110	1.6
L107	08:46:30	514	110	0.2	110	1.6
L108	08:49:22	511	106	-1.2	110	1.6
L109	08:52:05	517	109	-0.1	110	1.6

APPENDIX C: HELICOPTER NOISE NPD TABLES

Appendix C presents left-side, center, and right-side (relative to the direction of travel) NPDs for the MD 600N helicopter. Though the current version of INM only uses centerline NPDs to model aircraft, the sideline NPDs are presented for completeness and in the event a future release of the INM may utilize sideline NPDs in its calculations. Data presented include tabular NPD results generated for four noise metrics: sound exposure level (SEL), denoted by the symbol L_{AE}, maximum, slow, A-weighted sound level (MXSA), denoted by the symbol L_{ASmx}, effective perceived noise level (EPNL), denoted by the symbol L_{EPN}, and tone-adjusted maximum, slow, perceived noise level (MXSPNT), denoted by the symbol L_{PNTSmx}. The helicopter's reference speed was 110 kts for all data presented in the table.

C.1 MD 600N NPD Tables

Table C-1. MD 600N L100 series NPDs (Ref. Speed = 110 kts).

	L_{AE}			L_{ASmx}			L_{EPN}			L_{PNTSmx}		
Dist. (ft)	**Left**	**Center**	**Right**	**Left**	**Center**	**Right**	**Left**	**Center**	**Right**	**Left**	**Center**	**Right**
200	83.0	81.4	83.9	79.5	77.2	80.7	87.0	86.3	87.9	93.5	91.7	95.1
400	79.4	77.1	80.4	72.8	70.5	74.1	82.8	81.0	83.7	86.3	84.4	87.8
630	76.8	74.3	77.7	68.3	65.9	69.6	79.6	77.4	80.5	81.1	79.2	82.7
1000	73.9	71.3	74.8	63.5	61.0	64.8	76.0	73.6	76.9	75.6	73.5	77.0
2000	69.0	66.4	69.9	55.8	53.2	57.0	70.0	67.4	70.9	67.2	64.6	68.4
4000	63.2	60.7	64.1	47.3	44.7	48.4	62.8	60.1	64.0	57.7	55.0	59.0
6300	58.9	56.5	59.6	41.1	38.6	42.1	57.2	54.4	58.6	51.0	48.1	52.4
10000	54.0	51.7	54.6	34.3	32.0	35.3	48.5	45.2	50.1	40.5	37.1	42.2
16000	48.8	46.6	49.2	26.9	24.8	28.0	36.9	32.7	39.3	28.6	24.2	30.8
25000	44.2	41.8	45.1	20.0	18.2	21.2	22.7	18.4	25.6	2.3	2.6	2.3

C.2 L_{AE} NPD Plots

Presented below is a graphical plot of the final, FAR 36 integrated procedure, L_{AE} NPDs for the MD 600N L100 test series. Sound levels from the centerline and sideline microphones are presented as Left Side, Centerline, and Right Side.

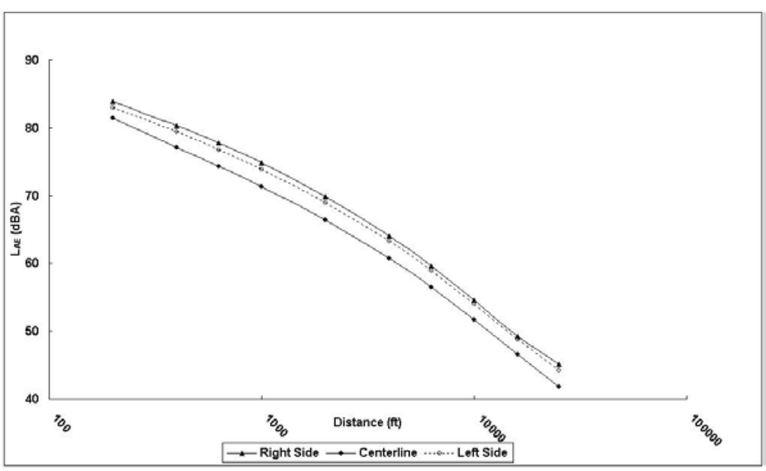

Figure C-1. MD 600N L100 series L_{AE} data (Ref. Speed = 110 kts)

APPENDIX D: SPECTRAL CLASS PROCESSING INFORMATION

The INM utilizes spectral data for some of its calculations; e.g., atmospheric absorption. Accordingly, representative spectral data are presented for the MD 600N L100 Series. Provided below is the 1,000-ft LFO adjusted spectral information used to determine the MD 600N's LFO spectral class. The spectrum was generated from noise data collected during the eight LFO events. These data were adjusted to 1,000 ft in VCAF's FAR 36 processing software and arithmetically averaged together. The resulting spectrum has been normalized to 70.0 dB at 1,000 Hz per the methodology employed in Reference 6. The INM spectral class assignment determined for the MD 600N is listed in Table D-1.

Table D-1. INM spectral class assignments.

Helicopter	**Operation**	**Spectral Class Assignment**
MD 600N	LFO	303

The spectral data used to determine the spectral class assignment are presented in Figure D-1.

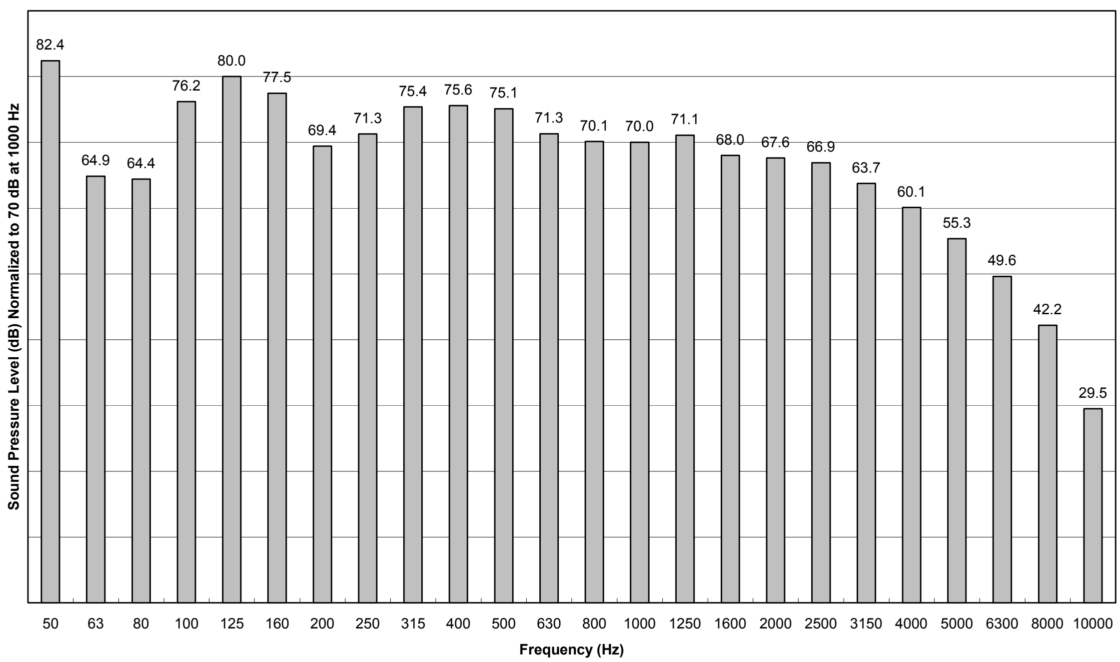

Figure D-1. MD 600N average 1,000-ft L100 series LFO spectrum (normalized)

APPENDIX E: INM DATABASE TABLES

E.1 Helicopter Database File Formats

Instructions on how to build the necessary INM database tables, including AIRCRAFT.DBF, NOIS_GRP.DBF, NPD_CURV.DBF, PROFILE.DBF, and PROF_PTS.DBF, can be found in Appendices E and F of the INM User's Guide (Reference 4). Included in the attached CD-ROM are completed versions of these files constructed using Crows Landing NPD data from Appendix C and the helicopter performance data presented for the MD 600N in Section 2.0. As discussed in Section 6.0, each measurement series NPD was generated from noise data collected during eight LFO events. These data were adjusted in VCAF's FAR 36 processing software and arithmetically averaged together.

Since the INM currently uses only centerline data to calculate aircraft noise, only one designated centerline NPD is included in the database files. A CD-ROM which contains all of the database files mentioned in this section has been included with this report.

E.1.1 Database Table Notes

E.1.1.1 NPD_CURV.DBF Reference Speed Duration Adjustment

As discussed in Section 6.0, INM NPDs for exposure-based noise metrics are derived for a reference speed of 160 kts. The MD 600N NPD noise metrics contained in the NPD_CURV.DBF file described in this appendix and found on the included CD-ROM are the only data in this report which have been adjusted to a reference speed of 160 kts.

E.1.1.2 PROFILE.DBF Spectral Class Information

The spectral class information included in the PROFILE.DBF file is based on an analysis of adjusted 1,000-ft spectra. These spectra, presented in Appendix D, consist of actual Crows Landing data, and, as discussed in Appendix D and Reference 6, are used by the INM to perform calculations which require spectral data; e.g., atmospheric absorption.

E.2 INM Version 6.1 vs. As-Measured L_{AE} Helicopter Data

A database file containing helicopter NPD data was distributed with INM Version 6.0c to facilitate simplified, uniform modeling of helicopter operations in INM. Consistent with this approach, a database file containing NPD data has been developed for the MD 600N and included in Appendix E. MD 600N performance data in Section 2.0 may be used to model the helicopter in INM. Distance, altitude, and speed data for the MD 600N are presented in Appendix B. These data were used to model MD 600N LFO events in INM Version 6.1.

E.2.1 Thrust Setting Identifiers

In keeping with the modeling technique used in the INM 6.0c database file containing helicopter NPD data, nominal thrust settings (THR_SET) of 1 and 2 were assigned to the two MD 600N LFO NPDs contained in the Crows Landing NPD_CURV.DBF file to be used in INM Version 6.1. The characteristics of these NPDs are described in Table E-1.

Table E-1. Thrust setting identifiers in INM Crows Landing helicopter modeling.

	MD 600N		
Operation Mode	**Thrust Setting**	**Ref. Speed (kts)**	**Ref. Descent Angle (deg)**
LFO[3]	1	110 (0.8*V_H)	NA
LFO	2	110 (0.8*V_H)	NA

Centerline microphone field measurement data collected for the MD 600N are compared with INM Version 6.1 predictions for single event LFOs. The L_{AE} results from these sensitivity tests are presented in Figure E-1. Good agreement is illustrated between the INM predictions and the as-measured data. The INM generally produced sound levels within about 2.0 dB(A) of the as-measured data. The conservative "bias" high in the predicted sound levels may be attributed to the process of averaging the left-, center and right-side NPDs for INM Version 6.1; a future version of the INM, which utilizes all three sets of NPDs, will model this flight condition even more accurately.

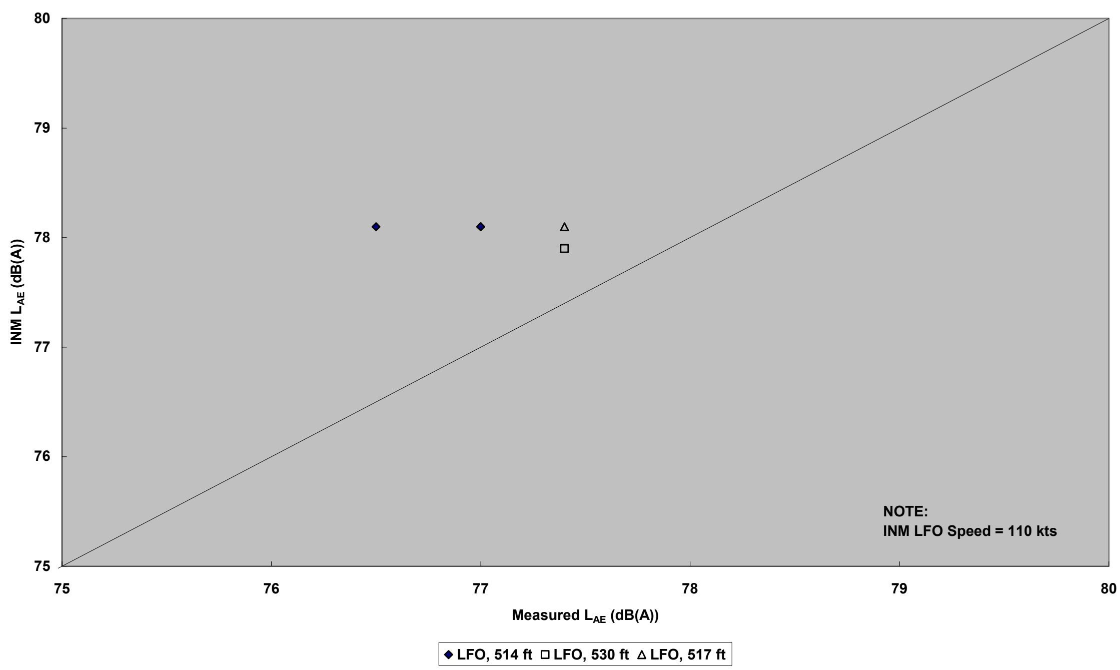

Figure E-1. MD 600N INM vs. measured centerline L_{AE} comparison

[3] Though the INM requires at least two LFO NPD curves, only one LFO NPD curve was measured. Therefore, the LFO NPD curve was duplicated in the INM.

APPENDIX F: ACRONYMS AND ABBREVIATIONS

ASCII	American Standard Code for Information Interchange
$\mathbf{AS_{SEG}}$	Ref. speed at closest point of approach between flight path and receiver (kts)
dB	Decibel, a unit of noise level or noise exposure level
dB(A)	Decibel with A-weighting applied
DBF	dBase IV database file format
$\mathbf{DUR_{ADJ}}$	Duration adjustment
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FPM	Feet Per Minute
ft	Feet
hp	Horsepower
hr	Hour
Hz	Hertz
INM	Integrated Noise Model
kts	Knot(s)
$\mathbf{L_{AE}}$	Sound exposure level
$\mathbf{L_{ASmx}}$	Maximum, slow-scale, A-weighted sound level
lb	Pound(s) force or weight
$\mathbf{L_{EPN}}$	Effective perceived noise level
LFO	Level Flyover
$\mathbf{L_{PNTSmx}}$	Tone-adjusted, maximum, slow-scale, perceived noise level
MGTW	Maximum gross takeoff weight (lb)
NASA	National Aeronautics and Space Administration
NOTAR	No tail rotor
NPD	Noise-Power-Distance
NRTC	National Rotorcraft Transportation Center
ROC	Rate of Climb
RPM	Revolutions Per Minute
VCAF	Volpe Center Acoustics Facility
Volpe	John A. Volpe National Transportation Systems Center
$\mathbf{V_H}$	Maximum speed in level flight with maximum continuous power (kts)
$\mathbf{V_N}$	Never exceed speed (kts)
$\mathbf{V_Y}$	Speed for best rate of climb (kts)