Federal Aviation Administration

Memorandum

Date: October 17, 2012

To: Carolina Forrester, Manager, Quality Integration and Process Division, AQS-100 and Gary Powell, Acting Division Manager, Flight Technology and Procedures Division, AFS-400

CC: Julie Marks, ~~Manager,~~ Environmental Policy and Operations, AEE-400

From: Rebecca Cointin, Manager, Noise Division, AEE-100

Subject: Approval of Aerobatic Practice Area (APA) noise equivalent methodology

PURPOSE

This memorandum provides approval on the use of the Volpe National Transportation System Center (Volpe) Report DOT-VNTSC-FAA-12-06 named "Use of Analysis of Aerobatic Aircraft Noise using the FAA's Integrated Noise Model" for use in National Environmental Policy Act (NEPA)[1] analysis under FAA Order 1050.1E (Change 1) *Environmental Impacts: Policies and Procedures*. Separate guidance pertaining to use of the data for analysis of *Categorical Exclusions for Regulatory Actions* (CATEXs) (including FAA Order 1050.1E, paragraph 312b) will be forthcoming. The Volpe report is provided in **Attachment 1** for reference.

APPLICABILITY

FAA Order 1050.1E, Appendix A, Section14.2b, states that "[a]ll detailed noise analyses must be performed using the most current version of the FAA's Integrated Noise Model (INM), Heliport Noise Model (HNM), or Noise Integrated Routing System (NIRS)." It goes on to state that "[u]se of an equivalent methodology and computer model must receive prior written approval from the FAA's Office of Environment and Energy (AEE)." In addition, Section 14.2c, states that "[u]nless it can be justified, all noise analysis must be performed using the FAA's INM, HNM, and/or NIRS standard and default data." It goes on to state that "[m]odification to standard or default data requires written approval from the Office of Environmental and Energy (AEE)."

Due to the unique nature of the practice routines used in Aerobatic Practice Areas (APA), the standard and default data in INM is not appropriate for use when modeling the noise consequences of the aircraft performing in the APA. Hence, a study was performed by Volpe to

[1] National Environmental Policy Act of 1969 (NEPA), as amended, 42 United States Code (U.S.C.) §§4321 et seq.

model the unique characteristics of aerobatic routines that are performed in APAs. The study expanded upon a study completed by Volpe that was documented in a May 5, 2006 memo with the subject Aerobatic Aircraft Noise Study Technical memorandum to AQS. In addition, this report enhanced the data in the 2006 memo by remodeling the routines in a more recent version of INM and should be used in place of the 2006 memo results where the same aircraft and routines were modeled. This study was performed at a figurative airport at mean sea level and used seven aircraft to represent one of each of seven different types of aircraft categories: low weight piston, mid weight piston, high weight piston, high weight radial, high power radial (warbird), mid power jet, and high power jet. See Appendix B in the Volpe Report for how the aerobatic aircraft considered in this study were mapped to each of these categories. Each of the aircraft was modeled using one or more of five aerobatic routines: sportsman, intermediate freestyle, advanced, unlimited (to 328 ft above ground level (AGL)), and unlimited (to 20 feet AGL). Appendix E of the Volpe report contains descriptions of each of the routines. The resulting analysis provides a non-standard methodology to determine the noise consequence of an APA on the surrounding communities. The methodology is outlined in Section 4.2 of the Volpe report (with examples in Appendix D).

AEE has reviewed the methodologies and data used to create the Volpe report and approves the use of the data in the report for determining the noise consequence of a proposed certificate of waiver for APAs where the routines and maneuvers[2] listed above are equivalent to those that are being flown by one of the aircraft listed in **Attachment 2** in this memorandum. If an analysis for an APA waiver includes a routine or maneuver that is not equivalent to one listed above (and described in Appendix E of the report) or an aircraft other than those listed in **Attachment 2** of this memorandum, per Section 14.2b and 14.2c, separate prior written approval from AEE is needed because they are considered new methodologies and non-standard data.

Attachment 3 provides a flow diagram with step-by-step instructions for using this memorandum and the Volpe Report for determining the noise consequence of a proposed certificate of waiver for APAs.

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[2] The routines modeled represent a compilation of maneuvers provided by the IAC, available in Appendix E of the Volpe Report. These routines can be considered a conservative representation of the routines that would be flown in any APA.

Attachment 1

Volpe Report DOT-VNTSC-FAA-12-06
"Use of Analysis of Aerobatic Aircraft Noise using the FAA's Integrated Noise Model"

DOT/FAA/AEE/2012-06
DOT-VNTSC-FAA-12-06

Analysis of Aerobatic Aircraft Noise Using the FAA's Integrated Noise Model

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Final Report

U.S. Department of Transportation

Federal Aviation Administration

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13. ABSTRACT (Maximum 200 words) This project has three main objectives. The first objective is to model noise from complete aerobatic routines for a range of aircraft. The second is to compare modeled and previously measured aircraft noise from complete aerobatic routines for a range of aircraft. The third is to model the noise from up to 50 daily aerobatic routines for a range of aircraft. The end result of this analysis is a matrix of modeled noise results for a range of aircraft performing a variety of aerobatic routines. The FAA can now utilize these results to help set the technical threshold for approving NEPA analyses for aircraft performing aerobatic routine represented within the matrix.				
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METRIC/ENGLISH CONVERSION FACTORS

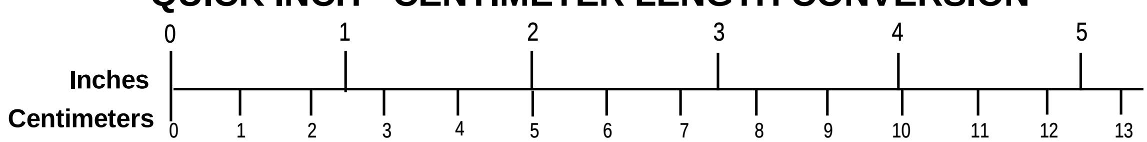
ENGLISH TO METRIC

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 CONVERSIO

°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. SD Catalog No. C13 10286

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EXECUTIVE SUMMARY

This report presents an analysis of noise from complete aerobatic routines for a range of aircraft modeled with the Federal Aviation Administration's (FAA) Integrated Noise Model (INM) Version 7.0c. The project has three main objectives. The first objective is to model noise from complete aerobatic routines for a range of aircraft in INM. The second is to compare INM modeled and previously measured aircraft noise from complete aerobatic routines for a range of aircraft. The third is to model the noise from up to 50 daily aerobatic routines for a range of aircraft in INM.

Seven aircraft (representing a range of aircraft that typically perform aerobatic routines) are modeled performing a range of aerobatic routines in INM. These modeled noise results are found to be in good agreement with the noise results from the 2006 analysis report "Aerobatic Aircraft Noise Study: Technical Memorandum", which were estimated from noise measurement data.

The aircraft are subdivided into two analysis categories ((1) medium to light propeller aircraft, and (2) heavy propeller aircraft and jets), and the corresponding noise results are compared against the 0.5 mile recommended distance between the aerobatic routine (at a point directly below the center of the aerobatic box) and noise sensitive receivers, established in the 2006 report. When considering the noise from 50 identical aerobatic routines, all four light to medium weight propeller aircraft result in noise levels well below the Federal land use guideline of 65 dBA DNL at a distance of 0.5 miles between the aerobatic routine and noise sensitive receivers. For the one heavy weight propeller aircraft and two jets, the noise from 50 identical aerobatic routines exceeds the 65 dBA DNL threshold at 0.5 miles, but meets the threshold at a distance of 2 miles.

The end result of this analysis is a matrix of modeled noise results for a range of aerobatic aircraft performing a variety of aerobatic routines, along with a method to estimate the general noise from a combination of different aerobatic routines performed by different aircraft. The

results may be used to inform National Environmental Policy Act (NEPA) analyses for aircraft performing aerobatic routine represented within the matrix.

1 INTRODUCTION

The noise due to aircraft operations in the vicinity of airports is commonly modeled with Federal Aviation Administration's (FAA) Integrated Noise Model (INM)[1] for National Environmental Policy Act (NEPA) analyses. Although aerobatic maneuvers are often undertaken in the vicinity of airports, aerobatic routines have not historically been modeled in these analyses, primarily due to a lack of aerobatic maneuver noise source data.

In 2005 and 2006, the United States Department of Transportation (USDOT) John A. Volpe National Transportation Systems Center (Volpe) conducted a noise measurement and modeling study of aerobatic aircraft at the request of the FAA[2]. The two objectives of this previous study were to: (1) measure high quality aerobatic source noise data for several representative aircraft for inclusion in INM; and (2) model complete aerobatic routines in INM and compare those results with measured noise levels. Noise source data were measured and processed for five aerobatic aircraft; the Zivko Edge 540 (Edge), the Extra EA-230 (Extra), the Sukhoi SU-29 (Sukhoi), the Aviat Pitts S-2C (Pitts), and the American Champion Decathlon (Decathlon). International Aerobatic Club (IAC) Sportsman Known 2005 routines were measured and modeled in INM for the Extra and the Pitts, and an IAC Intermediate 2005 Freestyle routine was measured and modeled for the Sukhoi. The measured noise levels were then used to estimate the day night average sound level metric (L_{dn} or DNL) for up to 50 identical aerobatic routines. The results for this study were summarized in "Aerobatic Aircraft Noise Study: Technical Memorandum" in 2006[2], which is included in Appendix F of this report.

While the 2006 report concluded that the noise from the aerobatic routines flown in that study would not have exceeded 65 dBA DNL at distances 0.5 mile or more from the center of the practice box[*], the study was limited to estimated noise levels for only three aircraft, each performing a single aerobatic routine (although up to 50 identical routines were estimated). The

[*] The 2006 report concluded that the noise from the aerobatic routines flown in that study would not have exceeded 65 dBA DNL at distances 0.25 mile or more from the center of the practice box, and then made a conservative recommendation to locate heavily utilized aerobatics practice boxes 0.5 mile or more from noise sensitive receivers.

goal of this report is to present a noise analysis for a range of complete aerobatic routines and aircraft modeled with INM. This will provide a matrix of modeled noise results that the FAA can utilize for performing NEPA analyses that include a range of aircraft performing aerobatic routines.

This report is organized into five sections. In Section 2, aerobatic aircraft noise modeling in INM is discussed focusing on aircraft acoustic source data (Section 2.1) and the performance modeling of aerobatic routines (Section 2.2). Section 3 presents INM noise modeling results. These results include remodeled aerobatic routines presented in the 2006 study (Section 3.1), aerobatic routines for the Edge and Sukhoi (Section 3.2), and a complete range of aerobatic routines for a range of aerobatic aircraft (Sections 3.3 and 3.4). Section 4 presents a summary and analysis of the results, including a method for estimating general noise from a combination of aircraft performing different aerobatic routines. Conclusions and recommendations are presented in Section 5. References can be found in Appendix A, and the complete INM input data and results are presented in Appendix B and Appendix C. Examples of computing the estimated noise from a combination of aircraft performing different aerobatic routines is presented in Appendix D. Appendix E includes the descriptions of the aerobatic routines modeled in this analysis. Finally, the 2006 technical memorandum is provided in Appendix F for reference.

2 NOISE MODELING OF AEROBATIC AIRCRAFT WITH INM

The technical goal of this research was to model a range of complete aerobatic routines for a range of aerobatic aircraft modeled with INM. Seven aircraft categories were modeled in this the study: low weight piston engine aircraft (represented by the Pitts), mid weight piston engine aircraft (represented by the Edge), high weight piston engine aircraft (represented by the Extra), high weight radial engine aircraft (represented by the Sukhoi), mid power jet (represented by the Mikoyan-Gurevich MiG-15 [MiG-15]), high power jet (represented by the Boeing (formerly McDonnell Douglas) F-15 Eagle [F-15]) and high power radial engine aircraft or "warbird" (represented by the Grumman F7F Tigercat [F7F]). Five different aerobatic routines were modeled in this study: IAC Sportsman, Intermediate, Advanced, Unlimited and a modified Unlimited routine scaled to a minimum altitude of 20 feet above field elevation (AFE). The Extra, Edge, Sukhoi and Pitts were all modeled flying all five aerobatic routines. The two jets and the warbird were only modeled flying the Sportsman routine, as they do not typically fly the other four routines. The aircraft acoustic source data required to model these seven aircraft in INM are discussed in Section 2.1. The methods for modeling the aircraft performance of the aerobatic routines in INM are discussed in Section 2.2.

2.1 AEROBATIC AIRCRAFT ACOUSTIC SOURCE DATA

The aerobatic aircraft acoustic source data used in this study are a combination of previously measured data and traditional INM data. The source data for the Pitts, Edge, Extra and Sukhoi were measured and reported on in the 2006 report[2]. The MiG-15, F-15 and F7F utilize noise data from the INM 7.0c database, with the MiG-15 based on the INM noise data for the Hawker Hunter with a Rolls-Royce Avon 207 turbojet engine, and the F7F similarly based on the noise data for the Convair C-131 Samaritan with Pratt & Whitney R-2800 radial engines. Note that the performance characteristics of the MiG-15, F-15, and F7F were developed from data collected by the FAA from actual aerobatic routines flown with these aircraft – the performance data used in the aerobatic modeling for these aircraft did not come from the INM. The seven aerobatic aircraft modeled in this study represent a range of aerobatic aircraft presented in Appendix A, and are considered conservative representations of those aircraft in each respective category.

The aircraft acoustic source data in the INM database are represented by Noise-Power-Distance (NPD) and spectral class data. NPDs are a set of aircraft-, noise metric-, and operational mode-specific noise levels at given thrust level over a range of distances from the aircraft source (200 ft to 25,000 ft). NPDs represent both the aircraft acoustic source and acoustic propagation in INM for aircraft approach, departure and level flight operations. A modified set of NPD data were developed for the four aerobatic aircraft in the 2006 report (Pitts, Edge, Extra and Sukhoi), that included additional aircraft attitudes that are typical for aerobatic routines: high speed (around 135 mph in both directions of travel; North to South, and South to North), low speed (around 70 mph), acceleration (accelerating using full power), inverted (at high speed), knife-edge facing left and facing right (at high speed)[*]. The aerobatic maneuvers in the study were modeled as sequences of these four or six altitude-specific NPDs for each aircraft. These altitude-specific NPDs were utilized in conjunction with the aircraft position and speed information to model aircraft level-flight events and aerobatic sequences.

The F-15, F7F and MiG-15 were all modeled with noise data from the INM 7.0c database, which only include approach and departure NPD data.

2.2 PERFORMANCE MODELING OF AEROBATIC ROUTINES

Because INM was primarily designed to model aircraft operations in the vicinity of an airport and not aerobatic maneuvers, special INM profiles were developed to model the aircraft performance during aerobatic routines. The aerobatic routines modeled in this analysis are the IAC Sportsman Known 2005, Intermediate Known 2005, Advanced Known 2011, Unlimited Known 2011 and a modified Unlimited Known 2011 routine scaled to a minimum altitude of 20 feet above field elevation (AFE)[†]. These routines are described in Appendix E. The methods for modeling the performance of the aerobatic routines in INM are documented in the 2006 report

[*] Some of the aircraft were unable to perform all six types of aircraft attitudes as level-flight events. For these aircraft, a smaller amount of aircraft attitudes were measured, which resulted in a smaller modified NPD data set. As such, knife-edge facing left and facing right NPDs could not be developed for the Extra and the Pitts.

[†] The IAC 2005 Known routines were modeled for the Sportsman and Intermediate routines in this analysis, to be consistent with the modeling in the 2006 letter report. The latest routines (2011 Known, at the start of this analysis) were used to model the remainder of the aerobatic routines (Advanced and Unlimited).

(also included in Appendix F of this report) It is important to note that the modeled aerobatic routines did take into account the aircraft entering and exiting the practice box, but they did not account for approaches to and departures from the study airport.

For the Extra, Pitts, and Sukhoi, actual aerobatic routines were measured and translated to INM model performance data as part of the 2006 report. For this report, translations of the 2011 Advanced and Intermediate routines provided by the FAA were used as the source for the INM performance data. Additional data on the minimum altitude threshold for all five aerobatic routines were also provided by the FAA. The data were translated into the same format as that used in the 2006 report. The data required the segments of each maneuver is:

- Direction of travel
- Airspeed
- Duration
- Flight path angle relative to the ground
- Thrust

These data are sufficient to produce the Profile Points data required by the INM. These INM required data are the distance along the flight track, altitude above the ground, speed of the aircraft and thrust. The same data are also used to calculate the flight track (i.e., position of the aircraft in an X-Y coordinate system relative to the INM study center).

Note that for the four original aerobatic aircraft, the noise data were associated with a particular flight mode, and not an actual thrust value. These flight modes were used as surrogates for thrust. For the jets and the F7F, the thrust settings associated with full power departures (without afterburner, in the case of the F-15) were used for the high power segments of the maneuvers, and the lowest departure power setting available was used for the low power segments of the maneuvers. In general, level and ascending segments were modeled with full power, while descents were modeled with the lowest power settings.

A minor error in the 2006 process was also corrected in the modeling of vertical maneuvers. The 2006 error resulted in a misalignment of the profile points and the flight track during vertical maneuvers. The small number of vertical maneuvers in the original 2006 work meant the error was relatively small (and hence was undiscovered in that work); but in the current work, with the large percentage of vertical maneuvers in the Advanced and Unlimited routines, this error was quite pronounced. The original routines, as well as the new routines, were run with the corrected process in this analysis.

3 NOISE MODELING RESULTS

A test matrix of the aircraft and corresponding aerobatic routines modeled in INM is presented in Table 1. Routines marked with an "A" were originally modeled for the 2006 report, and have been remodeled for this analysis (Section 3.1)[*]. Routines marked with a "B" are the complete range of aerobatic routines for the Edge and Sukhoi (Section 3.2). Routines marked with a "C" are additional aerobatic routines (Sections 3.3 and 3.4). Routines marked with an "n/a" represent routines not flown by the corresponding aircraft. This test matrix represents the range of common aerobatic routines performed by the current aerobatic aircraft fleet.

Table 1. Aerobatic Aircraft Test Matrix

		Aerobatic Routines Modeled in INM				
Category	**Representative Aircraft**	**Sportsman Known 2005 (to 1500 ft AGL[†])**	**Intermediate Known 2005 (to 1200 ft AGL)**	**Advanced Known 2011 (to 800 ft AGL)**	**Unlimited Known 2011 (to 328 ft AGL)**	**Unlimited Known 2011 (to 20 ft AGL)**
high weight piston	Extra EA-230	A	C	C	C	C
mid weight piston	Edge 540	B	B	B	B	B
high weight radial	Sukhoi SU-29	B	A	B	B	B
low weight piston	Pitts S-2C	A	C	C	C	C
mid power jet	MiG-15	C	n/a	n/a	n/a	n/a
high power jet	F-15	C	n/a	n/a	n/a	n/a
high power/radial	F7F	C	n/a	n/a	n/a	n/a

3.1 PREVIOUS ANALYSIS NOISE RESULTS

In the 2006 study, the noise from the complete aerobatic routines was estimated from measured data at five microphone locations (up to one mile away from the center of the practice box, see Figure 1), rather than modeled explicitly using INM. That analysis included estimated noise levels for 50 identical Sportsman routines for the Pitts and Extra, and 50 identical Intermediate

[*] Because the Sportsman and Intermediate routines had different minimum altitude thresholds in the 2006 study (1000 ft AGL) than those provided by the FAA for this analysis (1500 ft AGL for the Sportsman and 1200 ft AGL for the Intermediate), these routines were modeled twice. The old thresholds were modeled in Section 3.1 analyses for comparison with the 2006 report, and the new thresholds were used in the remainder of the analysis (Sections 3.2 through 3.4).

[†] Above ground level (AGL).

routines for the Sukhoi*. In order to baseline this analysis; the same aerobatic routines were modeled in INM 6.2†. The DNL results for 50 identical routines are presented in Table 2, and a comparison with the estimated DNL results from the corresponding 2006 runs is presented in Table 3.

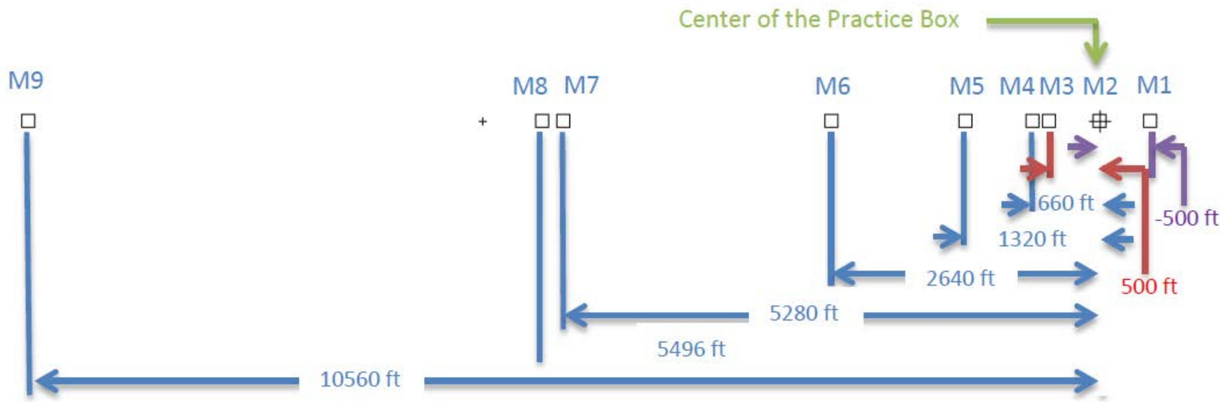

Figure 1. Measured Microphone Positions and Modeled Grid Points‡

Table 2. Estimated and INM 6.2 Modeled Noise Results from 50 Aerobatic Routines

		Noise from 50 Routines [2006 study, Estimated] (dBA DNL)			Noise from 50 Routines [INM 6.2] (dBA DNL)		
Distance (ft)§	Mic	Extra [Sportsman] (to 1000 ft AGL)	Pitts [Sportsman] (to 1000 ft AGL)	Sukhoi [Intermediate] (to 1000 ft AGL)	Extra [Sportsman] (to 1000 ft AGL)	Pitts [Sportsman] (to 1000 ft AGL)	Sukhoi [Intermediate] (to 1000 ft AGL)
-500	M1	56.1	57.8	56.8	56.6	55.7	57.6
0	M2	56.3	58.8	56.3	57.7	56.6	57.5
660	M4	53.6	57.4	54.8	57	56	56
1320	M5	51.2	55.4	52.8	54.7	54.1	53.7
5496	M8**	42.4	45.7	44.9	37	37.3	38

* In the 2006 study, the duration of a single aerobatic routine was between 2 and 5 minutes in length. Time histories for these aerobatic routines are presented in Appendix F.

† INM 6.2 was used for the measured versus modeled level flyover comparisons in the 2006 study.

‡ Only microphones M1, M2, M4, M5 and M8 were used in the 2006 study.

§ Distance represents the horizontal slant distance from directly below the center of the aerobatic routine in feet.

** Note that in the 2006 report, microphone M8 (at 5496 ft) was labeled M7. The microphone was renamed in this analysis to allow for a microphone at 5280 ft (now labeled M7).

Table 3. Difference between Estimated and INM 6.2 Modeled Noise Results from 50 Aerobatic Routines

		Difference in Noise from 50 Routines [INM 6.2 - Estimated] (ΔdBA DNL)		
Distance (ft)	**Mic**	**Extra [Sportsman] (to 1000 ft AGL)**	**Pitts [Sportsman] (to 1000 ft AGL)**	**Sukhoi [Intermediate] (to 1000 ft AGL)**
-500	M1	0.5	-2.1	0.8
0	M2	1.4	-2.2	1.2
660	M4	3.4	-1.4	1.2
1320	M5	3.5	-1.3	0.9
5496	M8	-5.4	-8.4	-6.9

Table 3 shows good agreement between the estimated and the INM 6.2 modeled noise results for these aerobatic routines, except for at the farthest distance (5496 ft). It is important to note that INM accounts for noise directivity to the side of an aircraft with a lateral attenuation adjustment[1, 3], which accounts for sound attenuation due to aircraft shielding, directivity and ground absorption. The lateral attenuation adjustment in INM is study geometry and aircraft position dependent. Lateral attenuation was not specifically accounted for in the 2006 estimated DNL levels, since they were based on measured data that already included aircraft shielding, directivity and ground absorption. INM 6.2 allows propeller aircraft to be modeled without the lateral attenuation adjustment. The INM 6.2 modeled results without lateral attenuation are presented in Table 4, and a comparison with the estimated DNL results from the corresponding 2006 runs is presented in Table 5.

Table 4. INM 6.2 Modeled Noise Results from 50 Aerobatic Routines (without Lateral Attenuation)

		Noise from 50 Routines [INM 6.2] (dBA DNL)		
Distance (ft)*	**Mic**	**Extra [Sportsman] (to 1000 ft AGL)**	**Pitts [Sportsman] (to 1000 ft AGL)**	**Sukhoi [Intermediate] (to 1000 ft AGL)**
-500	M1	56.6	55.7	57.6
0	M2	57.7	56.6	57.5
660	M4	57	56.1	56
1320	M5	54.8	54.1	53.9
5496	M8	42.4	43	43.1

Table 5. Difference between Estimated and INM 6.2 Modeled Noise Results from 50 Aerobatic Routines (without Lateral Attenuation)

		Difference in Noise from 50 Routines [INM 6.2 - Estimated] (ΔdBA DNL)		
Distance (ft)	**Mic**	**Extra [Sportsman] (to 1000 ft AGL)**	**Pitts [Sportsman] (to 1000 ft AGL)**	**Sukhoi [Intermediate] (to 1000 ft AGL)**
-500	M1	0.5	-2.1	0.8
0	M2	1.4	-2.2	1.2
660	M4	3.4	-1.3	1.2
1320	M5	3.6	-1.3	1.1
5496	M8	0	-2.7	-1.8

Table 5 shows much better agreement between the estimated noise levels and the INM 6.2 noise levels at the farthest distance when lateral attenuation is turned off (within -2.7 to 3.6 dBA DNL up to 1 mile from directly below the center of the aerobatic routine). Not only do these comparisons shows that the INM 6.2 modeled results are in reasonably close agreement with the 2006 results, they also indicate that the lateral attenuation adjustment in INM 6.2 should not be used in this analysis.

* The analysis points selected in Table 4 through Table 8 correspond to the measurement positions in the 2006 study.

Since 2006, INM has gone through numerous updates. The latest version is INM 7.0c, which uses an updated version of the lateral attenuation adjustment. The INM studies were imported into and rerun in INM 7.0c in order to develop a baseline using the most recent release of the software. The INM 7.0c modeled results with and without lateral attenuation are presented in Table 6; comparisons with the estimated DNL results from the corresponding 2006 runs are presented in Table 7. In addition, comparisons with the INM 6.2 modeled results from the corresponding 2006 runs are presented in Table 8.

Table 6. INM 7.0c Modeled Noise Results from 50 Aerobatic Routines (with and without Lateral Attenuation)

		Noise from 50 Routines with Lateral Attenuation [INM 7.0c] (dBA DNL)			Noise from 50 Routines without Lateral Attenuation [INM 7.0c] (dBA DNL)		
Distance (ft)	**Mic**	**Extra [Sportsman] (to 1000 ft AGL)**	**Pitts [Sportsman] (to 1000 ft AGL)**	**Sukhoi [Intermediate] (to 1000 ft AGL)**	**Extra [Sportsman] (to 1000 ft AGL)**	**Pitts [Sportsman] (to 1000 ft AGL)**	**Sukhoi [Intermediate] (to 1000 ft AGL)**
-500	M1	56.7	55.7	57.7	56.8	55.8	57.7
0	M2	57.8	56.7	57.6	57.9	56.8	57.6
660	M4	57.1	56.1	55.9	57.2	56.2	56
1320	M5	54.6	54	53.6	54.9	54.2	53.9
5496	M8	39.8	40.3	40.8	42.5	43.1	43.2

Table 7. Difference between Estimated and INM 7.0c Modeled Noise Results from 50 Aerobatic Routines (with and without Lateral Attenuation)

		Difference in Noise from 50 Routines with Lateral Attenuation [INM 7.0c - Estimated] (ΔdBA DNL)			Difference in Noise from 50 Routines without Lateral Attenuation [INM 7.0c - Estimated] (ΔdBA DNL)		
Distance (ft)	**Mic**	**Extra [Sportsman] (to 1000 ft AGL)**	**Pitts [Sportsman] (to 1000 ft AGL)**	**Sukhoi [Intermediate] (to 1000 ft AGL)**	**Extra [Sportsman] (to 1000 ft AGL)**	**Pitts [Sportsman] (to 1000 ft AGL)**	**Sukhoi [Intermediate] (to 1000 ft AGL)**
-500	M1	0.6	-2.1	0.9	0.7	-2	0.9
0	M2	1.5	-2.1	1.3	1.6	-2	1.3
660	M4	3.5	-1.3	1.1	3.6	-1.2	1.2
1320	M5	3.4	-1.4	0.8	3.7	-1.2	1.1
5496	M8	-2.6	-5.4	-4.1	0.1	-2.6	-1.7

Table 8. Difference between INM 7.0c and INM 6.2 Modeled Noise Results from 50 Aerobatic Routines (with and without Lateral Attenuation)

		Difference in Noise from 50 Routines with Lateral Attenuation [INM 7.0c - INM 6.2] (ΔdBA DNL)			Difference in Noise from 50 Routines without Lateral Attenuation [INM 7.0c - INM 6.2] (ΔdBA DNL)		
Distance (ft)	Mic	Extra [Sportsman] (to 1000 ft AGL)	Pitts [Sportsman] (to 1000 ft AGL)	Sukhoi [Intermediate] (to 1000 ft AGL)	Extra [Sportsman] (to 1000 ft AGL)	Pitts [Sportsman] (to 1000 ft AGL)	Sukhoi [Intermediate] (to 1000 ft AGL)
-500	M1	0.1	0	0.1	0.2	0.1	0.1
0	M2	0.1	0.1	0.1	0.2	0.2	0.1
660	M4	0.1	0.1	-0.1	0.2	0.1	0
1320	M5	-0.1	-0.1	-0.1	0.1	0.1	0
5496	M8	2.8	3	2.8	0.1	0.1	0.1

Table 7 and Table 8 show that the difference between the INM 6.0 and INM 7.0c noise results are due to the lateral attenuation adjustment update in INM 7.0c; when it is turned off, INM 7.0c noise results are in good agreement with the noise results estimated in the 2006 report. Therefore, INM 7.0c noise results without lateral attenuation are used in this analysis.

3.2 NOISE RESULTS FOR AEROBATIC ROUTINES PERFORMED BY THE EDGE 540 AND SUKHOI SU-29 (TASK 1A)

Based on field observations, the Edge and Sukhoi were expected to produce the loudest noise levels of the five aircraft from the 2006 study. Therefore, the complete range of aerobatic routines was modeled for both the Edge and the Sukhoi in INM 7.0c first. INM 7.0c modeled results for 50 identical routines without lateral attenuation are presented in Table 9 and Table 10. These results represent a conservative, "worst case" scenario. Results for a range of routines (from 1 to 50 identical routines) for the Edge and Sukhoi are presented in Appendix C.

Table 9. INM 7.0c Modeled Noise Results the Edge 540 Performing 50 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	55.7	58.3	60	62.6	64.9
0	M2	56.1	58.1	59.2	64.4	72.8
500	M3	56	57.4	58.1	62.7	65
660	M4	55.8	57.1	57.5	61.8	63.7
1320	M5	54.8	55.7	55.3	58.6	59.9
2640	M6	51.8	52.5	51.3	54	54.7
5280	M7	46.6	47.2	45.6	47.9	48.2
5496	M8	46.2	46.8	45.2	47.5	47.8
10560	M9	39.2	39.7	38.1	40.2	40.3

Table 10. INM 7.0c Modeled Noise Results the Sukhoi SU-29 Performing 50 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	52.9	55.5	57.9	61.0	63.4
0	M2	53.3	55.4	57.2	62.6	70.0
500	M3	53.2	54.7	56.2	61.0	63.4
660	M4	53.1	54.3	55.7	60.0	62.1
1320	M5	51.9	52.7	53.3	56.5	57.8
2640	M6	48.5	49.1	49.2	51.4	52.2
5280	M7	42.6	43.2	43.2	44.8	45.1
5496	M8	42.2	42.8	42.8	44.3	44.7
10560	M9	34.7	35.1	35.2	36.3	36.5

Note that the Advanced routines for some of these aircraft produce less noise than the Sportsman or Intermediate routines. This is because the Advanced routine has more vertical maneuvers than the others; these vertical maneuvers have less of the routine at high power settings since the descending maneuvers typically use idle power. In addition, the Intermediate routine has horizontal maneuver which are generally lower than the vertical maneuvers of the Advanced routine, and these high power settings at relatively low altitudes can dominate the noise levels at the closer distances.

Overall, the loudest noise levels for both the Edge and the Sukhoi were the results of modeling 50 identical, modified Unlimited routines scaled to a minimum altitude of 20 feet AFE, with the Edge being 1-4 dBA DNL louder than the Sukhoi.

3.3 NOISE RESULTS FOR AEROBATIC ROUTINES PERFORMED BY THE EXTRA EA-230 AND PITTS S-2C (TASK 1B)

The complete range of aerobatic routines was modeled for both the Extra and the Pitts in INM 7.0c. INM 7.0c modeled results for 50 identical routines without lateral attenuation are presented in Table 9 and Table 10. These results represent a conservative, "worst case" scenario. Results for a range of routines (from 1 to 50 identical routines) for the Extra and the Pitts are presented in Appendix C.

Table 11. INM 7.0c Modeled Noise Results the Extra EA-230 Performing 50 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	53.3	55.9	57.1	61.9	64.5
0	M2	53.8	55.7	56.6	64.2	73.2
500	M3	53.7	54.9	55.3	62	64.7
660	M4	53.5	54.5	54.6	60.9	63.2
1320	M5	52.3	52.6	51.6	57	58.5
2640	M6	48.6	48.6	46.4	51.4	52.2
5280	M7	42.3	42.2	39.6	44	44.4
5496	M8	41.9	41.8	39.2	43.5	43.9
10560	M9	34.0	33.9	31.4	35.1	35.3

Table 12. INM 7.0c Modeled Noise Results the Pitts S-2C Performing 50 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	52.6	55.2	56.6	60.6	63.1
0	M2	53	57.8	55.8	63.3	72.9
500	M3	53	54	54.4	60.8	63.4
660	M4	52.8	53.7	53.8	59.8	62.1
1320	M5	51.7	52.2	51.2	56.5	58.3
2640	M6	48.5	48.9	46.9	51.8	52.9
5280	M7	42.9	43.3	40.8	45.1	45.8
5496	M8	42.5	43	40.4	44.7	45.3
10560	M9	34.7	35.1	32.6	36.3	36.6

As mentioned in Section 3.2, the Advanced routines for these aircraft produce less noise than the Sportsman or Intermediate routines, because the Advanced routine has more vertical maneuvers than the others, which have less of the routine at high power settings since the descending maneuvers typically use idle power. Overall, the loudest noise levels for both the Extra and the Pitts were the results of modeling 50 identical, modified Unlimited routines scaled to a minimum altitude of 20 feet AFE, with the Pitts being 0-1.4 dBA DNL louder than the Extra at far distances (greater than 1320 ft), and the Extra being 0-1.4 dBA DNL louder than the Pitts at closer distances (less than 1320 ft). Both the Extra and the Pitts aerobatic routines produced noise levels that were 0-5 dBA DNL quieter than the Edge at most distances, and have comparable noise results directly below the routine (at M2).

3.4 NOISE RESULTS FOR AEROBATIC ROUTINES PERFORMED BY THE MIKOYAN-GUREVICH MIG-15, MCDONNELL DOUGLAS F-15 AND GRUMMAN F7F (TASK 1B)

The Sportsman aerobatic routine was modeled for the MiG-15, F-15 and F7F in INM 7.0c. INM 7.0c modeled results for 50 identical routines are presented in Table 13. Since the lateral attenuation adjustment cannot be turned off for jet aircraft in INM, only the warbird was modeled without lateral attenuation. These results represent a conservative, "worst case" scenario. Results for a range of routines (from 1 to 50 identical routines) for the MiG-15, F-15 and F7F are presented in Appendix C*.

Table 13. INM 7.0c Modeled Noise Results the MiG-15, F-15 and F7F Performing 50 Aerobatic Routines (Jets with Lateral Attenuation, Warbird without Lateral Attenuation)

		Modeled DNL values (dBA)		
Distance (ft)	Grid Point	MiG-15 [Sportsman] (to 1500 ft AGL)	F-15 [Sportsman] (to 1500 ft AGL)	F7F [Sportsman] (to 1500 ft AGL)
-500	M1	71.6	81	71.2
0	M2	71.9	81.6	71.4
500	M3	71.5	81.5	71.2
660	M4	71.3	81.4	71
1320	M5	70.2	80.2	69.8
2640	M6	67.5	77.1	66.8
5280	M7	63.3	71.5	61.6
5496	M8	63	71.1	61.2
10560	M9	57.2	63.7	54.5
15840	M10	52.5	58.2	49.7
21120	M11	48.3	53.3	45.4
26400	M12	44.9	49.3	42.1
31680	M13	42.1	46.0	39.3

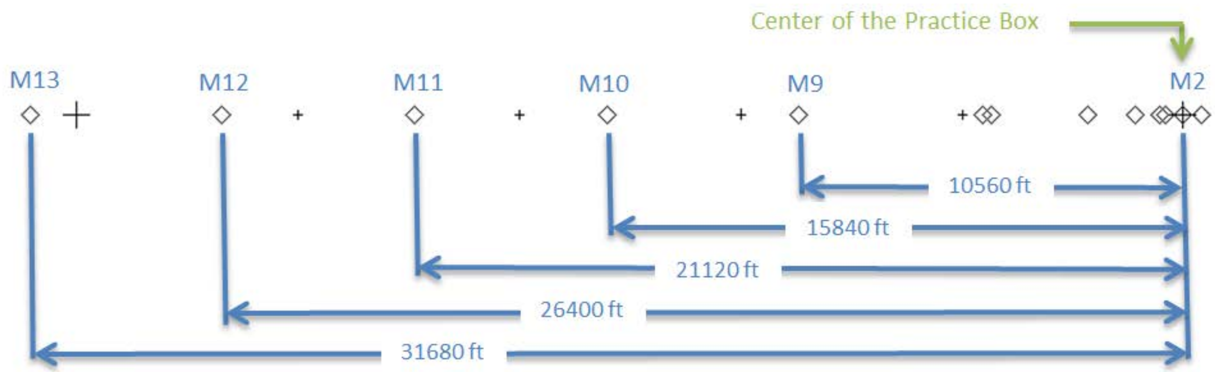

Figure 2. Additional Modeled Grid Points for the Jet and Warbird Noise Modeling

* Because the jet and warbird aircraft generate louder noise levels than the propeller aircraft, additional analysis locations at further distances were modeled (up to 6 miles away, see Figure 2).

Overall, the loudest noise levels for 50 identical routines were produced by the F-15, with the MiG-15 being 6.5-10.1 dBA DNL quieter than the F-15, and the F7F being 9.2-10.4 dBA DNL quieter than the F-15. All three of these aircraft resulted in noise levels significantly louder than the Extra, Edge, Sukhoi and Pitts at most distances (greater than 15 dBA DNL).

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4 SUMMARY AND ANALYSIS

Once the INM modeling is complete, the noise results are analyzed for the full range of aircraft flying aerobatic routines represented in this study (as summarized in Table 1). Section 4.1 presents the analysis of the noise results for the study aircraft performing up to 50 identical aerobatic routines. Section 4.2 presents a method for estimating the noise results for a combination of aircraft performing a combination of different aerobatic routines. Section 4.3 discusses the applicability of the INM modeled noise results for evaluating noise from aerobatic routines not represented in this analysis.

4.1 ANALYSIS OF NOISE RESULTS FOR MODELED AEROBATIC ROUTINES

The goal of this report is to present a noise analysis for a range of complete aerobatic routines and a range of aircraft modeled with INM, in order to provide a matrix of INM modeled noise results for a range of aircraft performing aerobatic routines that the FAA can utilize to perform NEPA analyses. The land-use compatibility threshold for aircraft noise in the vicinity of an airport is 65 dBA DNL. The noise levels for the aircraft flying aerobatic routines represented in this study (see Section 3and Appendix C) represent up to 50 identical aerobatic routines performed by each aircraft that can be evaluated against this threshold. Table 14 presents the minimum distance (from directly below the center of the aerobatic routine) that result aircraft-specific INM noise levels for 50 identical aerobatic routines below the 65 dBA DNL threshold. A conservative 55 dBA DNL threshold is presented in Table 15.

Table 14. Minimum Distance for INM Modeled Noise Levels to Drop Below the 65 dBA DNL for 50 Identical Aerobatic Routines

	Minimum Distance (ft)				
Representative Aircraft	**Sportsman Known 2005 (to 1500 ft AGL)**	**Intermediate Known 2005 (to 1200 ft AGL)**	**Advanced Known 2011 (to 800 ft AGL)**	**Unlimited Known 2011 (to 328 ft AGL)**	**Unlimited Known 2011 (to 20 ft AGL)**
Extra EA-230	0*	0	0	0	500
Edge 540	0	0	0	0	660
Sukhoi SU-29	0	0	0	0	500
Pitts S-2C	0	0	0	0	500
MiG-15	5280	n/a	n/a	n/a	n/a
F-15	10560	n/a	n/a	n/a	n/a
F7F	5280	n/a	n/a	n/a	n/a

Table 15. Minimum Distance for INM Modeled Noise Levels to Drop Below the 55 dBA DNL for 50 Identical Aerobatic Routines

	Minimum Distance (ft)				
Representative Aircraft	**Sportsman Known 2005 (to 1500 ft AGL)**	**Intermediate Known 2005 (to 1200 ft AGL)**	**Advanced Known 2011 (to 800 ft AGL)**	**Unlimited Known 2011 (to 328 ft AGL)**	**Unlimited Known 2011 (to 20 ft AGL)**
Extra EA-230	0	660	660	2640	2640
Edge 540	1320	2640	2640	2640	2640
Sukhoi SU-29	0	660	1320	2640	2640
Pitts S-2C	0	660	660	2640	2640
MiG-15	15840	n/a	n/a	n/a	n/a
F-15	21120	n/a	n/a	n/a	n/a
F7F	10560	n/a	n/a	n/a	n/a

* In this case, a distance of 0 ft indicates that the aircraft are directly overhead.

When considering the cumulative noise from 50 identical aerobatic routines from the loudest aircraft represented by this analysis, a minimum separation distance of 10,560 ft (2 miles) between the center of the aerobatic practice area and noise sensitive receivers is needed to meet the 65 dBA DNL threshold. The distance needed for the 55 dBA DNL threshold is 21,120 ft (4 miles). However, the results can be subdivided into two categories: (1) medium to light propeller aircraft, and (2) heavy propeller aircraft and jets. When considering 50 identical aerobatic routines from any of the medium to light propeller aircraft, the minimum separation distance needed to meet the 65 dBA DNL threshold is 660 ft, and 2,640 ft for the 55 dBA DNL threshold. For 50 identical aerobatic routines from any of the heavy propeller aircraft and jets, the thresholds of 10,560 ft for 65 dBA DNL and 21,120 ft for 55 dBA DNL still apply.

4.2 METHOD FOR ESTIMATING NOISE RESULTS FOR COMIBNATIONS OF AEROBATIC ROUTINES

INM models noise from multiple aircraft events (or routines) through the accumulation of noise levels from the corresponding individual aircraft events. For the purposes of modeling DNL for this analysis, the noise levels at a specific analysis location from multiple aircraft events are calculated with the following equation*:

$$L_{DN,i} = 10 \times log_{10}\{\sum_{acft=1}^{n_{acft}} \sum_{flt=1}^{n_{flt}} [N_{day,acft,flt} \times (10^{L_{DN,acft,flt,i}/10})]\} \qquad \textbf{Equation 1}$$

where

$N_{day,\ acft,\ flt}$	number of identical, aircraft-specific ("acft"), aerobatic routines ("flt") that occur during the analysis period at daytime hours,
$L_{DN,acft,flt,i}$	noise level (in dBA DNL) from the aircraft ("acft") performing an aerobatic routine ("flt") at a specific distance from the aerobatic practice box ("i" ft), found in Appendix C,
n_{acft}	number of unique aircraft ("acft") in the analysis study,
n_{flt}	number of unique aerobatic routines ("flt") in the analysis study, and

* Please note that this equation has been simplified for modeling DNL for this analysis, which assumes that the specific routines for a specific aircraft are identical if they occur multiple times, and all the events occur during the day between 7 AM and 10 PM. An unabridged description of this computation in INM may be found in Section 3.7 of the INM Version 7.0 Technical Manual.

$L_{DN, i}$ cumulative day-night average noise level in dBA DNL at a specific distance from the aerobatic practice box ("i" ft).

When using this equation, INM can account for identical aircraft events with the scaling factor $N_{day, acft, flt}$.

Given the results presented in Appendix C of this report, Equation 1 can be used to estimate the maximum number of identical aerobatic routines performed by a specific aircraft for a given day. Table 16 and Table 17 present the maximum number identical aerobatic routines that may be modeled for a given aircraft to meet the 65 dBA DNL threshold at a distance of 0.25 mile and 0.5 mile from directly below the center of the aerobatic routine, respectively*. Table 18 and Table 19 present the corresponding results for a more conservative 55 dBA DNL threshold.

Table 16. Maximum Number of Identical Aerobatic Routines to Meet the 65 dBA DNL Threshold at a Distance of 1320 ft (0.25 mile)

	Maximum Number of Identical Aerobatic Routines				
Representative Aircraft	**Sportsman Known 2005 (to 1500 ft AGL)**	**Intermediate Known 2005 (to 1200 ft AGL)**	**Advanced Known 2011 (to 800 ft AGL)**	**Unlimited Known 2011 (to 328 ft AGL)**	**Unlimited Known 2011 (to 20 ft AGL)**
Extra EA-230	940	880	1100	315	225
Edge 540	520	430	470	220	164
Sukhoi SU-29	1030	850	740	355	265
Pitts S-2C	1080	950	1200	355	235
MiG-15	15	n/a	n/a	n/a	n/a
F-15	1	n/a	n/a	n/a	n/a
F7F	16	n/a	n/a	n/a	n/a

* In the 2006 report, none of the aerobatic routines analyzed would have exceeded 65 dBA DNL at distances 0.25 mile or more from the center of the practice box, and a conservative recommendation was made to locate heavily utilized aerobatics practice boxes 0.5 mile or more from noise sensitive receivers. Therefore, those same 0.25 and 0.5 miles distances were utilized in this analysis.

Table 17. Maximum Number of Identical Aerobatic Routines to Meet the 65 dBA DNL Threshold at a Distance of 2640 ft (0.5 mile)

	Maximum Number of Identical Aerobatic Routines				
Representative Aircraft	**Sportsman Known 2005 (to 1500 ft AGL)**	**Intermediate Known 2005 (to 1200 ft AGL)**	**Advanced Known 2011 (to 800 ft AGL)**	**Unlimited Known 2011 (to 328 ft AGL)**	**Unlimited Known 2011 (to 20 ft AGL)**
Extra EA-230	2200	2200	3600	1150	950
Edge 540	1020	890	1170	630	540
Sukhoi SU-29	2260	1950	1900	1150	950
Pitts S-2C	2260	2050	3250	1050	820
MiG-15	28	n/a	n/a	n/a	n/a
F-15	3	n/a	n/a	n/a	n/a
F7F	33	n/a	n/a	n/a	n/a

Table 18. Maximum Number of Identical Aerobatic Routines to Meet the 55 dBA DNL Threshold at a Distance of 1320 ft (0.25 mile)

	Maximum Number of Identical Aerobatic Routines				
Representative Aircraft	**Sportsman Known 2005 (to 1500 ft AGL)**	**Intermediate Known 2005 (to 1200 ft AGL)**	**Advanced Known 2011 (to 800 ft AGL)**	**Unlimited Known 2011 (to 328 ft AGL)**	**Unlimited Known 2011 (to 20 ft AGL)**
Extra EA-230	94	88	110	31	22
Edge 540	52	43	47	22	16
Sukhoi SU-29	103	85	74	35	26
Pitts S-2C	108	95	120	35	23
MiG-15	1	n/a	n/a	n/a	n/a
F-15	0	n/a	n/a	n/a	n/a
F7F	1	n/a	n/a	n/a	n/a

Table 19. Maximum Number of Identical Aerobatic Routines to Meet the 55 dBA DNL Threshold at a Distance of 2640 ft (0.5 mile)

	Maximum Number of Identical Aerobatic Routines				
Representative Aircraft	**Sportsman Known 2005 (to 1500 ft AGL)**	**Intermediate Known 2005 (to 1200 ft AGL)**	**Advanced Known 2011 (to 800 ft AGL)**	**Unlimited Known 2011 (to 328 ft AGL)**	**Unlimited Known 2011 (to 20 ft AGL)**
Extra EA-230	220	220	360	115	95
Edge 540	102	89	117	63	54
Sukhoi SU-29	226	195	190	115	95
Pitts S-2C	226	205	325	105	82
MiG-15	2	n/a	n/a	n/a	n/a
F-15	0	n/a	n/a	n/a	n/a
F7F	3	n/a	n/a	n/a	n/a

In addition, Equation 1 can be used to estimate the noise from multiple different aircraft performing different aerobatic routines. Examples of this type of estimate are presented in Appendix D.

4.3 APPLICABILITY OF STUDY ANALYSIS

In this analysis, several assumptions were made concerning aircraft source noise levels, aircraft performance and orientation, flight path geometries, the variability of aerobatic aircraft routines, receiver locations respective to the aerobatic routines, and environmental conditions (such as airport elevation and weather), in order to make general estimates of noise levels due to aircraft performing aerobatic routines at specific receiver locations. Therefore, this method may be used to estimate noise from the following:

(1) a range of aircraft that typically perform aerobatic routines (see Appendix B);
(2) a range of aerobatics routines represented in this analysis (see Section 2.2);
(3) aerobatic routines performed in studies with reference elevations at or near sea level;
(4) aerobatic routines performed in studies with standard weather conditions*; and

* INM references SAE-AIR-1845 "Procedure for the Computation of Airplane Noise in the Vicinity of Airports"[4], which includes a specification for a standard atmosphere. In general, INM guidance characterizes non-standard weather conditions as weather conditions, where there are significant variations from minimum absorption conditions (~70-80°F, ~70% RH)[5].

(5) daytime operations.

While it is impossible to predict with 100% certainty the noise produced by any aircraft event, these assumptions are considered reasonable, and the aircraft noise modeling method developed for this analysis is considered a good method for estimating general noise from aircraft performing aerobatic routines.

It is also important to note that the INM modeling for this analysis does not take into account the following:

(1) noise from aircraft significantly different than those represented in this analysis (see Appendix B;
(2) noise from aerobatics routines significantly different than those represented in this analysis (see Section 2.2);
(3) noise from aircraft approaches to or departures from the aerobatic routines;
(4) noise from other sources (including other non-aerobatic flights and ambient noise)
(5) noise from aerobatic routines performed in studies with reference elevations significantly different from sea level;
(6) noise from aerobatic routines performed in studies with non-standard weather conditions; and
(7) noise from nighttime operations.

Additional INM modeling may be able to provide reasonable estimates for the noise levels generated under these conditions not represented in the current analysis. Furthermore, additional aircraft noise measurements may be able to supplement and validate the noise modeling of these aircraft and operations (or routines) not represented in this analysis.

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5 CONCLUSIONS AND RECOMMENDATIONS

The 2006 study concluded that none of the aerobatic routines flown in that study (Sportsman routines for the Extra and the Pitts, and Intermediate routine for the Sukhoi) would have exceeded 65 dBA DNL at distances 0.25 mile or more from the center of the practice box[*]. A conservative recommendation to locate heavily utilized aerobatics practice boxes 0.5 mile or more from noise sensitive receivers was made in part based on those results. INM 7.0c noise results for the corresponding aerobatic routines confirmed this recommendation.

INM 7.0c modeled results for the full range of aerobatic routines for the medium to light propeller aircraft from the 2006 study (Extra, Edge, Pitts and Sukhoi) further support this recommendation, when modeling noise from 50 identical aerobatic routines. However, it should be noted that INM 7.0c produces noise levels up to 59.9 dBA DNL at a distance of 0.25 mile for the Edge, when performing 50 identical Unlimited routines at a minimum altitude of 20 ft AFE. Noise levels were below 54.7 dBA DNL at a distance of 0.5 mile from the aerobatic practice box for the full range of aerobatic routines for all four aircraft. Separate aircraft and aerobatic routine specific thresholds may be determined from the results presented in Section 4.1.

The INM 7.0c modeled noise from heavy propeller aircraft and jets (MiG-15, F-15 and F7F) performing 50 identical routines exceeded the 65 dBA DNL threshold DNL at a distance of 0.5 mile from the aerobatic practice box. In order to meet the 65 dBA DNL threshold for all three aircraft, the recommended minimum distance between the aerobatic routines and noise sensitive receivers should be 2 miles. This minimum distance should be extended to 4 miles, when considering a 55 dBA DNL threshold. Separate aircraft and aerobatic routine specific thresholds may be determined from the results presented in Section 4.1.

Finally, when evaluating noise for aircraft, routines or conditions not represented by this analysis, additional INM noise modeling is recommended. This may be further supplemented and validated with additional aircraft noise measurements.

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[*] This was a conservative estimate. In the 2006 report, the estimated DNL values for 50 identical routines for each of the three aircraft were less than 56 dBA DNL.

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Appendix A References

1. Boeker, et al.: Integrated Noise Model (INM) Version 7.0 Technical Manual, Report No. FAA-AEE-08-01, Washington, D.C.: Federal Aviation Administration, January 2008.

2. Boeker, Eric: Aerobatic Aircraft Noise Study: Technical Memorandum, May 2006.

3. Society of Automotive Engineers, Committee A-21, Aircraft Noise, Method for Predicting Lateral Attenuation of Airplane Noise, Aerospace Information Report No. 5662, Warrendale, PA: Society of Automotive Engineers, Inc., April 2006.

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

5. INM Version 7.0a Software Update, Release Notes, May 2006.

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Appendix B Substitution Aerobatic Aircraft

The range of aerobatic aircraft represented in INM for this analysis is presented in Table 20 through Table 26. The representative aircraft were selected by FAA's Office of Environment and Energy are considered conservative representations of those aircraft in each respective category.

Table 20. Low Weight Piston Engine Aircraft Represented in INM

Aircraft Type	Aircraft Name	Cruise Speed (mph)	# Engines	Max. Takeoff Weight (lb)	Engine	Comments and Data Source
Low Weight Piston	Steen Skybolt	145	1	1,650	Lycoming HO-360-B1B piston, 180 hp (130 kW)	
	American Champion Citibria	162	1	1,650	Lycoming O-320-A2B, 150 hp (111.9 kW)	
	Pitts S-2	210	1	1,625	Textron Lycoming AEIO-540-D4A5 flat-six air cooled piston engine, 260 hp (194 kW)	Representative Aircraft. Data in 2006 Report.
	RV-6	210	1	1,600	Lycoming O-320 or Lycoming O-360 fixed pitch or constant speed, 150-180hp (112-134 kW)	
	RV-4	210	1	1,500	Lycoming O-320, O-360 or IO-360, 150-180hp (110-135 kW)	
	Piper J-3	87	1	1,220	Continental A-65-8 air-cooled flat four, 65 hp (48 kW) at 2,350 rpm	
	Aviat Eagle	184	1	?	Lycoming AEIO-360-A1D, 200 hp (149 kW)	
	Great Lakes 2T	?	?	?	Lycoming engine	
	Lazer 230	?	?	?	piston engine	
	Stearman	?	?	?	radial engine	

Table 21. Mid Weight Piston Engine Aircraft Represented in INM

Aircraft Type	Aircraft Name	Cruise Speed (mph)	# Engines	Max. Takeoff Weight (lb)	Engine	Comments and Data Source
Mid Weight Piston	Zlin 242	196	1	2,028	Avia M 137A inverted 6 cylinder inline engine, 134 kW (180 hp)	
	American Champion 8KAB Decathlon	155	1	1,950 (or 1,800 aerobatic)	Lycoming AEIO-360-H1B CSU, 180 hp (134.2 kW)	Data in 2006 Report. Aircraft not utilized, because it can be represented by the Edge 540.
	RV-7	217	1	1,800	Lycoming O-320 or Lycoming O-360 Constant Speed or Fixed Pitch, 160 to 200 hp (119 to 149 kW)	
	RV-8	210	1	1,800	Lycoming O-320, Lycoming O-360 or Lycoming IO-360 fixed pitch or constant speed, 150-200hp (112-149 kW)	
	Edge 540	265	1	1,800	Modified Lycoming AEIO-540 Hartzell composite, 3 blade, 254 kW (340 hp)	Representative Aircraft. Data in 2006 Report.
	Cap 232	205	1	1,800	Lycoming AEI0-540-L1 B5D air-cooled flat-six, 224 kW (300 hp)	
	Giles 202	258	1	cruise: 1600; max. aerobatic weight: 1400; competition aerobatics: 1,200	Lycoming AEIO-360-A1E piston engine, 235 hp ()	

Table 22. High Weight Piston Engine Aircraft Represented in INM

Aircraft Type	Aircraft Name	Cruise Speed (mph)	# Engines	Max. Takeoff Weight (lb)	Engine	Comments and Data Source
High Weight Piston	Grob G120	197	1	3,175	Lycoming AEIO-540-D4D5 6-cylinder, horizontally opposed engine, 194 kW (260 hp)	
	Extra 300	253	1	2095	Lycoming AEIO-540-L1B5 MT-Propeller composite propeller (3- or 4-blade), 224 kW (300 hp)	Representative Aircraft. Data in 2006 Report.

Table 23. High Weight Radial Engine Aircraft Represented in INM

Aircraft Type	Aircraft Name	Cruise Speed (mph)	# Engines	Max. Takeoff Weight (lb)	Engine	Comments and Data Source
High Weight Radial	Yak 52	177	1	2,877	Vedeneyev M-14P 9-cylinder radial engine, 268 kW (360 hp)	
	Sukhoi 31	205	1	2,315	Vedeneyev M-14PF, 294 kW (400 hp)	Representative Aircraft. Sukhoi SU-29 data (which has a little less power) in 2006 Report.
	Yak 55	190	1	2,150	Vedeneyev M14P 9-cylinder radial engine, 268.5 kW (360.1 hp)	
	Super solution	?	1	?	Pratt & Whitney R-1340 Radial, 535 hp (399 kW)	

Table 24. High Power Radial Engine Aircraft (Warbird) Represented in INM

Aircraft Type	Aircraft Name	Max. Speed (mph)	# Engines	Engine Power (hp)	Engine	Comments and Data Source
	Hawker Sea Fury	460	1	2480	Bristol Centaurus XVIIC 18-cylinder twin-row radial engine, 2,480 hp (1,850 kW)	
	North American T6	208	1	600	Pratt & Whitney R-1340-AN-1 Wasp radial engine, 600 hp (450 kW)	
	North American P51 Mustang	487	1	1490	Packard V-1650-7 liquid-cooled supercharged V-12, 1,490 hp (1,111 kW) at 3,000 rpm;[76] 1,720 hp (1,282 kW) at WEP	
	Lockheed P-38	443	2	1725	Allison V-1710-111/113 V-12 piston engine, 1,725 hp [N 7] (1,194 kW) each	
High Power Radial (Warbird)	Grumman 7F7	460	2	2100	Pratt & Whitney R-2800-34W "Double Wasp" radial engines, 2,100 hp (1,566 kW) each	Representative Aircraft. Noise data represented by Convair C-131 data in INM 7.0c database.
	P-47	433	1	2535	Pratt & Whitney R-2800-59 twin-row radial engine, 2,535 hp (1,890 kW)	
	Grumman F8F Bearcat	421	1	2100	Pratt & Whitney R-2800-34W "Double Wasp" two-row radial engine, 2,100 hp (1,567 kW)	
	North American A36	365	1	1325	Allison V-1710-87 liquid-cooled piston V12 engine, 1,325 hp (988 kW)	
	North American T28	343	1	1425	Wright R-1820 single row radial 1425 hp	

Table 25. Mid Power Jet Engine Aircraft Represented in INM

Aircraft Type	Aircraft Name	Max. Speed (mph)	# Engines	Engine Power (kN)	Engine	Comments and Data Source
Mid Power Jet	Aero Vodochody L39C	466	1	16.87	Ivchenko AI-25TL turbofan, 16.87 kN (3,792 lbf)	
	MiG 15 UTi	668	1	26.5	Klimov VK-1 turbojet, 26.5 kN (5,950 lbf)	Representative Aircraft. Noise data represented by Hawker Hunter data in INM 7.0c database.
	Dornier alpha jet	621	2	13.24	SNECMA Turbomeca Larzac 04-C5 turbofans, 13.24 kN (2,976 lbf) each	

Table 26. High Power Jet Engine Aircraft Represented in INM

Aircraft Type	Aircraft Name	Max. Speed (mph)	# Engines	Engine Power (kN)	Engine	Comments and Data Source
High Power Jet	F-15	900 (low altitude)	2	111.2 (afterburn)	Pratt & Whitney F100-100 or −220 afterburning turbofans	Representative Aircraft. Represented in INM 7.0c database.
	F-16	915 (low altitude)	1	127 (afterburn)	F110-GE-100 afterburning turbofan	

In addition, the following performance source data were used for the MiG-15, F-15, and F7F (see Table 27). Note that the original data for the MiG-15 and the F7F are based on the Hawker Hunter and the C-131, respectively. The actual thrust data may be different for these aircraft – the data presented below represent how the data is used by the INM to reference the associated noise data.

Table 27. Additional Performance Data Used to Model the Jets and Warbird in INM

Aircraft	Max. Thrust	Min Thrust	Max. Airspeed	Min. Airspeed
MiG-15	100.7 %N1	88 %N1	578 knots	231 knots
F-15	92.2 %N1	71 %N1	600 knots	240 knots
F7F	71 in-Hg	30 in-Hg	300 knots	120 knots

Appendix C INM 7.0c Noise Results for the 2012 Study

The complete set of INM modeled noise for a range of aircraft performing different aerobatic routines are presented in this appendix.

Table 28. INM 7.0c Modeled Noise Results the Edge 540 Performing 1 Aerobatic Routine (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)*	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	38.7	41.3	43.0	45.6	47.9
0	M2	39.1	41.1	42.2	47.4	55.8
500	M3	39.0	40.4	41.1	45.7	48.0
660	M4	38.8	40.1	40.6	44.8	46.7
1320	M5	37.8	38.7	38.3	41.6	42.9
2640	M6	34.9	35.5	34.3	37.0	37.7
5280	M7	29.6	30.2	28.6	30.9	31.2
5496	M8	29.2	29.8	28.2	30.5	30.8
10560	M9	22.2	22.7	21.1	23.2	23.3

Table 29. INM 7.0c Modeled Noise Results the Edge 540 Performing 5 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	45.7	48.3	50.0	52.6	54.9
0	M2	46.1	48.1	49.2	54.4	62.8
500	M3	46.0	47.4	48.1	52.7	55.0
660	M4	45.8	47.1	47.6	51.8	53.7
1320	M5	44.8	45.7	45.3	48.6	49.9
2640	M6	41.9	42.5	41.3	44.0	44.7
5280	M7	36.6	37.2	35.6	37.9	38.2
5496	M8	36.2	36.8	35.2	37.5	37.8
10560	M9	29.2	29.7	28.1	30.2	30.3

** Distance (ft) represents the distance directly below the center of the aerobatic Routine (in feet).

Table 30. INM 7.0c Modeled Noise Results the Edge 540 Performing 10 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	48.7	51.3	53.0	55.6	57.9
0	M2	49.1	51.1	52.2	57.4	65.8
500	M3	49.0	50.4	51.1	55.7	58.0
660	M4	48.8	50.1	50.6	54.8	56.7
1320	M5	47.8	48.7	48.3	51.6	52.9
2640	M6	44.9	45.5	44.3	47.0	47.7
5280	M7	39.6	40.2	38.6	40.9	41.2
5496	M8	39.2	39.8	38.2	40.5	40.8
10560	M9	32.2	32.7	31.1	33.2	33.3

Table 31. INM 7.0c Modeled Noise Results the Edge 540 Performing 20 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	51.7	54.3	56.0	58.6	60.9
0	M2	52.1	54.1	55.2	60.4	68.8
500	M3	52.0	53.4	54.1	58.7	61.0
660	M4	51.8	53.1	53.6	57.8	59.7
1320	M5	50.8	51.7	51.3	54.6	55.9
2640	M6	47.9	48.5	47.3	50.0	50.7
5280	M7	42.6	43.2	41.6	43.9	44.2
5496	M8	42.2	42.8	41.2	43.5	43.8
10560	M9	35.2	35.7	34.1	36.2	36.3

Table 32. INM 7.0c Modeled Noise Results the Edge 540 Performing 30 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	53.5	56.1	57.8	60.4	62.7
0	M2	53.9	55.9	57.0	62.2	70.6
500	M3	53.8	55.2	55.9	60.5	62.8
660	M4	53.6	54.9	55.4	59.6	61.5
1320	M5	52.6	53.5	53.1	56.4	57.7
2640	M6	49.7	50.3	49.1	51.8	52.5
5280	M7	44.4	45.0	43.4	45.7	46.0
5496	M8	44.0	44.6	43.0	45.3	45.6
10560	M9	37.0	37.5	35.9	38.0	38.1

Table 33. INM 7.0c Modeled Noise Results the Edge 540 Performing 40 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	54.7	57.3	59.0	61.6	63.9
0	M2	55.1	57.1	58.2	63.4	71.8
500	M3	55.0	56.4	57.1	61.7	64.0
660	M4	54.8	56.1	56.6	60.8	62.7
1320	M5	53.8	54.7	54.3	57.6	58.9
2640	M6	50.9	51.5	50.3	53.0	53.7
5280	M7	45.6	46.2	44.6	46.9	47.2
5496	M8	45.2	45.8	44.2	46.5	46.8
10560	M9	38.2	38.7	37.1	39.2	39.3

Table 34. INM 7.0c Modeled Noise Results the Edge 540 Performing 50 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	55.7	58.3	60.0	62.6	64.9
0	M2	56.1	58.1	59.2	64.4	72.8
500	M3	56.0	57.4	58.1	62.7	65.0
660	M4	55.8	57.1	57.5	61.8	63.7
1320	M5	54.8	55.7	55.3	58.6	59.9
2640	M6	51.8	52.5	51.3	54.0	54.7
5280	M7	46.6	47.2	45.6	47.9	48.2
5496	M8	46.2	46.8	45.2	47.5	47.8
10560	M9	39.2	39.7	38.1	40.2	40.3

Table 35. INM 7.0c Modeled Noise Results the Sukhoi SU-29 Performing 1 Aerobatic Routine (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	35.9	38.6	40.9	44.0	46.4
0	M2	36.3	38.4	40.2	45.6	53.0
500	M3	36.2	37.7	39.2	44.0	46.4
660	M4	36.1	37.3	38.7	43.0	45.1
1320	M5	34.9	35.7	36.3	39.5	40.8
2640	M6	31.5	32.1	32.2	34.4	35.2
5280	M7	25.7	26.3	26.2	27.8	28.1
5496	M8	25.3	25.9	25.8	27.3	27.7
10560	M9	17.7	18.1	18.2	19.3	19.5

Table 36. INM 7.0c Modeled Noise Results the Sukhoi SU-29 Performing 5 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	42.9	45.6	47.9	51.0	53.4
0	M2	43.3	45.4	47.2	52.6	60.0
500	M3	43.2	44.7	46.2	51.0	53.4
660	M4	43.1	44.3	45.7	50.0	52.1
1320	M5	41.9	42.7	43.3	46.5	47.8
2640	M6	38.5	39.1	39.2	41.4	42.2
5280	M7	32.7	33.3	33.2	34.8	35.1
5496	M8	32.3	32.9	32.8	34.3	34.7
10560	M9	24.7	25.1	25.2	26.3	26.5

Table 37. INM 7.0c Modeled Noise Results the Sukhoi SU-29 Performing 10 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	45.9	48.6	50.9	54.0	56.4
0	M2	46.3	48.4	50.2	55.6	63.0
500	M3	46.2	47.7	49.2	54.0	56.4
660	M4	46.1	47.3	48.7	53.0	55.1
1320	M5	44.9	45.7	46.3	49.5	50.8
2640	M6	41.5	42.1	42.2	44.4	45.2
5280	M7	35.7	36.3	36.2	37.8	38.1
5496	M8	35.3	35.9	35.8	37.3	37.7
10560	M9	27.7	28.1	28.2	29.3	29.5

Table 38. INM 7.0c Modeled Noise Results the Sukhoi SU-29 Performing 20 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	48.9	51.6	53.9	57.0	59.4
0	M2	49.3	51.4	53.2	58.6	66.0
500	M3	49.2	50.7	52.2	57.0	59.4
660	M4	49.1	50.3	51.7	56.0	58.1
1320	M5	47.9	48.7	49.3	52.5	53.8
2640	M6	44.5	45.1	45.2	47.4	48.2
5280	M7	38.7	39.3	39.2	40.8	41.1
5496	M8	38.3	38.9	38.8	40.3	40.7
10560	M9	30.7	31.1	31.2	32.3	32.5

Table 39. INM 7.0c Modeled Noise Results the Sukhoi SU-29 Performing 30 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	50.7	53.4	55.7	58.8	61.2
0	M2	51.1	53.2	55.0	60.4	67.8
500	M3	51.0	52.5	54.0	58.8	61.2
660	M4	50.9	52.1	53.5	57.8	59.9
1320	M5	49.7	50.5	51.1	54.3	55.6
2640	M6	46.3	46.9	47.0	49.2	50.0
5280	M7	40.5	41.1	41.0	42.6	42.9
5496	M8	40.1	40.7	40.6	42.1	42.5
10560	M9	32.5	32.9	33.0	34.1	34.3

Table 40. INM 7.0c Modeled Noise Results the Sukhoi SU-29 Performing 40 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	51.9	54.6	56.9	60.0	62.4
0	M2	52.3	54.4	56.2	61.6	69.0
500	M3	52.2	53.7	55.2	60.0	62.4
660	M4	52.1	53.3	54.7	59.0	61.1
1320	M5	50.9	51.7	52.3	55.5	56.8
2640	M6	47.5	48.1	48.2	50.4	51.2
5280	M7	41.7	42.3	42.2	43.8	44.1
5496	M8	41.3	41.9	41.8	43.3	43.7
10560	M9	33.7	34.1	34.2	35.3	35.5

Table 41. INM 7.0c Modeled Noise Results the Sukhoi SU-29 Performing 50 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	52.9	55.5	57.9	61.0	63.4
0	M2	53.3	55.4	57.2	62.6	70.0
500	M3	53.2	54.7	56.2	61.0	63.4
660	M4	53.1	54.3	55.7	60.0	62.1
1320	M5	51.9	52.7	53.3	56.5	57.8
2640	M6	48.5	49.1	49.2	51.4	52.2
5280	M7	42.6	43.2	43.2	44.8	45.1
5496	M8	42.2	42.8	42.8	44.3	44.7
10560	M9	34.7	35.1	35.2	36.3	36.5

Table 42. INM 7.0c Modeled Noise Results the Extra EA-230 Performing 1 Aerobatic Routine (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	36.3	38.9	40.1	44.9	47.5
0	M2	36.8	38.7	39.6	47.2	56.2
500	M3	36.7	37.9	38.3	45.0	47.7
660	M4	36.5	37.5	37.6	43.9	46.2
1320	M5	35.3	35.6	34.6	40.0	41.5
2640	M6	31.6	31.6	29.4	34.4	35.2
5280	M7	25.3	25.2	22.6	27.0	27.4
5496	M8	24.9	24.8	22.2	26.6	26.9
10560	M9	17.0	16.9	14.4	18.1	18.3

Table 43. INM 7.0c Modeled Noise Results the Extra EA-230 Performing 5 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	43.3	45.9	47.1	51.9	54.5
0	M2	43.8	45.7	46.6	54.2	63.2
500	M3	43.7	44.9	45.3	52.0	54.7
660	M4	43.5	44.5	44.6	50.9	53.2
1320	M5	42.3	42.6	41.6	47.0	48.5
2640	M6	38.6	38.6	36.4	41.4	42.2
5280	M7	32.3	32.2	29.6	34.0	34.4
5496	M8	31.9	31.8	29.2	33.6	33.9
10560	M9	24.0	23.9	21.4	25.1	25.3

Table 44. INM 7.0c Modeled Noise Results the Extra EA-230 Performing 10 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	46.3	48.9	50.1	54.9	57.5
0	M2	46.8	48.7	49.6	57.2	66.2
500	M3	46.7	47.9	48.3	55.0	57.7
660	M4	46.5	47.5	47.6	53.9	56.2
1320	M5	45.3	45.6	44.6	50.0	51.5
2640	M6	41.6	41.6	39.4	44.4	45.2
5280	M7	35.3	35.2	32.6	37.0	37.4
5496	M8	34.9	34.8	32.2	36.6	36.9
10560	M9	27.0	26.9	24.4	28.1	28.3

Table 45. INM 7.0c Modeled Noise Results the Extra EA-230 Performing 20 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	49.3	51.9	53.1	57.9	60.5
0	M2	49.8	51.7	52.6	60.2	69.2
500	M3	49.7	50.9	51.3	58.0	60.7
660	M4	49.5	50.5	50.6	56.9	59.2
1320	M5	48.3	48.6	47.6	53.0	54.5
2640	M6	44.6	44.6	42.4	47.4	48.2
5280	M7	38.3	38.2	35.6	40.0	40.4
5496	M8	37.9	37.8	35.2	39.6	39.9
10560	M9	30.0	29.9	27.4	31.1	31.3

Table 46. INM 7.0c Modeled Noise Results the Extra EA-230 Performing 30 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	51.1	53.7	54.9	59.7	62.3
0	M2	51.6	53.5	54.4	62.0	71.0
500	M3	51.5	52.7	53.1	59.8	62.5
660	M4	51.3	52.3	52.4	58.7	61.0
1320	M5	50.1	50.4	49.4	54.8	56.3
2640	M6	46.4	46.4	44.2	49.2	50.0
5280	M7	40.1	40.0	37.4	41.8	42.2
5496	M8	39.7	39.6	37.0	41.4	41.7
10560	M9	31.8	31.7	29.2	32.9	33.1

Table 47. INM 7.0c Modeled Noise Results the Extra EA-230 Performing 40 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	52.3	54.9	56.1	60.9	63.5
0	M2	52.8	54.7	55.6	63.2	72.2
500	M3	52.7	53.9	54.3	61.0	63.7
660	M4	52.5	53.5	53.6	59.9	62.2
1320	M5	51.3	51.6	50.6	56.0	57.5
2640	M6	47.6	47.6	45.4	50.4	51.2
5280	M7	41.3	41.2	38.6	43.0	43.4
5496	M8	40.9	40.8	38.2	42.6	42.9
10560	M9	33.0	32.9	30.4	34.1	34.3

Table 48. INM 7.0c Modeled Noise Results the Extra EA-230 Performing 50 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	53.3	55.9	57.1	61.9	64.5
0	M2	53.8	55.7	56.6	64.2	73.2
500	M3	53.7	54.9	55.3	62.0	64.7
660	M4	53.5	54.5	54.6	60.9	63.2
1320	M5	52.3	52.6	51.6	57.0	58.5
2640	M6	48.6	48.6	46.4	51.4	52.2
5280	M7	42.3	42.2	39.6	44.0	44.4
5496	M8	41.9	41.8	39.2	43.5	43.9
10560	M9	34.0	33.9	31.4	35.1	35.3

Table 49. INM 7.0c Modeled Noise Results the Pitts S-2C Performing 1 Aerobatic Routine (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	35.6	38.2	39.6	43.6	46.1
0	M2	36.1	37.8	38.8	46.3	55.9
500	M3	36.0	37.0	37.4	43.9	46.4
660	M4	35.8	36.7	36.8	42.9	45.1
1320	M5	34.7	35.2	34.2	39.5	41.3
2640	M6	31.5	31.9	29.9	34.8	35.9
5280	M7	25.9	26.4	23.8	28.2	28.8
5496	M8	25.5	26.0	23.4	27.7	28.3
10560	M9	17.7	18.1	15.6	19.3	19.6

Table 50. INM 7.0c Modeled Noise Results the Pitts S-2C Performing 5 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	42.6	45.2	46.6	50.6	53.1
0	M2	43.1	44.8	45.8	53.3	62.9
500	M3	43.0	44.0	44.4	50.9	53.4
660	M4	42.8	43.7	43.8	49.9	52.1
1320	M5	41.7	42.2	41.2	46.5	48.3
2640	M6	38.5	38.9	36.9	41.8	42.9
5280	M7	32.9	33.4	30.8	35.2	35.8
5496	M8	32.5	33.0	30.4	34.7	35.3
10560	M9	24.7	25.1	22.6	26.3	26.6

Table 51. INM 7.0c Modeled Noise Results the Pitts S-2C Performing 10 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	45.6	48.2	49.6	53.6	56.1
0	M2	46.1	47.8	48.8	56.3	65.9
500	M3	46.0	47.0	47.4	53.9	56.4
660	M4	45.8	46.7	46.8	52.9	55.1
1320	M5	44.7	45.2	44.2	49.5	51.3
2640	M6	41.5	41.9	39.9	44.8	45.9
5280	M7	35.9	36.4	33.8	38.2	38.8
5496	M8	35.5	36.0	33.4	37.7	38.3
10560	M9	27.7	28.1	25.6	29.3	29.6

Table 52. INM 7.0c Modeled Noise Results the Pitts S-2C Performing 20 Aerobatic Routines (without Lateral Attenuation)

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		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	48.6	51.2	52.6	56.6	59.1
0	M2	49.1	50.8	51.8	59.3	68.9
500	M3	49.0	50.0	50.4	56.9	59.4
660	M4	48.8	49.7	49.8	55.9	58.1
1320	M5	47.7	48.2	47.2	52.5	54.3
2640	M6	44.5	44.9	42.9	47.8	48.9
5280	M7	38.9	39.4	36.8	41.2	41.8
5496	M8	38.5	39.0	36.4	40.7	41.3
10560	M9	30.7	31.1	28.6	32.3	32.6

Table 53. INM 7.0c Modeled Noise Results the Pitts S-2C Performing 30 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	50.4	53.0	54.4	58.4	60.9
0	M2	50.9	52.6	53.6	61.1	70.7
500	M3	50.8	51.8	52.2	58.7	61.2
660	M4	50.6	51.5	51.6	57.7	59.9
1320	M5	49.5	50.0	49.0	54.3	56.1
2640	M6	46.3	46.7	44.7	49.6	50.7
5280	M7	40.7	41.2	38.6	43.0	43.6
5496	M8	40.3	40.8	38.2	42.5	43.1
10560	M9	32.5	32.9	30.4	34.1	34.4

Table 54. INM 7.0c Modeled Noise Results the Pitts S-2C Performing 40 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	51.6	54.2	55.6	59.6	62.1
0	M2	52.1	53.8	54.8	62.3	71.9
500	M3	52.0	53.0	53.4	59.9	62.4
660	M4	51.8	52.7	52.8	58.9	61.1
1320	M5	50.7	51.2	50.2	55.5	57.3
2640	M6	47.5	47.9	45.9	50.8	51.9
5280	M7	41.9	42.4	39.8	44.2	44.8
5496	M8	41.5	42.0	39.4	43.7	44.3
10560	M9	33.7	34.1	31.6	35.3	35.6

Table 55. INM 7.0c Modeled Noise Results the Pitts S-2C Performing 50 Aerobatic Routines (without Lateral Attenuation)

		Modeled DNL values (dBA)				
Distance (ft)	Grid Point	Sportsman Known 2005 (to 1500 ft AGL)	Intermediate Known 2005 (to 1200 ft AGL)	Advanced Known 2011 (to 800 feet AGL)	Unlimited Known 2011 (to 328 feet AGL)	Unlimited Known 2011 (to 20 feet AGL)
-500	M1	52.6	55.2	56.6	60.6	63.1
0	M2	53.0	57.8	55.8	63.3	72.9
500	M3	53.0	54.0	54.4	60.8	63.4
660	M4	52.8	53.7	53.8	59.8	62.1
1320	M5	51.7	52.2	51.2	56.5	58.3
2640	M6	48.5	48.9	46.9	51.8	52.9
5280	M7	42.9	43.3	40.8	45.1	45.8
5496	M8	42.5	43.0	40.4	44.7	45.3
10560	M9	34.7	35.1	32.6	36.3	36.6

Table 56. INM 7.0c Modeled Noise Results the MiG-15, F-15 and F7F Performing 1 Aerobatic Routine (Jets with Lateral Attenuation, Warbird without Lateral Attenuation)

		Modeled DNL values (dBA)		
Distance (ft)	Grid Point	MiG-15 [Sportsman] (to 1500 ft AGL)	F-15 [Sportsman] (to 1500 ft AGL)	F7F [Sportsman] (to 1500 ft AGL)
-500	M1	54.6	64.0	54.2
0	M2	54.9	64.6	54.5
500	M3	54.5	64.5	54.2
660	M4	54.3	64.4	54.0
1320	M5	53.2	63.3	52.8
2640	M6	50.5	60.1	49.8
5280	M7	46.3	54.5	44.6
5496	M8	46.0	54.1	44.3
10560	M9	40.2	46.8	37.5
15840	M10	35.5	41.2	32.7
21120	M11	31.3	36.3	28.4
26400	M12	27.9	32.3	25.1
31680	M13	25.1	29.0	22.3

Table 57. INM 7.0c Modeled Noise Results the MiG-15, F-15 and F7F Performing 5 Aerobatic Routines (Jets with Lateral Attenuation, Warbird without Lateral Attenuation)

		Modeled DNL values (dBA)		
Distance (ft)	Grid Point	MiG-15 [Sportsman] (to 1500 ft AGL)	F-15 [Sportsman] (to 1500 ft AGL)	F7F [Sportsman] (to 1500 ft AGL)
-500	M1	61.6	71.0	61.2
0	M2	61.9	71.6	61.5
500	M3	61.5	71.5	61.2
660	M4	61.3	71.4	61.0
1320	M5	60.2	70.3	59.8
2640	M6	57.5	67.1	56.8
5280	M7	53.3	61.5	51.6
5496	M8	53.0	61.1	51.3
10560	M9	47.2	53.8	44.5
15840	M10	42.5	48.2	39.7
21120	M11	38.3	43.3	35.4
26400	M12	34.9	39.3	32.1
31680	M13	32.1	36.0	29.3

Table 58. INM 7.0c Modeled Noise Results the MiG-15, F-15 and F7F Performing 10 Aerobatic Routines (Jets with Lateral Attenuation, Warbird without Lateral Attenuation)

		Modeled DNL values (dBA)		
Distance (ft)	Grid Point	MiG-15 [Sportsman] (to 1500 ft AGL)	F-15 [Sportsman] (to 1500 ft AGL)	F7F [Sportsman] (to 1500 ft AGL)
-500	M1	64.6	74.0	64.2
0	M2	64.9	74.6	64.5
500	M3	64.5	74.5	64.2
660	M4	64.3	74.4	64.0
1320	M5	63.2	73.3	62.8
2640	M6	60.5	70.1	59.8
5280	M7	56.3	64.5	54.6
5496	M8	56.0	64.1	54.3
10560	M9	50.2	56.8	47.5
15840	M10	45.5	51.2	42.7
21120	M11	41.3	46.3	38.4
26400	M12	37.9	42.3	35.1
31680	M13	35.1	39.0	32.3

Table 59. INM 7.0c Modeled Noise Results the MiG-15, F-15 and F7F Performing 20 Aerobatic Routines (Jets with Lateral Attenuation, Warbird without Lateral Attenuation)

		Modeled DNL values (dBA)		
Distance (ft)	Grid Point	MiG-15 [Sportsman] (to 1500 ft AGL)	F-15 [Sportsman] (to 1500 ft AGL)	F7F [Sportsman] (to 1500 ft AGL)
-500	M1	67.6	77.0	67.2
0	M2	67.9	77.6	67.5
500	M3	67.5	77.5	67.2
660	M4	67.3	77.4	67.0
1320	M5	66.2	76.3	65.8
2640	M6	63.5	73.1	62.8
5280	M7	59.3	67.5	57.6
5496	M8	59.0	67.1	57.3
10560	M9	53.2	59.8	50.5
15840	M10	48.5	54.2	45.7
21120	M11	44.3	49.3	41.4
26400	M12	40.9	45.3	38.1
31680	M13	38.1	42.0	35.3

Table 60. INM 7.0c Modeled Noise Results the MiG-15, F-15 and F7F Performing 30 Aerobatic Routines (Jets with Lateral Attenuation, Warbird without Lateral Attenuation)

		Modeled DNL values (dBA)		
Distance (ft)	**Grid Point**	**MiG-15 [Sportsman] (to 1500 ft AGL)**	**F-15 [Sportsman] (to 1500 ft AGL)**	**F7F [Sportsman] (to 1500 ft AGL)**
-500	M1	69.4	78.8	69.0
0	M2	69.7	79.4	69.3
500	M3	69.3	79.3	69.0
660	M4	69.1	79.2	68.8
1320	M5	68.0	78.1	67.6
2640	M6	65.3	74.9	64.6
5280	M7	61.1	69.3	59.4
5496	M8	60.8	68.9	59.1
10560	M9	55.0	61.6	52.3
15840	M10	50.3	56.0	47.5
21120	M11	46.1	51.1	43.2
26400	M12	42.7	47.1	39.9
31680	M13	39.9	43.8	37.1

Table 61. INM 7.0c Modeled Noise Results the MiG-15, F-15 and F7F Performing 40 Aerobatic Routines (Jets with Lateral Attenuation, Warbird without Lateral Attenuation)

		Modeled DNL values (dBA)		
Distance (ft)	**Grid Point**	**MiG-15 [Sportsman] (to 1500 ft AGL)**	**F-15 [Sportsman] (to 1500 ft AGL)**	**F7F [Sportsman] (to 1500 ft AGL)**
-500	M1	70.6	80.0	70.2
0	M2	70.9	80.6	70.5
500	M3	70.5	80.5	70.2
660	M4	70.3	80.4	70.0
1320	M5	69.2	79.3	68.8
2640	M6	66.5	76.1	65.8
5280	M7	62.3	70.5	60.6
5496	M8	62.0	70.1	60.3
10560	M9	56.2	62.8	53.5
15840	M10	51.5	57.2	48.7
21120	M11	47.3	52.3	44.4
26400	M12	43.9	48.3	41.1
31680	M13	41.1	45.0	38.3

Table 62. INM 7.0c Modeled Noise Results the MiG-15, F-15 and F7F Performing 50 Aerobatic Routines (Jets with Lateral Attenuation, Warbird without Lateral Attenuation)

		Modeled DNL values (dBA)		
Distance (ft)	**Grid Point**	**MiG-15 [Sportsman] (to 1500 ft AGL)**	**F-15 [Sportsman] (to 1500 ft AGL)**	**F7F [Sportsman] (to 1500 ft AGL)**
-500	M1	71.6	81.0	71.2
0	M2	71.9	81.6	71.4
500	M3	71.5	81.5	71.2
660	M4	71.3	81.4	71.0
1320	M5	70.2	80.2	69.8
2640	M6	67.5	77.1	66.8
5280	M7	63.3	71.5	61.6
5496	M8	63.0	71.1	61.2
10560	M9	57.2	63.7	54.5
15840	M10	52.5	58.2	49.7
21120	M11	48.3	53.3	45.4
26400	M12	44.9	49.3	42.1
31680	M13	42.1	46.0	39.3

Appendix D Example of Estimating Noise from Multiple Different Aircraft Performing Aerobatic Routines

This appendix presents several examples of using the data in this report and the methods discussed in Section 4.2 (specifically Equation 1) to compute a rough estimate of noise levels due to a combination of multiple different aircraft performing aerobatic routines for an analysis.

D.1 Example of 20 Edge 540 Advanced Routines

This is an example of the method used to estimate the noise from 20 identical Advanced routines performed by the Edge. The input data are presented in Table 63 and Equation 2 is used to compute the cumulative noise levels presented in Table 64. These estimated results were verified with INM 7.0c.

Table 63. Input Data for Example D.1

Representative Aircraft	Aerobatic Routine	Number of Events	Source of Data
Edge 540	Advanced Known 2011 (to 800 ft AGL)	20	Appendix C, Table 28

$$L_{DN,i} = 10 \times log_{10}\{20 \times (10^{L_{DN,acft,flt,i}/10})\}$$ **Equation 2**

where

$L_{DN,acft,flt,i}$ noise level (in dBA DNL) from the aircraft (Edge 540) performing an aerobatic routine (Advanced) at a distance from the aerobatic practice box ("i" ft). These noise levels are found in Appendix C (Table 28 for this example) and referenced above in Table 63. E.g., at a distance of 500 ft from the center of the practice box, this term can be rewritten as $L_{DN,Edge,Advanced,500ft}$.

Table 64. Noise Results for Example D.1

Distance (ft)	Grid Point	Output Noise Levels (dBA DNL)
-500	M1	56.0
0	M2	55.2
500	M3	54.1
660	M4	53.6
1320	M5	51.3
2640	M6	47.3
5280	M7	41.6
5496	M8	41.2
10560	M9	34.1

D.2 Example of 7 Different Sportsman Routines

This is an example of the method used to estimate the noise from seven different aircraft performing the Sportsman Routine. The input data are presented in Table 65 and Equation 3 is used to compute the cumulative noise levels presented in Table 66. These estimated results were verified with INM 7.0c.

Table 65. Input Data for Example D.2

Representative Aircraft	Aerobatic Routine	Number of Events	Source of Data
Extra EA-230	Sportsman Known 2005 (to 1500 ft AGL)	1	Appendix C, Table 42
Edge 540	Sportsman Known 2005 (to 1500 ft AGL)	1	Appendix C, Table 28
Sukhoi SU-29	Sportsman Known 2005 (to 1500 ft AGL)	1	Appendix C, Table 35
Pitts S-2C	Sportsman Known 2005 (to 1500 ft AGL)	1	Appendix C, Table 49
MiG-15	Sportsman Known 2005 (to 1500 ft AGL)	1	Appendix C, Table 56
F-15	Sportsman Known 2005 (to 1500 ft AGL)	1	Appendix C, Table 56
F7F	Sportsman Known 2005 (to 1500 ft AGL)	1	Appendix C, Table 56

$$L_{DN,i} = 10 \times log_{10}\{[1 \times (10^{L_{DN,Extra,Sportsman,i}/10})] + [1 \times (10^{L_{DN,Edge,Sportsman,i}/10})] + [1 \times (10^{L_{DN,Sukhoi,Sportsman,i}/10})] + [1 \times (10^{L_{DN,Pitts,Sportsman,i}/10})] + [1 \times (10^{L_{DN,MiG-15,Sportsman,i}/10})] + [1 \times (10^{L_{DN,F-15,Sportsman,i}/10})] + [1 \times (10^{L_{DN,F7F,Sportsman,i}/10})]\}$$

Equation 3

Table 66. Noise Results for Example D.2

Distance (ft)	Grid Point	Output Noise Levels (dBA DNL)
-500	M1	64.9
0	M2	65.4
500	M3	65.3
660	M4	65.2
1320	M5	64.1
2640	M6	60.9
5280	M7	55.5
5496	M8	55.1
10560	M9	48.1

D.3 Example of 2 Occurrences of Each of the 7 Noisiest Routines

This is an example of the method used to estimate the noise from seven different aircraft performing the noisiest routines: the Unlimited routines at a minimum altitude of 20 ft AFE for the light to medium propeller aircraft (Extra, Edge, Sukhoi and Pitts), and the Sportsman routines for the heavy propeller and jet aircraft (MiG-15, F-15 and F7F). Two occurrences of each routine were modeled. The input data are presented in Table 67 and Equation 4 is used to compute the cumulative noise levels presented in Table 68. These estimated results were verified with INM 7.0c.

Table 67. Input Data for Example D.3

Representative Aircraft	Aerobatic Routine	Number of Events	Source of Data
Extra EA-230	Unlimited Known 2011 (to 20 ft AGL)	2	Appendix C, Table 42
Edge 540	Unlimited Known 2011 (to 20 ft AGL)	2	Appendix C, Table 28
Sukhoi SU-29	Unlimited Known 2011 (to 20 ft AGL)	2	Appendix C, Table 35
Pitts S-2C	Unlimited Known 2011 (to 20 ft AGL)	2	Appendix C, Table 49
MiG-15	Sportsman Known 2005 (to 1500 ft AGL)	2	Appendix C, Table 56
F-15	Sportsman Known 2005 (to 1500 ft AGL)	2	Appendix C, Table 56
F7F	Sportsman Known 2005 (to 1500 ft AGL)	2	Appendix C, Table 56

$$
\begin{aligned}
L_{DN,i} = 10 \times log_{10}\{&[2 \times (10^{L_{DN,Extra,Unlimited\ to\ 20ft,i}/10})] \\
&+ [2 \times (10^{L_{DN,Edge,Unlimited\ to\ 20ft,i}/10})] \\
&+ [2 \times (10^{L_{DN,Sukhoi,Unlimited\ to\ 20ft,i}/10})] \\
&+ [2 \times (10^{L_{DN,Pitts,Unlimited\ to\ 20ft,i}/10})] \\
&+ [2 \times (10^{L_{DN,MiG-15,Sportsman,i}/10})] \\
&+ [2 \times (10^{L_{DN,F-15,Sportsman,i}/10})] \\
&+ [2 \times (10^{L_{DN,F7F,Sportsman,i}/10})]\}
\end{aligned}
$$

Equation 4

Table 68. Noise Results for Example D.3

Distance (ft)	Grid Point	Output Noise Levels (dBA DNL)
-500	M1	68.1
0	M2	69.9
500	M3	68.5
660	M4	68.4
1320	M5	67.2
2640	M6	64.0
5280	M7	58.5
5496	M8	58.2
10560	M9	51.1

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Appendix E Aerobatic Routines

The descriptions of the aerobatic routines modeled in INM for this analysis are presented in this appendix. The minimum and maximum altitudes modeled for each aerobatic routine in INM are presented in Table 69 and Table 70. The IAC scoresheets used to define the aerobatic maneuvers that make up each aerobatic routine are presented in Figure 3 through Figure 6. Additional documentation on these aerobatic routines, including detailed definitions of each aerobatic maneuver, is available through IAC*.

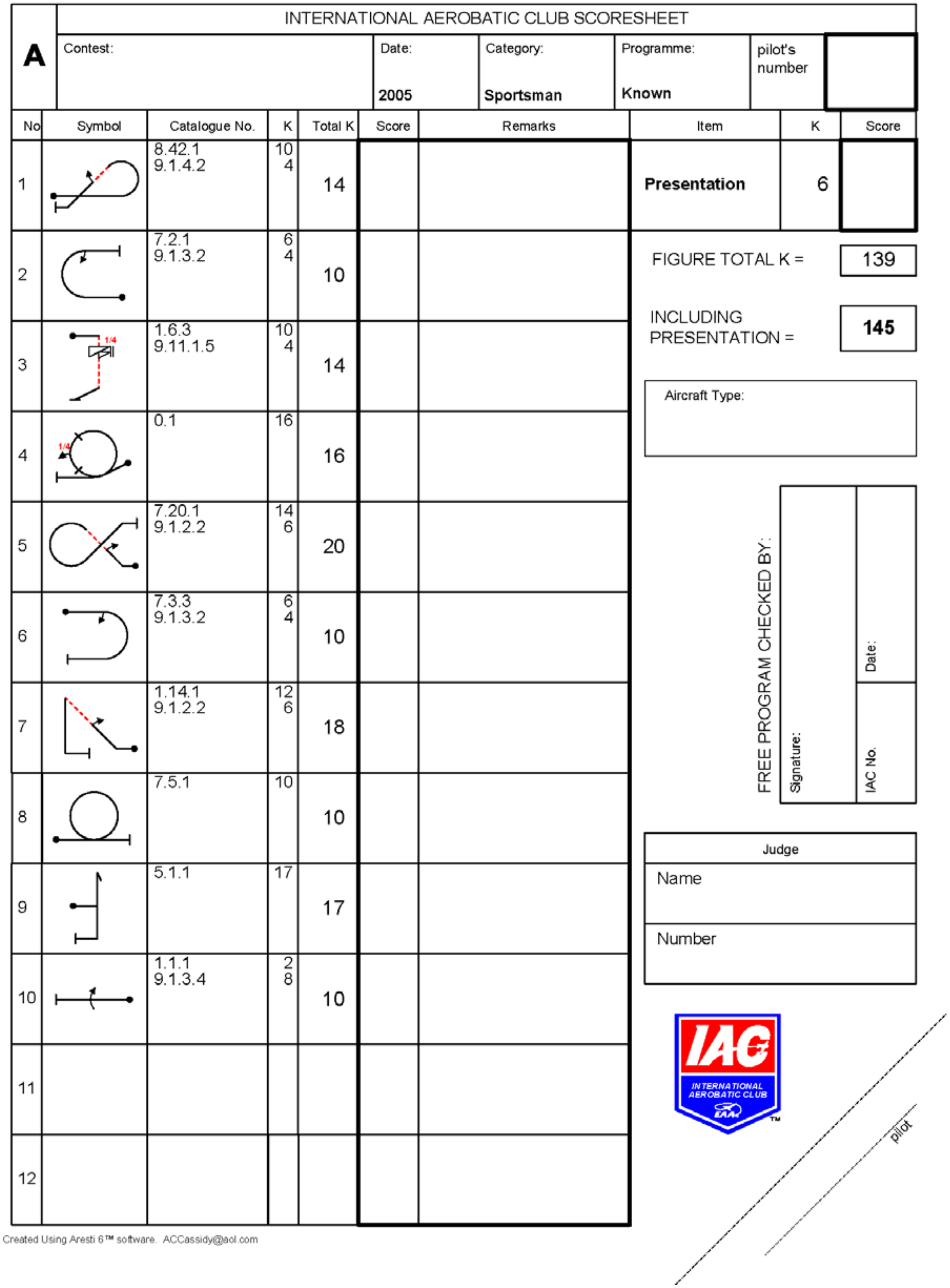
Table 69. Minimum Altitude of Aerobatic Routines Modeled in INM

		Minimum Altitude of Aerobatic Routines Modeled in INM (in ft AGL)				
Category	**Representative Aircraft**	**Sportsman Known 2005**	**Intermediate Known 2005**	**Advanced Known 2011**	**Unlimited Known 2011**	**Unlimited Known 2011 - Adjusted**
high weight piston	Extra EA-230	1500.6	1200.1	800.5	331.2	22.6
mid weight piston	Edge 540	1500.6	1200.1	800.5	331.2	22.6
high weight radial	Sukhoi SU-29	1500.6	1200.1	800.5	331.2	22.6
low weight piston	Pitts S-2C	1500.6	1200.1	800.5	331.2	22.6
mid power jet	MiG-15	1499.6	n/a	n/a	n/a	n/a
high power jet	F-15	1498.8	n/a	n/a	n/a	n/a
high power/radial	F7F	1500	n/a	n/a	n/a	n/a

Table 70. Maximum Altitude of Aerobatic Routines Modeled in INM

		Maximum Altitude of Aerobatic Routines Modeled in INM (in ft AGL)				
Category	**Representative Aircraft**	**Sportsman Known 2005**	**Intermediate Known 2005**	**Advanced Known 2011**	**Unlimited Known 2011**	**Unlimited Known 2011 - Adjusted**
high weight piston	Extra EA-230	2454.6	2689.3	2673.7	2187.8	1879.2
mid weight piston	Edge 540	2454.6	2689.3	2673.7	2187.8	1879.2
high weight radial	Sukhoi SU-29	2454.6	2689.3	2673.7	2187.8	1879.2
low weight piston	Pitts S-2C	2454.6	2689.3	2673.7	2187.8	1879.2
mid power jet	MiG-15	11924.7	n/a	n/a	n/a	n/a
high power jet	F-15	16167.8	n/a	n/a	n/a	n/a
high power/radial	F7F	3669.8	n/a	n/a	n/a	n/a

* http://www.iac.org/



INTERNATIONAL AEROBATIC CLUB SCORESHEET

A	Contest:	Date: 2005	Category: Sportsman	Programme: Known	pilot's number

No	Symbol	Catalogue No.	K	Total K	Score	Remarks
1		8.42.1 9.1.4.2	10 4	14		
2		7.2.1 9.1.3.2	6 4	10		
3		1.6.3 9.11.1.5	10 4	14		
4		0.1	16	16		
5		7.20.1 9.1.2.2	14 6	20		
6		7.3.3 9.1.3.2	6 4	10		
7		1.14.1 9.1.2.2	12 6	18		
8		7.5.1	10	10		
9		5.1.1	17	17		
10		1.1.1 9.1.3.4	2 8	10		
11						
12						

Item	K	Score
Presentation	6	

FIGURE TOTAL K = 139

INCLUDING PRESENTATION = **145**

Aircraft Type:

FREE PROGRAM CHECKED BY: Signature: Date: IAC No.

Judge
Name
Number

pilot

Created Using Aresti 6™ software. ACCassidy@aol.com

Figure 3. Description of the IAC Sportsman Known 2005 Aerobatic Routine

INTERNATIONAL AEROBATIC CLUB SCORESHEET

A	Contest:	Date: 2005	Category: Intermediate	Programme: Known	pilot's number	

No	Symbol	Catalogue No.	K	Total K	Score	Remarks
1		1.2.1 9.1.2.4	7 10	**17**		
2		1.6.3 9.11.1.6	10 3	**13**		
3		1.18.1 9.4.4.2	13 5	**18**		
4		5.1.1 9.1.1.1	17 6	**23**		
5		1.7.1 9.1.1.1	9 6	**15**		
6		8.38.4 9.1.4.2 9.4.3.2	11 4 5	**20**		
7		1.2.3 9.9.4.4	7 11	**18**		
8		7.2.1 9.1.3.2	6 4	**10**		
9		7.3.3 9.1.3.6	6 10	**16**		
10		7.5.1 9.2.3.4	10 9	**19**		
11		8.42.1 9.1.4.2	10 4	**14**		
12		7.1.1 9.1.3.4	6 8	**14**		
13		2.2.4	4	**4**		
14						
15						
16						

Item	K	Score
Presentation	**8**	

FIGURE TOTAL K = 201

INCLUDING POSITIONING = **209**

Aircraft Type:

FREE PROGRAM CHECKED BY:

Signature: Date: IAC No.

Judge
Name
Number

IAC INTERNATIONAL AEROBATIC CLUB EAA ™

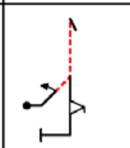
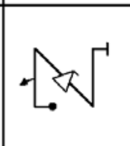
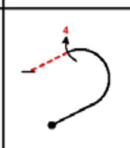
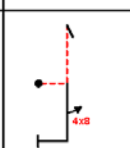
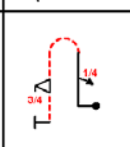
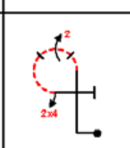
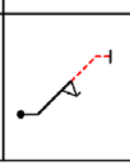
pilot

Created Using Aresti 6™ software. ACCassidy@aol.com

Figure 4. Description of the IAC Intermediate Known 2005 Aerobatic Routine

A — INTERNATIONAL AEROBATIC CLUB SCORESHEET

Contest:	Date: 2011	Category: Advanced	Programme: Known	pilot's number	

No	Symbol	Catalogue No.	K	Total K	Grade	Remarks
1		5.3.1 9.1.2.2 9.9.5.2	24 6 11	41		
2		1.40.1 9.1.1.2 9.9.4.4	22 8 11	41		
3		1.6.3 9.11.1.5	10 4	14		
4		7.1.1 9.4.3.4	6 11	17		
5		2.8.2	31	31		
6		5.1.4 9.8.5.2	22 7	29		
7		8.3.1 9.1.1.1 9.9.10.3	15 6 13	34		
8		8.40.1 9.2.3.4 9.4.3.2	14 9 5	28		
9		1.3.1 9.9.2.2	7 13	20		

Item	K	Score
Presentation	**12**	

FIGURE TOTAL K = 255

INCLUDING PRESENTATION = **267**

Aircraft Type:

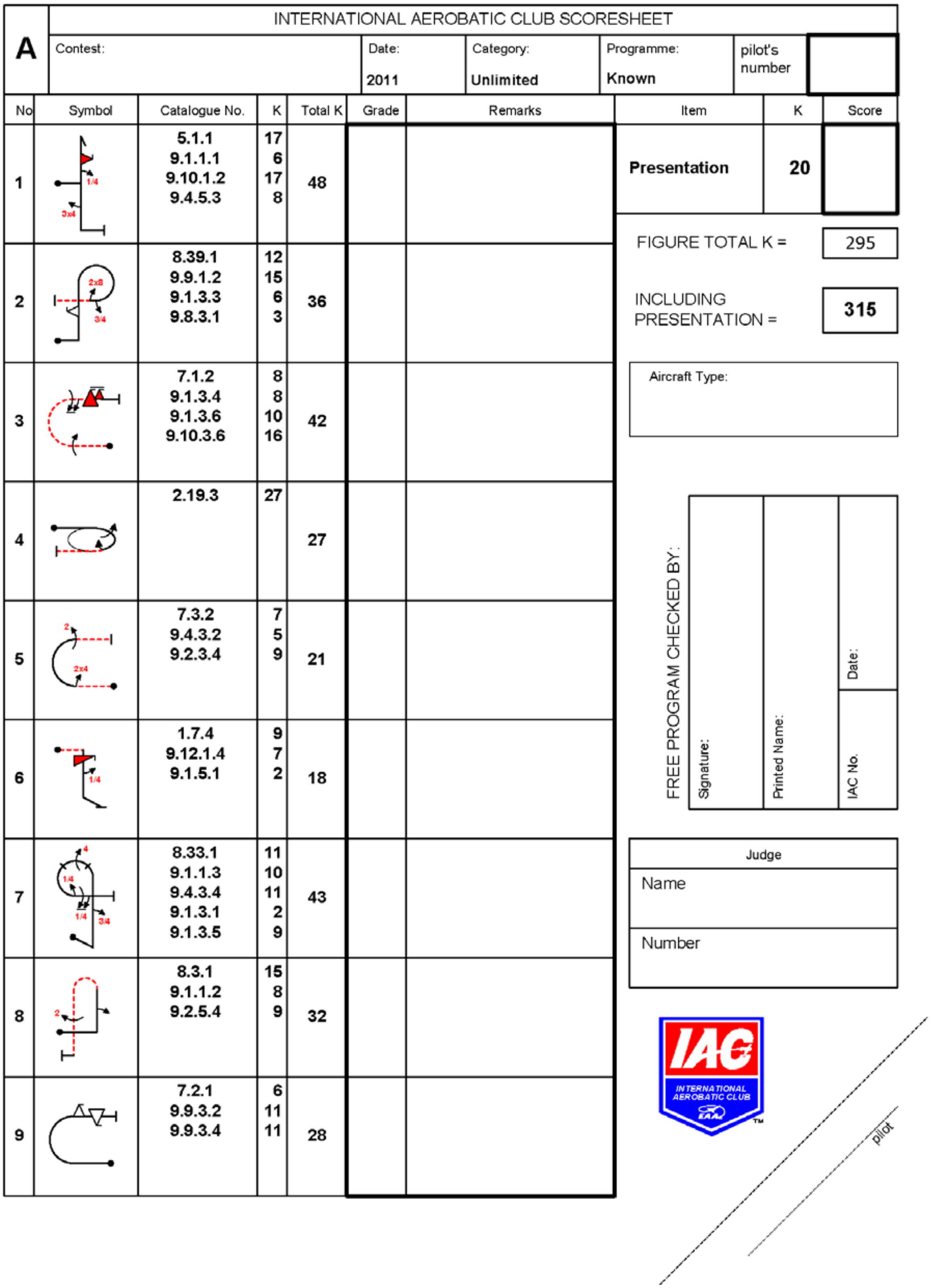
FREE PROGRAM CHECKED BY: Signature: Printed Name: Date: IAC No.

Judge
Name
Number

pilot

Created Using Aresti 2010™ software. ACCassidy@aol.com

Figure 5. Description of the IAC Advanced Known 2011 Aerobatic Routine



A | INTERNATIONAL AEROBATIC CLUB SCORESHEET

Contest:	Date: 2011	Category: Unlimited	Programme: Known	pilot's number	

No	Symbol	Catalogue No.	K	Total K	Grade	Remarks
1		5.1.1 9.1.1.1 9.10.1.2 9.4.5.3	17 6 17 8	48		
2		8.39.1 9.9.1.2 9.1.3.3 9.8.3.1	12 15 6 3	36		
3		7.1.2 9.1.3.4 9.1.3.6 9.10.3.6	8 8 10 16	42		
4		2.19.3	27	27		
5		7.3.2 9.4.3.2 9.2.3.4	7 5 9	21		
6		1.7.4 9.12.1.4 9.1.5.1	9 7 2	18		
7		8.33.1 9.1.1.3 9.4.3.4 9.1.3.1 9.1.3.5	11 10 11 2 9	43		
8		8.3.1 9.1.1.2 9.2.5.4	15 8 9	32		
9		7.2.1 9.9.3.2 9.9.3.4	6 11 11	28		

Item	K	Score
Presentation	**20**	

FIGURE TOTAL K = 295

INCLUDING PRESENTATION = **315**

Aircraft Type:

FREE PROGRAM CHECKED BY:
Signature:
Printed Name:
Date:
IAC No.

Judge
Name
Number

pilot

Figure 6. Description of the IAC Unlimited Known 2011 Aerobatic Routine

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Appendix F Previous Aerobatic Aircraft Noise Memorandum

This original 2006 technical report entitled “Aerobatic Aircraft Noise Study: Technical Memorandum” is included in this Appendix for completeness.

Subject: Aerobatic Aircraft Noise Study Technical Memorandum

Date: May 5, 2006

From: Eric Boeker
Volpe TSC, Acoustics Facility

Reply to Attn. of: DTS-34

To: Gene Kirkendall
FAA

CC: Jeff Weller (FAA), Ed Kelleher (FAA), Gregg Fleming (Volpe)

At the Federal Aviation Administration's (FAA) request, the Volpe Center Acoustics Facility (Volpe) conducted a noise measurement study of aerobatic aircraft. The study was conducted at the Galt Airport in Greenwood, IL from August 22nd to 26th, 2005.

This study had two main objectives. The first objective was to measure high quality source noise data for several representative aerobatic aircraft for inclusion in the FAA's Integrated Noise Model (INM). The second objective was to measure noise from complete aerobatic routines, in order to evaluate the: (1) noise levels at specific microphone locations, and (2) modeling of aerobatic routines in INM through a comparison of modeled versus measured noise levels. This memorandum provides a summary of the measurements (Appendix A), and the results from the analysis of all five aerobatic aircraft; the Zivko Edge 540 (Edge), the Extra EA-230 (Extra), the Sukhoi SU-29 (Sukhoi), the Aviat Pitts S-2C (Pitts), and the American Champion Decathlon (Decathlon). An initial analysis of the Sukhoi was undertaken as a verification of principals, prior to analyzing the data from the remaining four aircraft. The Sukhoi was selected for the initial analysis because it is one of the louder aerobatic aircraft in use today. A technical memorandum on this initial analysis was generated on February 28th, 2006, and those findings have been incorporated into this document.

Source noise measurements were conducted for the Edge, the Extra and the Sukhoi on August 23rd, 2005 and for the Pitts, and the Decathlon on August 24th, 2005. In addition, noise measurements of full aerobatic routines were conducted on August 25th, 2005 for three of the aircraft, where the Extra and the Pitts performed International Aerobatic Club (IAC) Sportsman 2005 Known routines, and the Sukhoi performed the IAC Intermediate 2005 Freestyle routine. A summary of these measurements and the subsequent data processing and analysis is presented in Appendix A of this memorandum. The measurements resulted in noise data for 82 level-flight events[1] and five full aerobatic sequences measured at several positions. These results are presented in Appendix B.

[1] Six different types of level-flight events were conducted for this noise measurement study; high speed (around 135 mph in both directions of travel; North to South, and South to North), low speed (around 70 mph), acceleration (accelerating to full throttle), inverted (at high speed), knife-edge facing left and facing right (at high speed). Not all of the aerobatic aircraft were able to perform all six types of level-flight events.

The noise data for these events were then used to develop Noise-Power-Distance (NPD) data for each of the aircraft, which were entered into INM along with aircraft position information, derived from a Volpe, video-based, position tracking system. This allowed the Extra's, the Sukhoi's, and the Pitts's level-flight events and full aerobatic sequences to be modeled in INM, as described in more detail in Appendix C. The INM modeled results were then compared with the measured noise levels for the corresponding full aerobatic sequences (see Figures 1 through 6).

The modeled results for the Extra were between 1.5 and 3.5 dB louder than the measured levels directly under the center of the practice box, 1/8 mile away, and 1/4 mile away. At the same locations, the modeled results for the Pitts were between 1 and 3 dB quieter than the measured levels, and the modeled results for the Sukhoi were between 0.5 and 3 dB louder than the measured levels. Previous INM validation studies for commercial aircraft have shown measured/modeled differences, which are generally consistent with the results of this study[2]. ***Based on these comparative results, one can conclude that the INM is an acceptable tool for modeling noise from aerobatic aircraft.***

Furthermore, a good deal of repeatability was observed, when comparing the measured noise levels between routines for the same aircraft. The difference between noise levels from the two Pitts sequences was less than 1 dB at all measurement locations, and the difference between the Sukhoi routines (which were flown freestyle) was less than 2 dB at all measurement locations. This repeatability can be attributed to the fact that these are high performance, well-maintained aircraft operated by precision pilots performing a standard and consistent set of aerobatic maneuvers. This repeatability along with the aforementioned acceptable differences observed between measured and modeled data further supports the use of INM as a tool for modeling noise from aerobatic aircraft.

In addition, both the measured and modeled noise levels for all three aircraft were below 91 dB(A) SEL directly below the practice box, and 88 dB(A) SEL 1/4 mile away from the center of the practice box, which is still on airport property. These levels indicate that the noise generated by the Sukhoi SU-29 flying IAC Intermediate 2005 Freestyle aerobatic routines, or the Extra or the Pitts flying IAC Sportsman 2005 Known routines would also be below 88 dB SEL at the Galt Airport property line (around 1/2 mile away from the center of the practice box). Of more significance is that the noise levels for each aerobatic routine measured at a distance of one mile were only slightly higher than the ambient level at Galt Airport.

Although SEL is a good metric for analyzing individual noise events, airport noise analyses are typically based on the day night average sound level metric (L_{dn} or DNL), which is a 24-hour-long average sound level with a 10 dB nighttime penalty (10 PM to 7 AM). In the vicinity of airports, noise levels due to airport operations above 65 dB DNL are of particular interest. Although DNL measurements were not performed as part of this measurement study, estimated DNL values were

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[2] Page, et. al., Validation of Aircraft Noise Models at Lower Levels of Exposure. NASA Contract Report 198315. Hampton, VA. National Aeronautics and Space Administration, Langley Research Center. June 1996.

Miller, et. al., Examining INM Accuracy Using Empirical Sound Monitoring and Radar Data. NASA/CR-2000-210113. Hampton, VA. National Aeronautics and Space Administration, Langley Research Center. April 2000.

calculated from the measured SEL data[3]. The estimated DNL of a single, daytime aerobatic routine was less than 42 dB(A) for all three aircraft at all measurement positions. Even when multiple daytime routines were considered (up to 50 identical routines), the estimated DNL values due to any of the aerobatic routines never exceeded 60 dB(A) DNL directly below the practice box, 56 dB(A) DNL 1/4 mile away from the center of the practice box, or 46 dB(A) DNL one mile away. Although these estimated DNLs did not take into account approaches to and departures from the practice box, it may be inferred that even with their inclusion, none of the aerobatic routines flown in this study would have exceeded 65 dB DNL at distances 1/4 mile or more from the center of the practice box. ***A conservative recommendation would be to locate heavily utilized aerobatics practice boxes 1/2 mile or more from noise sensitive receivers.***

Additional analyses of the measured and modeled data are presented in Appendix D.

[3] It is important to note that these estimated DNL values are based solely on the measured aerobatic routines, and did not take into account other aircraft operations, or noise sources.

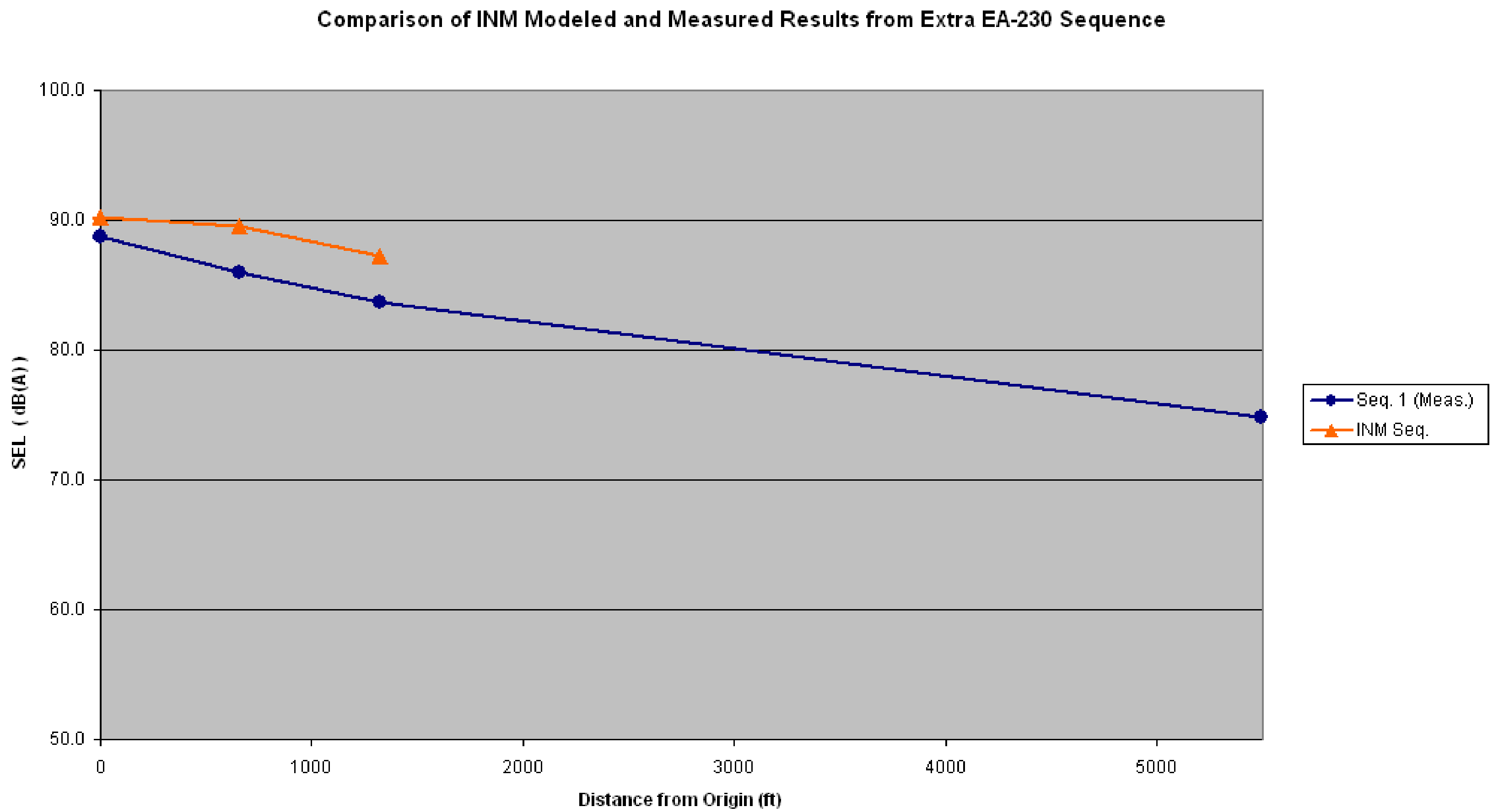

Figure 1: Comparison of Extra EA-230 Aerobatic Sequences
with Corresponding INM Results - SEL[4]

[4] Modeling was not performed for the 1-mile measurement position, as sufficient aircraft track data was not available to ensure accurate modeling.

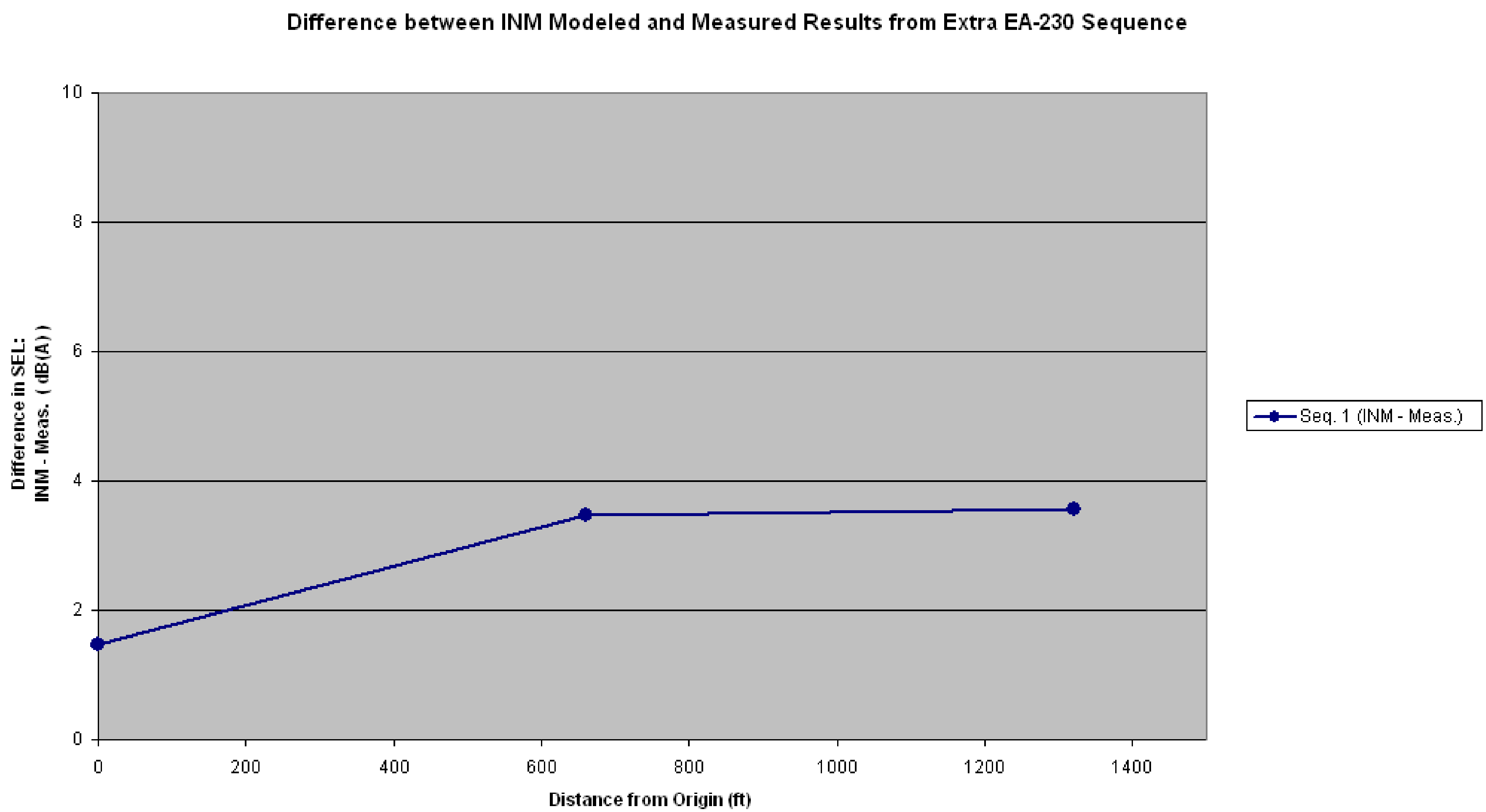

Figure 2: Difference between INM Measured and Modeled Results
for the Extra EA-230 Aerobatic Sequences

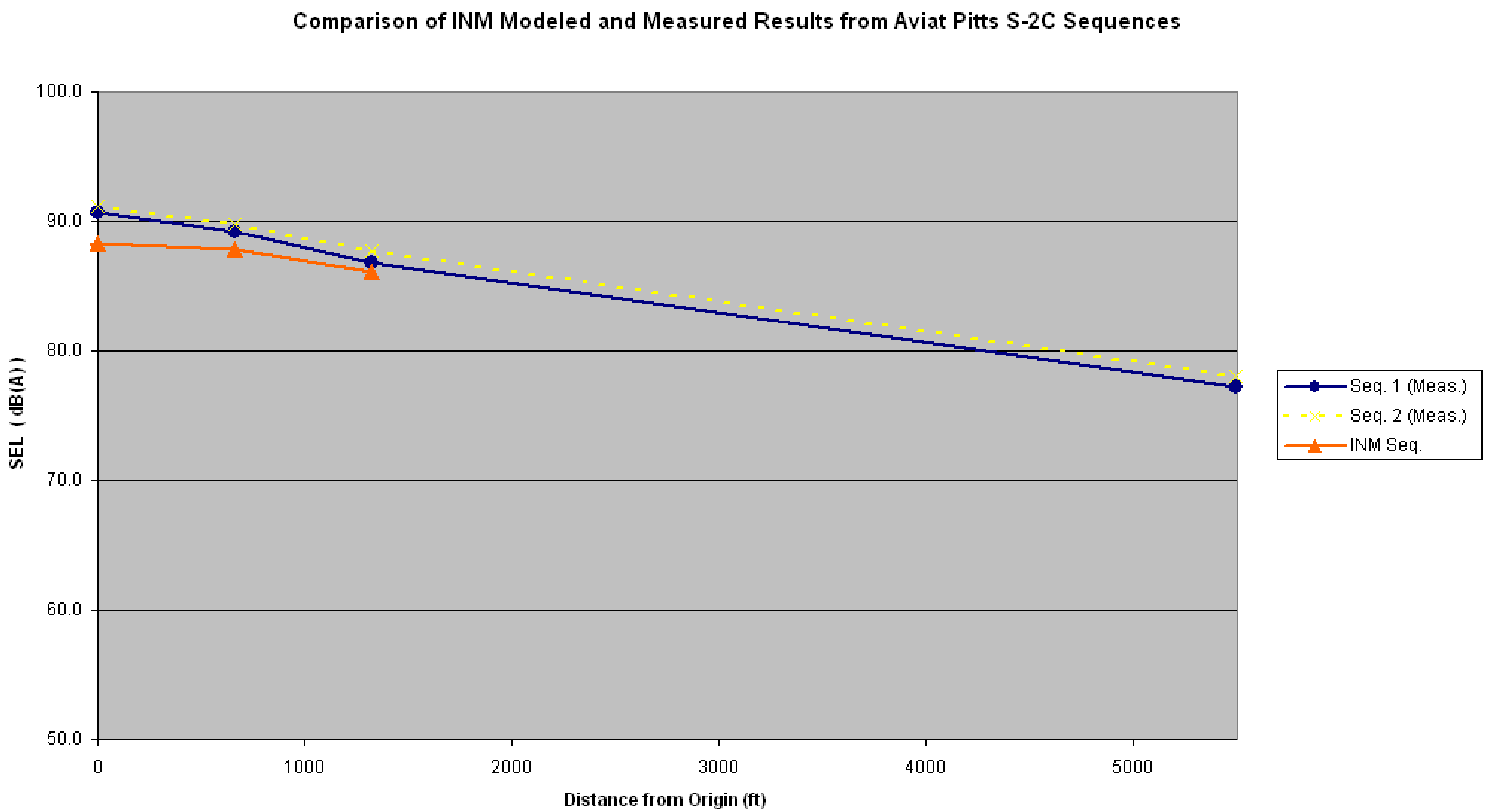

Figure 3: Comparison of Aviat Pitts S-2C Aerobatic Sequences
with Corresponding INM Results - SEL[5]

[5] The two Pitts aerobatic sequences were similar enough, that they could be represented by a single INM sequence.

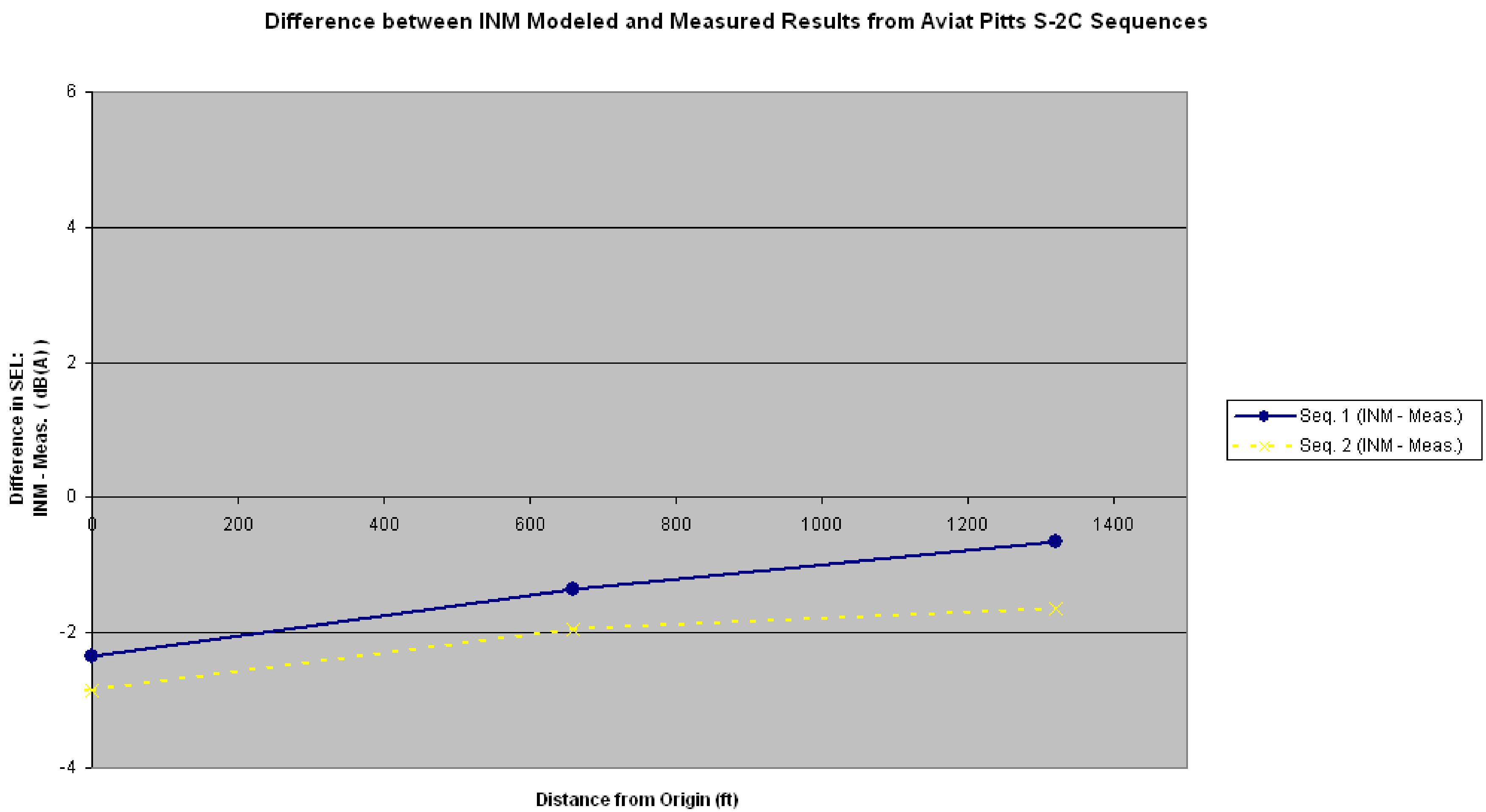

Figure 4: Difference between INM Measured and Modeled Results
for the Aviat Pitts S-2C Aerobatic Sequences

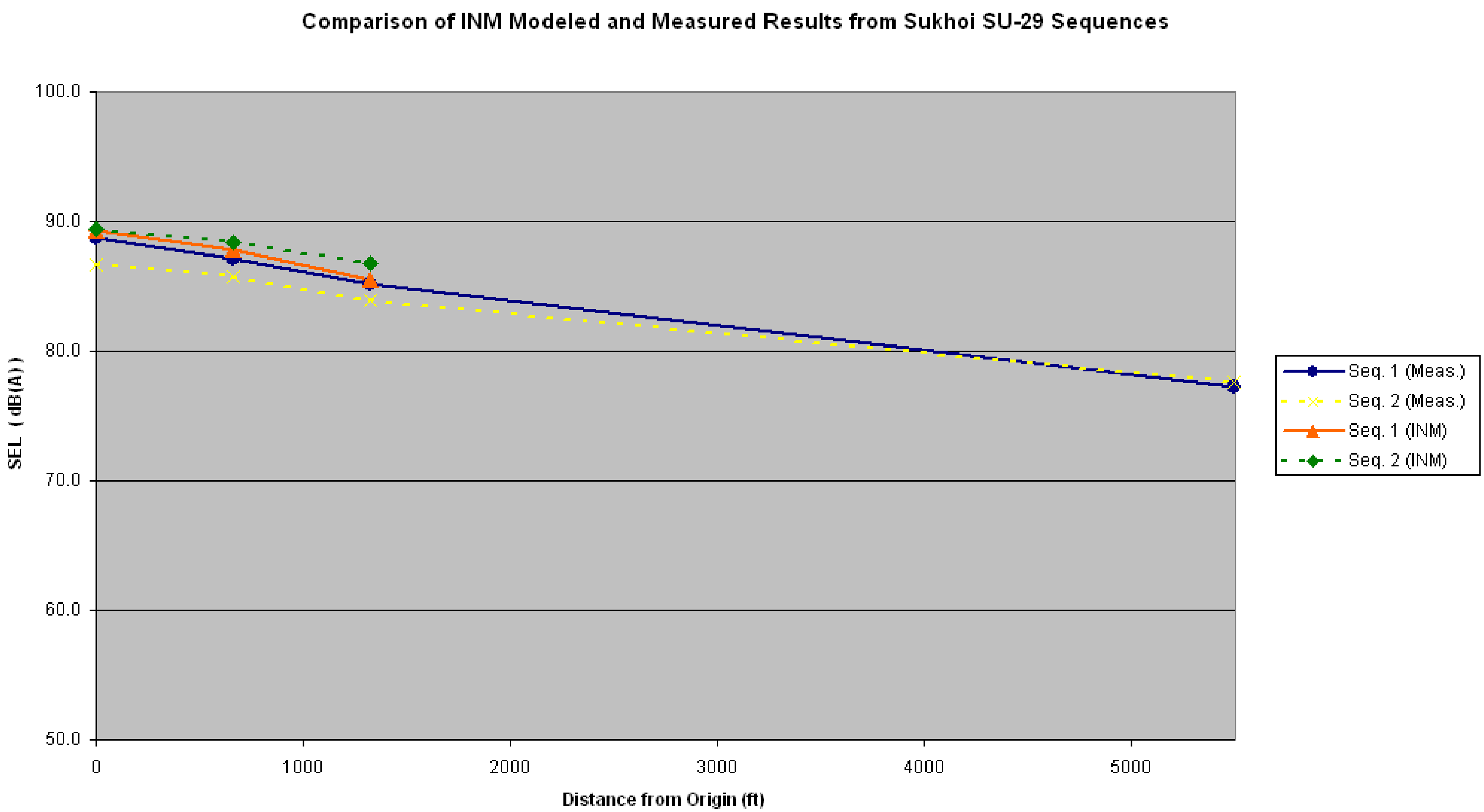

Figure 5: Comparison of Sukhoi SU-29 Aerobatic Sequences
with Corresponding INM Results - SEL[6]

[6] Since the two Sukhoi aerobatic sequences were "Freestyle", they were different enough, that they were each modeled in INM separately.

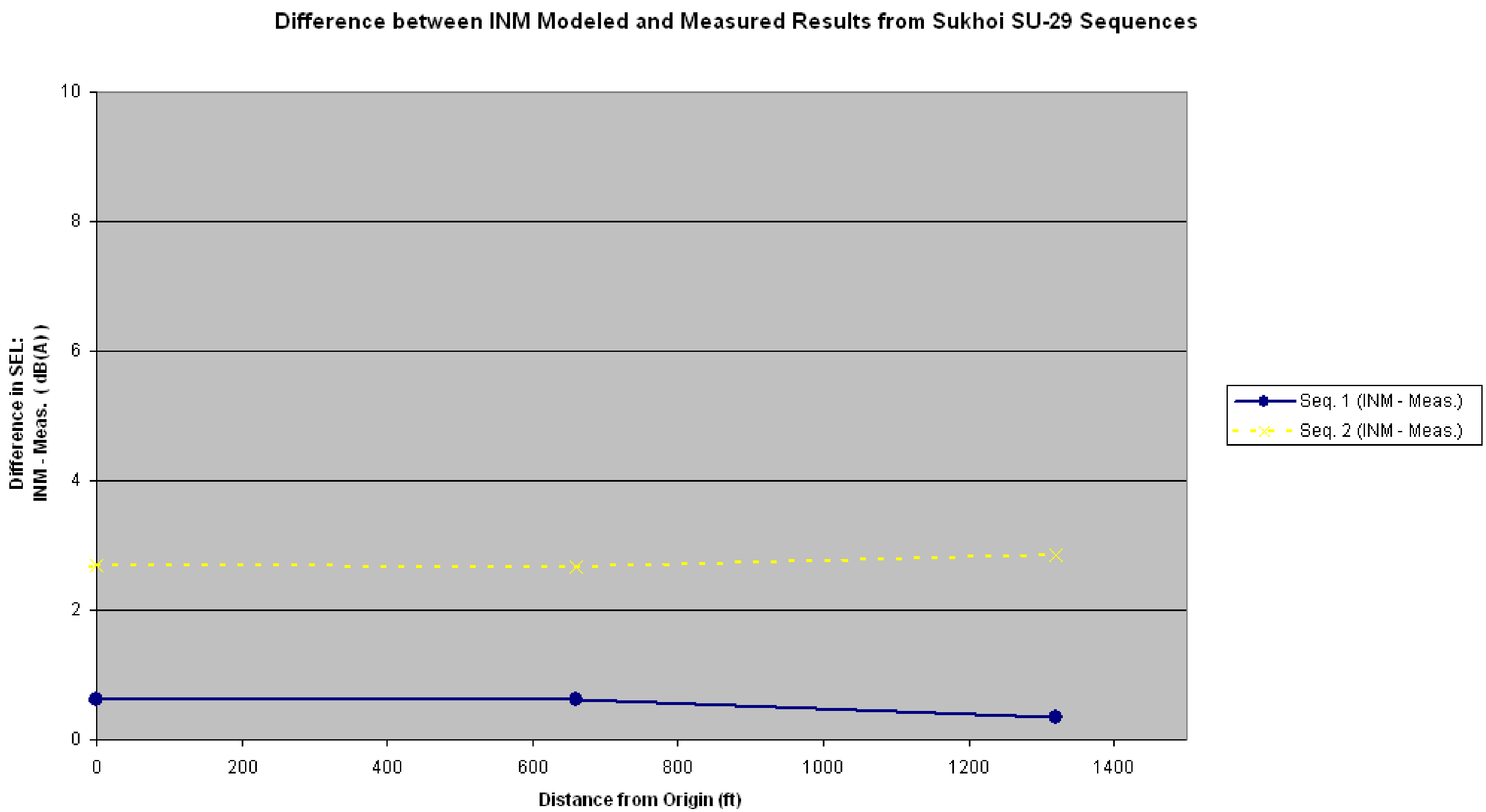

Figure 6: Difference between INM Measured and Modeled Results
for the Sukhoi SU-29 Aerobatic Sequences

Appendix A. Noise Measurement Summary

Source noise measurements were conducted for the Extra, the Edge and the Sukhoi on August 23rd, 2005 and for the Pitts, and the Decathlon on August 24th, 2005. Noise and aircraft position data were measured for a series of different level-flight events, representing a range of operational conditions. All of the events were conducted at an altitude of 500 ft above field elevation and were centered over the west edge of the north-south runway at Galt Airport. This measurement program focused on six different types of events: high speed (around 135 mph)[7], low speed (around 70 mph), acceleration (accelerating to full throttle), inverted (at high speed), knife-edge facing left and facing right (at high speed)[8]. Each type of event was repeated until a minimum of three acceptable events were measured. The acceptability criteria were based on observed aircraft performance, meteorological and ambient noise conditions.

For each event, aircraft source noise data were measured at microphones located 500 ft East of the origin (M1 [Left]), at the origin (M2 [Center]) and 500 ft West (M3 [Right]), as shown in Figures 7 and 8[9]. One-second, A-weighted, equivalent sound pressure level (L_{Aeq}) data and the corresponding 1/3-octave-band spectra were measured and stored for each event, and the corresponding audio signal was recorded to digital audio tape (DAT). Aircraft position information for each event was captured by the cameras of the video tracking system. A detailed description of all measurement equipment utilized during this study was presented in the study test plan[10].

In addition, noise measurements of full aerobatic routines were conducted on August 25th, 2005 for three of the aircraft; the Extra, the Pitts and the Sukhoi. The Extra and the Pitts performed International Aerobatic Club (IAC) Sportsman 2005 Known routines, and the Sukhoi performed the IAC Intermediate 2005 Freestyle routine. These routines were centered above the intersection of the two runways. For each sequence, noise data were measured at microphones located 500 ft East of the origin (M1), at the origin (M2), at 1/8 mile West (M4), ¼ mile West (M5) and 1 mile West (M7, off of airport property), as shown in Figure 9. Noise data were not measured at ½ mile West of the origin (M6), because that position was located in the middle of a concert-stage construction area. One-second L_{Aeq} data and the corresponding 1/3-octave-band spectra were measured continuously for each aerobatic routine, and the time histories were recorded to digital audio tape (DAT). Position information for each sequence was also captured by the video tracking system.

[7] For the Sukhoi, Pitts and Decathlon, high speed events were conducted in both directions of travel; North to South, and South to North. These directional high speed events were handled separately in the data processing, analysis and INM modeling.

[8] It is important to note that not all of the aircraft were able to perform all six types of level-flight events. Only the Edge 540 and the Sukhoi SU-29 were able to perform all six types of events. The Extra 230 and the Pitts were able to perform the high speed, slow speed, accelerating and inverted events, while the Decathlon was only able to perform high speed, slow speed and accelerating events.

[9] The Left-Center-Right naming convention is relative to a flight track flown North to South, which applies to all level-flight events in this study, except for a handful of high speed events flown South to North.

[10] Boeker, et. al., Test Plan for Aerobatic Aircraft Noise Measurements. Cambridge, MA: John A Volpe National Transportations Systems Center Acoustics Facility, June 2005

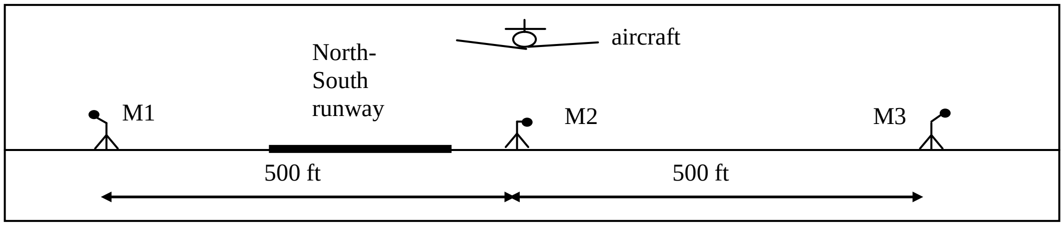

Figure 7: Site Configuration for Level-Flight Measurements (Rear Profile View)

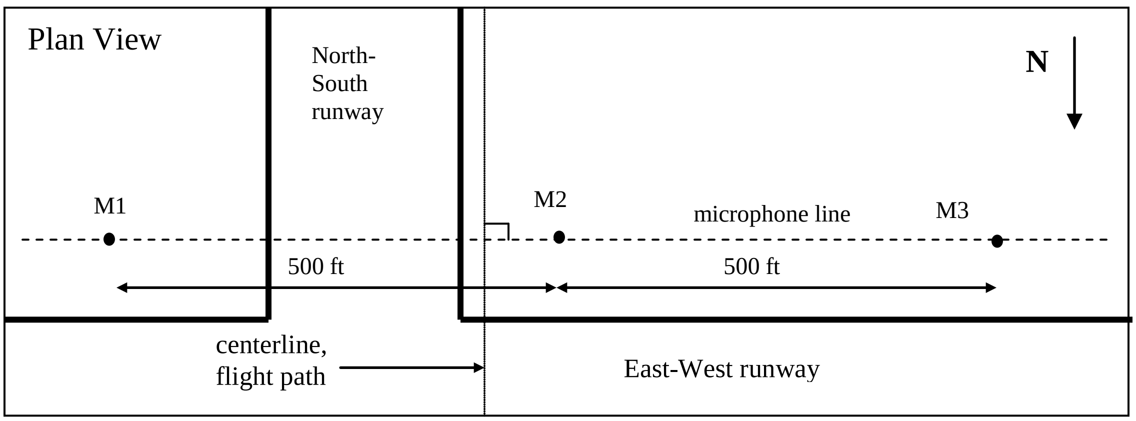

Figure 8: Site Configuration for Level-Flight Measurements (Plan View)

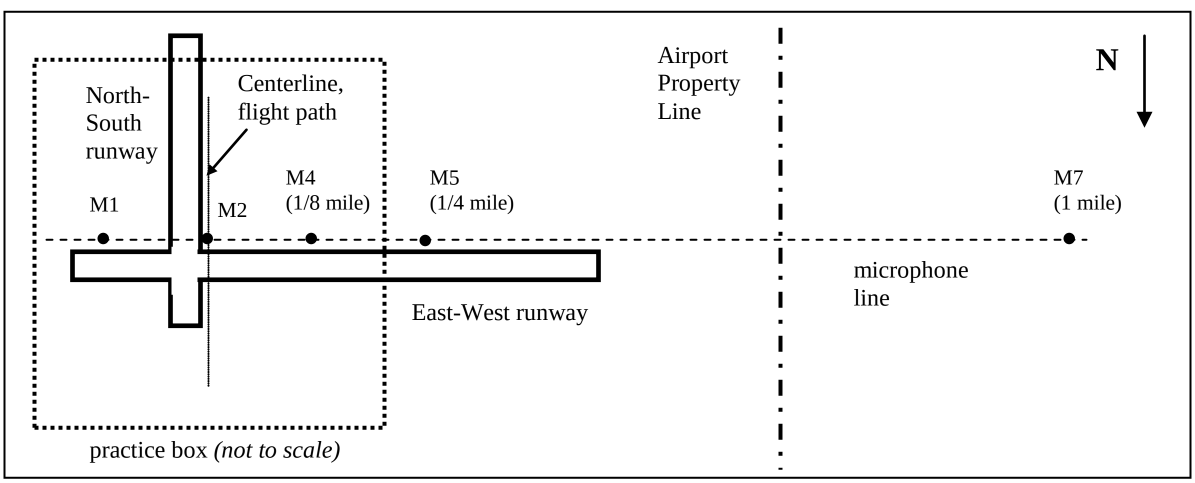

Figure 9: Site Configuration for Validation Measurements (Plan View)

Appendix B. Noise Data Processing Summary

Data processing for this study was separated into three major tasks; video processing, acoustic processing, and Noise-Power-Distance (NPD) data generation.

Position information for each event and each aerobatic sequence were captured with Volpe's video tracking system. The video data were processed with Volpe-developed video processing software, which calculates aircraft position and speed information for each event. Because of large elevation changes in the vicinity of Galt Airport and physical constraints of the video tracking system[11], some portions of the aerobatic sequences were outside of the camera views and could not be processed with the video tracking software. These portions of the routines (which were utilized in the INM Modeling portion of this study) were then estimated. This estimation process was supplemented by audio descriptions of the sequences provided by Jeff Weller and Gerry Molidor (IAC).

Acoustic data for each level-flight event and each aerobatic sequences were measured with integrating-averaging sound level meters (measuring and storing one-second L_{Aeq} data and the corresponding 1/3-octave-band spectra), and recorded to digital audio tape. The noise data processing procedure consisted of data quality evaluation, and noise metric calculation. Data quality was verified through the evaluation of calibration information[12], meteorological data[13], ambient noise data[14], and observer logs of interfering sounds[15] over the course of each level-flight event. Although these measurements were not conducted for the purpose of aircraft noise certification, they were generally consistent with the procedures of Federal Aviation Regulation Part 36 (FAR 36). For example, the meteorological criteria in FAR 36 Appendix G were used in the data quality determination for this study.

Next, the desired noise metrics were calculated for each of the level-flight events and full aerobatic sequences. For the purpose of this study, A-weighted maximum sound pressure levels with slow exponential response (LAMAX) were determined for each of the events, and A-weighted sound exposure levels (SEL) were calculated for each event and each aerobatic sequence. The data reduction and analysis process yielded 82 acceptable level-flight events[16] and five acceptable full aerobatic sequences[17]. The results for the level-flight events are presented in Table 1 through 5, and the results for the aerobatic sequences are presented in Table 6 through 8.

A small amount of ambient noise data was also measured at each of the microphone positions immediately following the two of the aerobatic routines. It is important to note, that this ambient data in no way indicates a definitive description of the ambient noise at Galt Airport. It was only

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[11] Some physical constraints of the video tracking system are that it must remain in a fixed position.
[12] Acceptable calibration drift of 0.3 dB or less at 1 kHz.
[13] Acceptable temperature range of 35-95 F, relative humidity range of 20-95%, wind limit of 10 kts, and cross wind limit of 5 kts.
[14] A rise and fall of 10 dB or more above the ambient noise for each level-flight event.
[15] Lack of audible interference from other noise sources at each microphone location.
[16] There were 22 events for the Edge, 16 events for the Extra, 21 events for the Sukhoi, 10 events for the Pitts, and 13 events for the Decathlon. As mentioned earlier, not all of the aerobatic aircraft were able to perform all six types of level-flight events.
[17] There was 1 complete sequence for the Extra, 2 for the Pitts, and 2 for the Sukhoi. The Extra sequence lasted 171 seconds, the two Pitts sequences lasted 172 seconds and 197 seconds respectively, and the two Sukhoi sequences lasted 285 seconds and 233 seconds respectively.

meant to provide a brief, cursory indication of if the noise from the aerobatic sequences were discernable from the ambient noise at those microphone positions. The results are presented in Table 9. Longer-duration ambient noise measurements were not possible due to air traffic and other noise sources outside of the measurement team's control (construction noise, road traffic noise, farm noise, etc.)[18]. In order to verify that the noise levels from the five aerobatic sequences were above the ambient, the sound pressure level time histories for each sequence were plotted against the ambient noise L_{Aeq} (see Figures 10 through 14). The louder of the two ambients (Ambient 2) directly under the practice box (M2) was used in this analysis. As Figures 10 through 14 indicate, the aerobatic maneuvers making up each sequence were well above the ambient noise, except for a few quiet lulls in the sequence. The only major exception was the microphone 1-mile away from the practice box (M7), which was only slightly louder than the ambient noise for all five aerobatic sequences.

The SELs for each level-flight event, along with the 1/3-octave-band spectra corresponding to the maximum sound pressure level (LAMAX) and the aircraft position information, were then used to generate Noise-Power-Distance (NPD) data for each level-flight event. NPDs, which were generated using the procedures of SAE-AIR-1845, are used by the FAA's Integrated Noise Model (INM) as aircraft source noise data. For this study, the NPDs consist of aircraft-specific noise source data expressed as function of aerobatic attitude[19] and distance, and are corrected for aircraft speed, atmospheric absorption, distance duration, and divergence. These corrections are applied by Volpe-developed acoustic processing software used specifically to generate INM NPDs. These NPDs were then averaged for each type of aerobatic attitude, and were utilized in the INM modeling portion of this study. The resulting NPDs are presented in Tables 10 through 24 in Appendix C.

[18] Ambient Event 1 lasted 81 seconds, and Ambient Event 2 lasted 65 seconds.
[19] The six aerobatic attitude types are high speed, low speed, accelerating, inverted, knife edge (left wing down) and knife edge (right wing down). Only high speed events flown North to South were used in the calculations of the high speed NPDs.

B.1. Measured LAMAX and SEL[20] Noise Levels for Level-Flight Events

Table 1: LAMAX and SEL levels for Zivko Edge 540 Level-Flight Events

Event	Type	Speed (kts)	LAMAX (dB(A)) M1 [Left]	LAMAX (dB(A)) M2 [Center]	LAMAX (dB(A)) M3 [Right]	SEL (dB(A)) M1 [Left]	SEL (dB(A)) M2 [Center]	SEL (dB(A)) M3 [Right]
110	High Speed	130.5	81.4	85.6	81.7	85.7	88.4	86.1
120	High Speed	133.8	83.6	84.2	79.4	87.8	88.3	84.3
130	High Speed	169.5	82.2	86.7	80.6	86.5	89.5	85.1
220	Low Speed	73.4	78.1	81.3	*75.5*	83.0	85.9	*81.2*
240	Low Speed	67.6	74.2	77.5	70.2	80.6	82.6	77.3
250	Low Speed	64.5	71.6	73.4	69.2	78.3	79.8	76.0
310	Accelerating	104.1	85.7	86.3	80.5	90.1	91.3	86.1
320	Accelerating	105.4	82.6	88.1	83.4	88.3	92.2	88.6
330	Accelerating	99.0	82.8	85.3	81.4	88.5	91.0	87.1
340	Accelerating	99.5	82.2	85.4	81.4	88.5	91.1	87.0
350	Accelerating	101.4	83.6	85.9	82.2	89.5	91.3	86.8
370	Accelerating	97.3	82.9	86.5	82.1	88.3	91.5	87.7
410	Inverted	128.1	80.1	83.3	80.4	83.2	85.5	84.1
420	Inverted	128.4	79.0	81.4	79.6	83.6	85.1	83.3
430	Inverted	124.8	78.0	80.3	78.3	82.2	84.4	82.9
440	Inverted	146.0	79.7	82.9	78.5	83.8	85.8	83.5
520	Knife Edge (left wing down)	131.0	95.6	96.8	85.2	98.6	98.5	88.0
530	Knife Edge (left wing down)	123.1	94.6	95.3	86.4	97.3	98.1	89.8
550	Knife Edge (left wing down)	135.3	96.4	94.8	84.4	98.1	96.9	87.8
630	Knife Edge (right wing down)	125.6	96.3	93.6	85.1	98.6	97.5	89.9
640	Knife Edge (right wing down)	133.2	92.5	92.4	86.6	95.8	95.3	90.4
650	Knife Edge (right wing down)	124.6	97.1	95.2	85.3	98.8	97.8	90.5

[20] These SEL values are presented as-measured, and correspond to the speeds listed in these tables.

Table 2: LAMAX and SEL levels for Extra EA-230 Level-Flight Events

Event	Type	Speed (kts)	LAMAX (dB(A)) M1 [Left]	LAMAX (dB(A)) M2 [Center]	LAMAX (dB(A)) M3 [Right]	SEL (dB(A)) M1 [Left]	SEL (dB(A)) M2 [Center]	SEL (dB(A)) M3 [Right]
1110	High Speed	124.4	81.0	85.2	78.4	87.5	90.6	85.7
1140		124.6	82.1	87.0	77.6	88.4	91.7	87.2
1150		126.3	81.0	85.0	77.6	88.1	91.1	86.4
1160		127.6	80.1	86.0	78.3	87.7	91.3	87.1
1170		123.8	80.1	84.9	78.1	87.2	90.5	86.4
1210	Low Speed	63.4	66.4	66.6	*62.5*	75.1	76.3	*72.2*
1220		67.4	65.1	67.4	*62.4*	75.1	77.1	*73.6*
1230		68.0	62.4	65.8	62.5	72.5	74.8	72.7
1240		68.1	63.1	66.2	61.0	72.3	74.3	70.5
1320	Accelerating	105.2	79.6	85.9	78.5	87.4	91.6	86.8
1330		108.7	80.1	84.6	78.6	87.3	90.9	86.9
1340		101.7	81.3	85.0	78.0	87.8	90.9	87.0
1410	Inverted	131.8	75.4	81.3	80.1	83.2	86.3	84.2
1420		120.9	77.9	82.8		84.5	89.2	
1430		120.4	77.0	82.7	77.5	84.1	88.5	84.1
1450		125.1	77.2	82.1	76.5	83.9	88.3	84.1

Table 3: LAMAX and SEL levels for Sukhoi SU-29 Level-Flight Events

Event	Type	Speed (kts)	LAMAX (dB(A)) M1 [Left]	LAMAX (dB(A)) M2 [Center]	LAMAX (dB(A)) M3 [Right]	SEL (dB(A)) M1 [Left]	SEL (dB(A)) M2 [Center]	SEL (dB(A)) M3 [Right]
2110	High Speed (North to South)	135.8	75.5	79.7	77.7	83.2	86.2	84.3
2120		135.9	79.3	81.1	76.4	85.8	87.3	84.1
2140		132.7	76.7	79.7	77.9	84.2	86.3	84.4
2150	High Speed (South to North)	134.0	78.3	80.5	76.6	85.3	87.2	84.3
2160		122.8	79.5	79.0	73.4	85.9	86.1	82.2
2170		129.9	79.0	80.7	75.7	85.9	87.1	83.3
2210	Low Speed	81.6	69.8	70.2		78.0	78.8	
2220		80.7	68.3	71.5	66.6	77.4	79.5	75.7
2240		84.7	68.7	70.9	66.5	77.1	80.0	75.7
2310	Accelerating	111.2	83.4	84.7	79.3	90.1	91.2	86.5
2320		121.2	84.3	82.5	76.9	89.8	89.2	85.0
2330		118.2	82.9	85.2	79.2	89.1	91.1	87.0
2340		123.8	79.3	83.8	80.2	87.2	90.5	87.7
2410	Inverted	134.7	74.3	74.5	71.5	80.3	81.0	78.6
2420		128.6	74.1	76.2	73.1	80.9	81.2	78.8
2440		124.1	74.1	74.9	72.0	80.5	81.0	78.6
2520	Knife Edge (left wing down)	137.2	86.2	90.2	87.1	89.6	93.9	91.8
2530		131.8	85.2	88.7	86.1	89.3	92.8	91.3
2550		140.6	89.1	90.2	85.9	92.5	94.4	91.1
2620	Knife Edge (right wing down)	143.3	80.5	83.6	82.1	86.9	88.8	86.1
2630		163.7	82.3	84.2	82.7	87.7	88.7	87.2

Table 4: LAMAX and SEL levels for Aviat Pitts S-2C Level-Flight Events

Event	Type	Speed (kts)	LAMAX (dB(A)) M1 [Left]	LAMAX (dB(A)) M2 [Center]	LAMAX (dB(A)) M3 [Right]	SEL (dB(A)) M1 [Left]	SEL (dB(A)) M2 [Center]	SEL (dB(A)) M3 [Right]
120	High Speed (North to South)	155.8	82.2	82.3	73.2	85.6	85.4	80.1
140		151.3	77.3	81.5	75.7	82.8	85.9	81.2
150		117.4	77.6	81.6	77.3	82.9	86.2	82.1
180	High Speed (South to North)	168.4	80.7	82.0	76.4	84.0	86.1	80.9
220	Low Speed	64.8	64.3	66.1	59.6	72.6	74.9	70.8
230		68.1		63.7	62.0		72.0	71.0
250		64.2	61.6	64.0	56.7	71.8	72.7	69.1
340	Accelerating	110.2	79.2	80.0	74.4	84.0	84.4	79.2
350		111.0	80.7	81.0	75.8	85.8	86.0	81.1
430	Inverted	120.1	79.1	79.1	77.3	82.7	84.0	82.0

Table 5: LAMAX and SEL levels for American Champion Decathlon Level-Flight Events

Event	Type	Speed (kts)	LAMAX (dB(A)) M1 [Left]	LAMAX (dB(A)) M2 [Center]	LAMAX (dB(A)) M3 [Right]	SEL (dB(A)) M1 [Left]	SEL (dB(A)) M2 [Center]	SEL (dB(A)) M3 [Right]
1110	High Speed (North to South)	87.3	77.4	79.7	77.4	82.7	85.3	82.3
1120		91.0	77.6	80.4	78.3	83.3	85.0	82.7
1130		85.7	77.0	81.5	75.8	82.9	85.3	81.8
1140		90.3	77.1	80.8	76.8	82.9	85.1	82.8
1150	High Speed (South to North)	94.7	77.8	80.7	76.1	82.4	84.7	81.9
1160		92.9	77.7	79.7	76.9	82.5	84.4	82.0
1170		92.6	77.2	79.6	75.7	82.5	84.5	81.5
1220	Low Speed	50.3	64.2	65.3	61.0	73.1	73.3	70.6
1250		46.9	63.0	64.5	60.7	73.3	73.5	70.9
1260		50.5	65.3	64.5	62.0	73.0	73.4	70.8
1270		46.8	64.4	66.7	62.4	73.7	74.3	70.9
1320	Accelerating	79.4	77.6	79.1	75.5	83.3	84.4	81.5
1330		78.1	78.2	80.7	75.0	83.8	85.4	81.9

B.2. Measured SELs for Full Aerobatic Sequences

Table 6: SELs for Extra EA-230 Aerobatic Sequence

	SEL (dB(A))				
Sequence	**M1 (-500 ft)**	**M2 (0 ft)**	**M4 (660 ft)**	**M5 (1320 ft)**	**M7 (5496 ft)**
1	88.5	88.7	86.0	83.6	74.8

Table 7: SELs for Aviat Pitts S-2C Aerobatic Sequences

	SEL (dB(A))				
Sequence	**M1 (-500 ft)**	**M2 (0 ft)**	**M4 (660 ft)**	**M5 (1320 ft)**	**M7 (5496 ft)**
1	90.0	90.7	89.2	86.8	77.3
2	90.1	91.1	89.7	87.7	78.0

Table 8: SELs for Sukhoi SU-29 Aerobatic Sequences

	SEL (dB(A))				
Sequence	**M1 (-500 ft)**	**M2 (0 ft)**	**M4 (660 ft)**	**M5 (1320 ft)**	**M7 (5496 ft)**
1	89.2	88.7	87.2	85.1	77.3
2	87.2	86.7	85.7	84.0	77.5

B.3. Measured L_{Aeq} Ambient Noise Levels

Table 9: L_{Aeq}s for Ambient Noise

	LAeq (dB(A))				
Ambient	**M1 (-500 ft)**	**M2 (0 ft)**	**M4 (660 ft)**	**M5 (1320 ft)**	**M7 (5496 ft)**
1	50.6	47.1	47.0	43.8	48.4
2	55.2	49.2	49.4	47.0	46.7

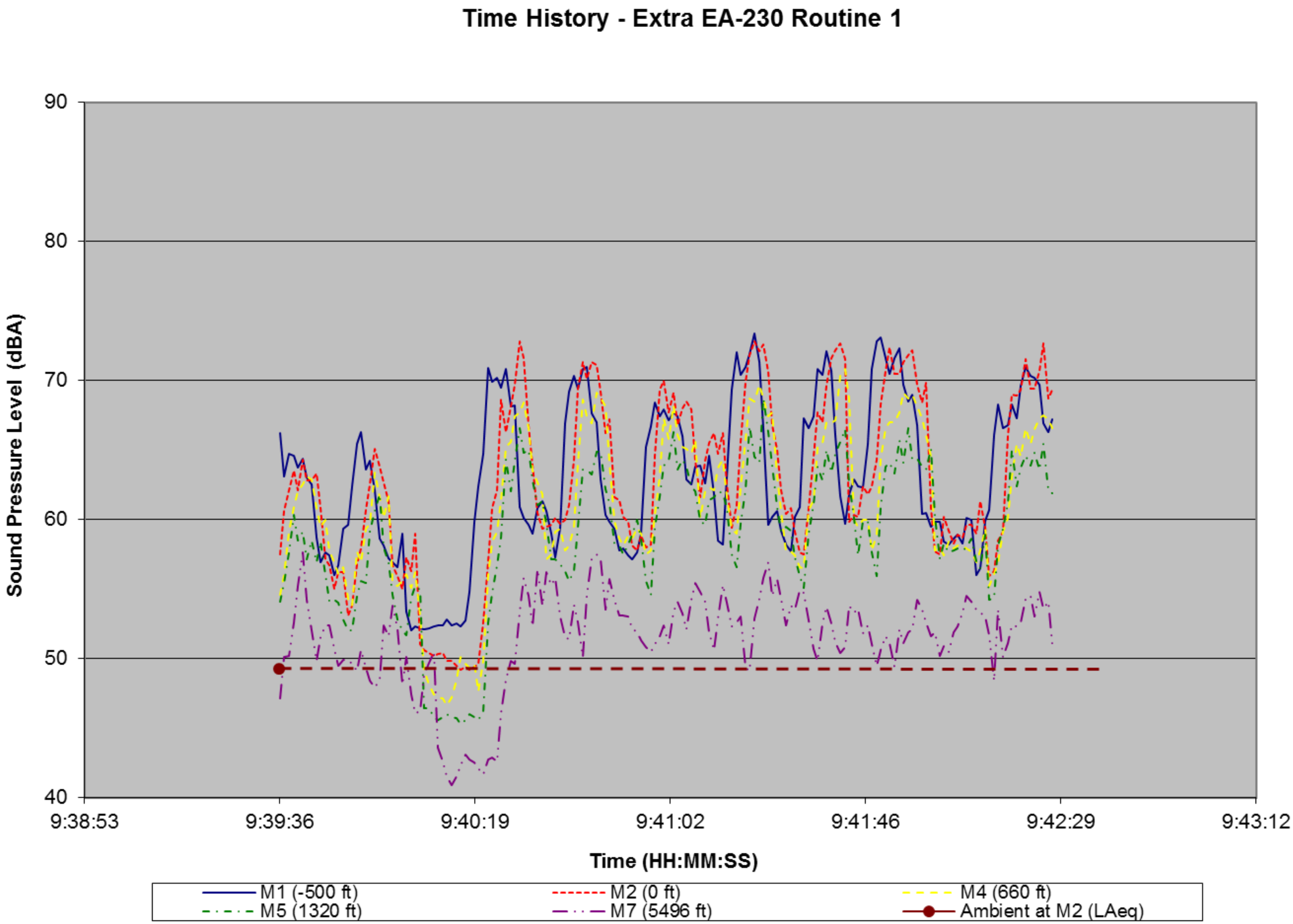

Figure 10: Sound Pressure Level Time History for the Extra EA-230 Routine 1

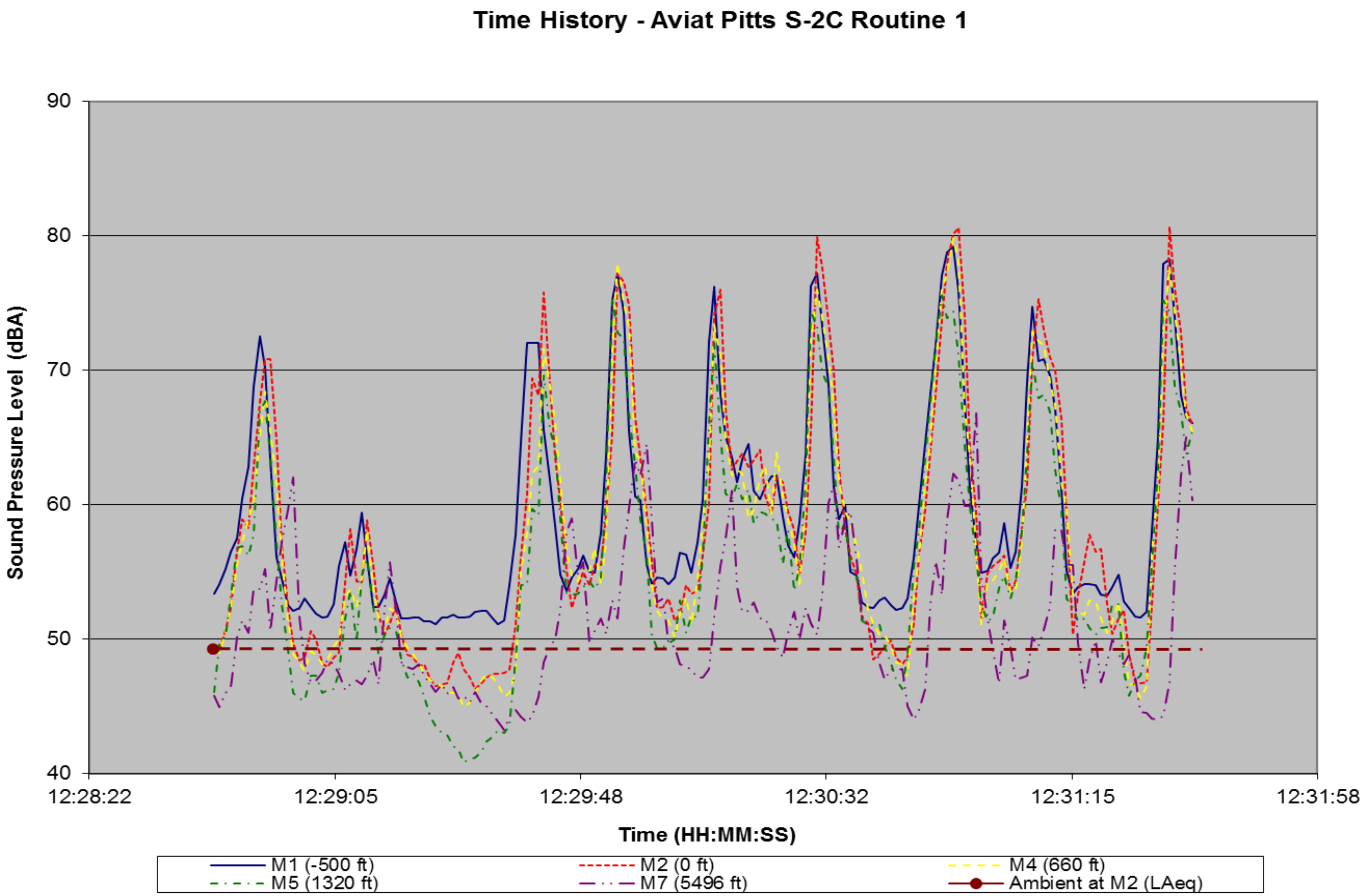

Figure 11: Sound Pressure Level Time History for the Aviat Pitts S-2C Routine 1

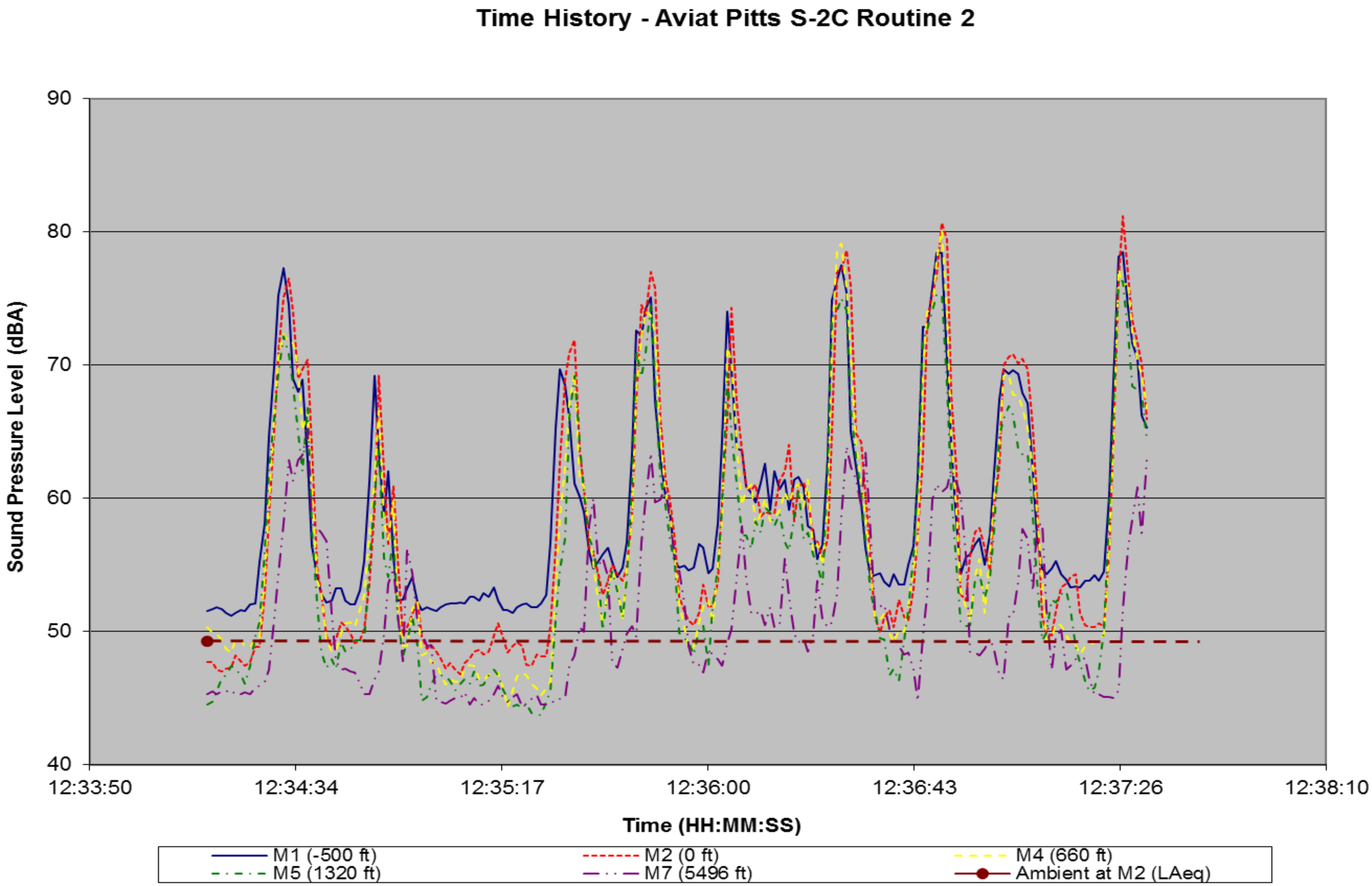

Figure 12: Sound Pressure Level Time History for the Aviat Pitts S-2C Routine 2

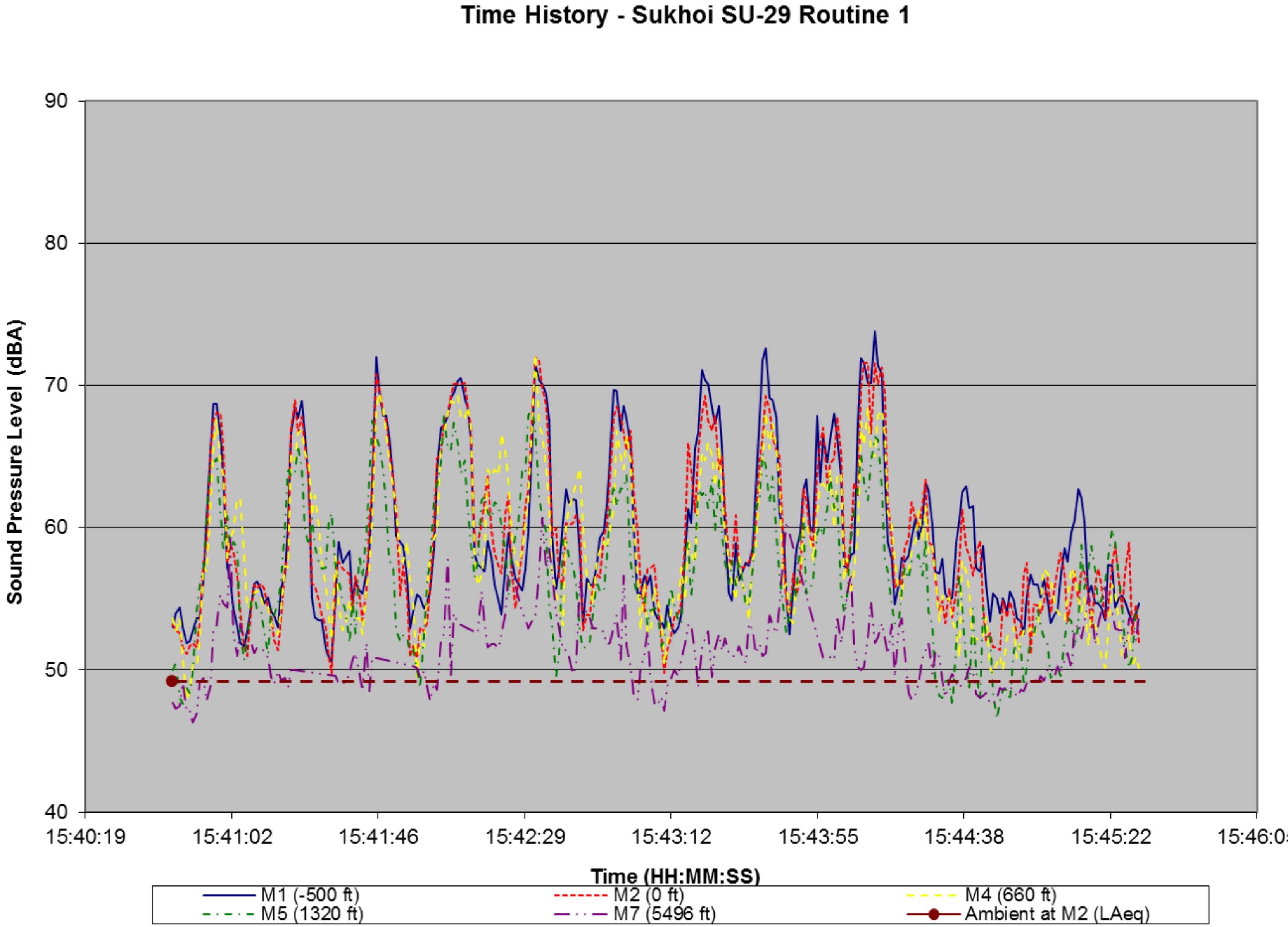

Figure 13: Sound Pressure Level Time History for the Sukhoi SU-29 Routine 1

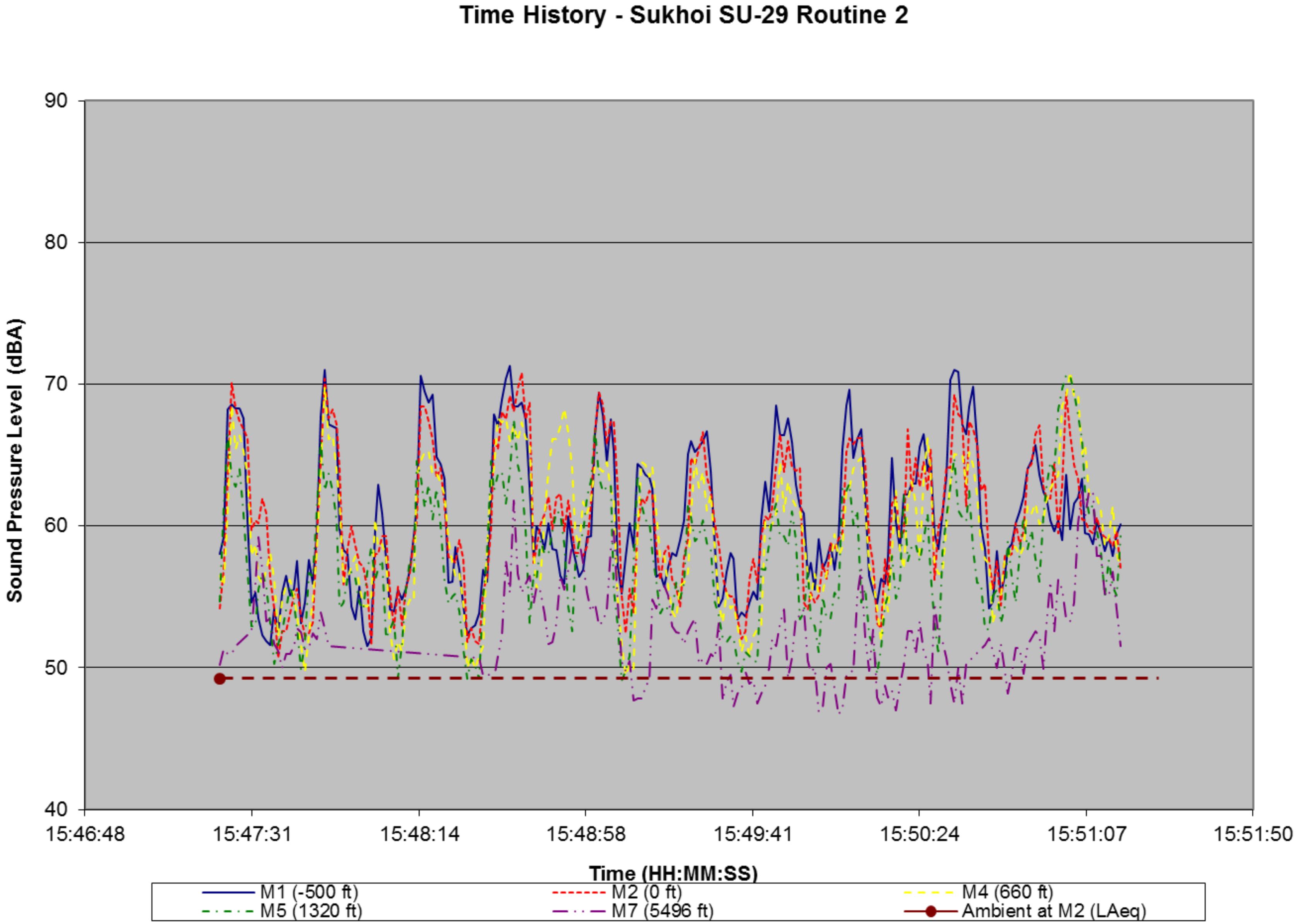

Figure 14: Sound Pressure Level Time History for the Sukhoi SU-29 Routine 2

Appendix C. INM Modeling Overview

The modeling effort for this study consisted of representing the aircraft as user-defined aircraft in the INM with the different attitude-specific NPDs, and modeling the flight tracks and profiles of each aerobatic event (both individual level-flight events and aerobatic sequences). For this study, INM Version 6.2 was used. Only the Extra EA-230, the Sukhoi SU-29 and the Aviat Pitts S-2C were modeled in INM for this study, because they were the only ones to perform full aerobatic routines during the noise measurements. To aid future modeling efforts, INM input data for all five aircraft are presented in this Appendix and can be made available in INM database format for direct inclusion in the model.

Each aircraft was modeled as a user-defined aircraft in INM, using aircraft-specific NPDs generated for this study (see Tables 10 through 24), and representative spectral classes[21] (see Table 25). Although the NPDs in the standard INM database are organized according to thrust values (the 'P - power' in NPD is usually expressed in terms of corrected net thrust in pounds), the NPDs for the aerobatic aircraft were organized and referenced according to aircraft attitude. Even though three NPDs were generated for each aerobatic attitude of each aircraft, only the center NPD curves were used to represent the aerobatic flights of these aircraft in INM[22, 23]. These NPDs are presented in the following Tables: the Extra in Table 14, the Sukhoi in Table 17, and the Pitts in Table 20. These NPDs were all setup as Departure NPDs. In addition, only departure spectral classes were utilized in the INM modeling.

Both individual level-flight events and aerobatic sequences were modeled in INM with unique flight tracks and profiles. The aerobatic maneuvers in the study were modeled as sequences of either four or six attitude-specific NPDs for each aircraft. These attitude-specific NPDs were utilized in conjunction with the aircraft position and speed information to model aircraft level-flight events and aerobatic sequences[24, 25].

As an example of modeling methodology, one of the aerobatic routines modeled in INM was the IAC Sportsman 2005 Known Aerobatic Routine, which was flown by both the Pitts and the Extra[26]. Each aerobatic maneuver in this routine was modeled using attitude-specific NPDs in conjunction with the aircraft position and speed information, as mentioned above. Figure 15 illustrates this procedure for the Half Cuban Eight maneuver.

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[21] Existing INM spectral classes were utilized in the modeling portion of this study. These spectral classes were selected by comparing measured one-third octave spectra for each aerobatic aircraft against the existing spectral classes in the INM database, and assigning those aerobatic aircraft spectral classes that resemble their noise spectra.

[22] Only high speed events flown North to South were utilized in the calculation of these high speed NPDs.

[23] It is important to note, that INM 7.0 (which is currently under development) has the capability to model simplified aircraft noise directivity by utilizing Left, Center and Right NPDs. This is primarily utilized to model helicopter noise, which is not axi-symmetric. Although aircraft are typically modeled with only a single (Center) NPD, Left, Center and Right NPDs were generated for this aircraft. Although they were not utilized in this initial modeling effort, they may be utilized in future modeling efforts using INM 7.0.

[24] Only aerobatic routines were modeled in this study. Aircraft approaches/landings and departures/takeoffs were not modeled.

[25] Although, the resolution of the video tracking system alone wasn't sufficient to determine the attitude of the aircraft during the full aerobatic routines, complete position information for each aerobatic routine was compiled from a combination of video tracking data, maneuver information given in the Known Sportsman routine diagram, and position information and commentary from a third video camera manually tracking each aircraft.

[26] Documentation on the IAC aerobatic routines is available through the IAC (http://www.iac.org/).

It is worthwhile to note that the transitions between vertical and horizontal flight in the aerobatic sequences were modeled with high speed level flight NPDs for the Suhkoi and accelerating NPDs for the Pitts and Extra. The initial strategy was to model all transitional maneuvers as accelerations. However, it was determined that this procedure would be unrepresentative for the Sukhoi; because the exhaust from the Suhkoi's radial engine dominated the acceleration NPDs, but not the actual transition maneuvers, where the propeller noise dominates. Therefore, the high speed NPD was used to model the transition maneuvers for the Sukhoi. Both the Pitts and Extra, which have opposed-cylinder engines, did not show this trait, so they were modeled with the acceleration NPD for the transitions, as initially intended.

The significance of the above detailed description of the modeling procedure adopted for this study is that the noise from aerobatic aircraft can be accurately modeled with the INM, as long as sufficient aircraft source data are available. The amount and type of data collected in this measurement study should be considered the minimum amount of data needed, in order to add an additional aerobatic aircraft. It is strongly recommended that inverted and knife edge level-flight data be collected for all aircraft, barring any safety or aircraft performance issues. While it is also recommended that level-flight data be collected at all three measurement positions (M1 [Left], M2 [Center], and M3 [Right]), their collection should not be considered absolutely necessary, until the implementation of Left, Center, and Right NPDs for aerobatic aircraft in INM 7.0 has been investigated further. Finally, it is also strongly recommended that all future aerobatic aircraft data collection efforts include measurements of multiple, full aerobatic sequences, especially for Advanced and Unlimited routines, since those routines are typically performed at lower altitudes with higher performance (louder) aircraft.

C.1. Zivko Edge 540 NPDs

Table 10: Zivko Edge 540 NPDs in SEL at M1 [Left]

	Zivko Edge 540 NPDs at M1 [Left]: SEL (dB(A))					
Distance (ft)	High Speed	Low Speed	Accelerating	Inverted	Knife Edge (left wing down)	Knife Edge (right wing down)
200	95.33	85.32	95.72	92.04	105.75	105.04
400	91.17	81.34	91.47	87.98	101.59	100.88
630	88.29	78.64	88.52	85.17	98.70	98.00
1000	85.19	75.79	85.35	82.15	95.59	94.89
2000	80.06	71.16	80.17	77.10	90.40	89.69
4000	74.05	65.80	74.27	71.09	84.23	83.52
6300	69.39	61.62	69.77	66.43	79.37	78.64
10000	63.85	56.54	64.45	61.03	73.56	72.74
16000	57.20	50.32	58.15	54.92	66.66	65.64
25000	49.83	43.50	51.54	48.52	59.42	58.22

Table 11: Zivko Edge 540 NPDs in SEL at M2 [Center]

	Zivko Edge 540 NPDs at M2 [Center]: SEL (dB(A))					
Distance (ft)	High Speed	Low Speed	Accelerating	Inverted	Knife Edge (left wing down)	Knife Edge (right wing down)
200	93.72	83.75	94.18	91.08	100.56	100.62
400	89.69	79.81	90.03	87.08	96.40	96.49
630	86.94	77.16	87.19	84.36	93.50	93.63
1000	84.02	74.37	84.17	81.45	90.35	90.52
2000	79.33	69.92	79.34	76.70	85.04	85.29
4000	74.10	65.01	74.03	71.26	78.75	78.99
6300	70.24	61.45	70.15	67.17	73.97	74.03
10000	65.81	57.52	65.72	62.45	68.55	68.09
16000	60.59	53.15	60.46	56.91	62.37	60.96
25000	54.72	48.47	54.49	50.73	55.70	53.21

Table 12: Zivko Edge 540 NPDs in SEL at M3 [Right]

	Zivko Edge 540 NPDs at M3 [Right]: SEL (dB(A))					
Distance (ft)	High Speed	Low Speed	Accelerating	Inverted	Knife Edge (left wing down)	Knife Edge (right wing down)
200	90.94	80.14	90.77	89.85	93.07	95.48
400	86.88	76.23	86.73	85.83	89.01	91.40
630	84.10	73.61	83.97	83.07	86.20	88.59
1000	81.12	70.85	81.03	80.10	83.17	85.56
2000	76.24	66.48	76.23	75.17	78.07	80.51
4000	70.60	61.58	70.70	69.32	71.93	74.49
6300	66.27	57.91	66.46	64.70	67.05	69.76
10000	61.13	53.62	61.42	59.12	61.15	64.07
16000	54.93	48.43	55.27	52.27	53.92	57.12
25000	47.87	42.37	48.19	44.60	45.51	49.11

C.2. Extra EA-230 NPDs

Table 13: Extra EA-230 NPDs in SEL at M1 [Left]

	Extra EA-230 NPDs at M1 [Left]: SEL (dB(A))			
Distance (ft)	High Speed	Low Speed	Accelerating	Inverted
200	95.01	78.69	94.94	91.15
400	90.54	74.31	90.35	87.10
630	87.36	71.26	87.02	84.32
1000	83.86	68.02	83.31	81.33
2000	78.01	62.86	77.05	76.40
4000	71.34	57.25	70.04	70.63
6300	66.47	53.22	65.11	66.18
10000	61.10	48.67	59.76	60.96
16000	55.26	43.41	53.91	54.85
25000	49.38	37.72	47.94	48.21

Table 14: Extra EA-230 NPDs in SEL at M2 [Center] (Used in INM Modeling)

	Extra EA-230 NPDs at M2 [Center]: SEL (dB(A))			
Distance (ft)	High Speed	Slow Speed	Accelerating	Inverted
200	94.03	77.38	95.40	91.59
400	89.44	73.15	90.76	87.57
630	86.12	70.22	87.37	84.83
1000	82.38	67.06	83.57	81.91
2000	75.95	61.94	77.11	77.13
4000	68.60	56.32	69.93	71.65
6300	63.39	52.30	65.01	67.53
10000	57.83	47.85	59.87	62.82
16000	51.85	42.85	54.40	57.38
25000	45.71	37.56	48.78	51.42

Table 15: Extra EA-230 NPDs in SEL at M3 [Right]

	Extra EA-230 NPDs at M3 [Right]: SEL (dB(A))			
Distance (ft)	High Speed	Low Speed	Accelerating	Inverted
200	92.17	75.05	92.68	88.67
400	87.74	70.99	88.09	84.63
630	84.57	68.21	84.77	81.86
1000	81.05	65.27	81.02	78.88
2000	75.09	60.57	74.55	73.94
4000	68.24	55.36	67.13	68.04
6300	63.25	51.51	61.81	63.39
10000	57.70	47.09	56.02	57.80
16000	51.44	41.84	49.71	51.03
25000	44.71	35.88	43.35	43.46

C.3. Sukhoi SU-29 NPDs

Table 16: Sukhoi SU-29 NPDs in SEL at M1 [Left]

	Sukhoi SU-29 NPDs at M1 [Left]: SEL (dB(A))					
Distance (ft)	High Speed	Low Speed	Accelerating	Inverted	Knife Edge (left wing down)	Knife Edge (right wing down)
200	93.07	83.01	95.63	88.05	97.97	96.34
400	88.77	78.87	91.41	83.91	93.95	92.22
630	85.75	76.03	88.48	81.05	91.20	89.38
1000	82.47	72.98	85.33	77.94	88.25	86.35
2000	77.08	68.04	80.21	72.82	83.39	81.43
4000	71.01	62.48	74.47	67.01	77.63	75.90
6300	66.59	58.29	70.20	62.86	73.10	71.77
10000	61.64	53.40	65.20	58.27	67.65	66.95
16000	55.89	47.60	59.11	52.91	60.98	61.14
25000	49.41	41.21	52.04	46.72	53.40	54.51

Table 17: Sukhoi SU-29 NPDs in SEL at M2 [Center] (Used in INM Modeling)

	Sukhoi SU-29 NPDs at M2 [Center]: SEL (dB(A))					
Distance (ft)	High Speed	Low Speed	Accelerating	Inverted	Knife Edge (left wing down)	Knife Edge (right wing down)
200	92.74	82.07	94.55	86.04	98.66	94.68
400	88.45	77.92	90.30	81.85	94.64	90.68
630	85.45	75.06	87.35	78.93	91.89	87.95
1000	82.18	72.03	84.16	75.74	88.94	85.06
2000	76.82	67.17	78.95	70.39	84.08	80.39
4000	70.83	61.80	73.13	64.24	78.36	75.09
6300	66.47	57.80	68.85	59.85	73.91	71.08
10000	61.50	53.15	63.90	55.07	68.57	66.35
16000	55.64	47.58	57.95	49.51	62.10	60.59
25000	49.05	41.39	51.12	43.10	54.77	53.97

Table 18: Sukhoi SU-29 NPDs in SEL at M3 [Right]

	Sukhoi SU-29 NPDs at M3 [Right]: SEL (dB(A))					
Distance (ft)	High Speed	Low Speed	Accelerating	Inverted	Knife Edge (left wing down)	Knife Edge (right wing down)
200	91.08	80.52	92.43	84.62	97.53	91.69
400	86.82	76.40	88.27	80.49	93.53	87.73
630	83.84	73.56	85.40	77.64	90.80	85.05
1000	80.60	70.54	82.31	74.56	87.88	82.21
2000	75.27	65.65	77.27	69.48	83.09	77.63
4000	69.32	60.19	71.60	63.73	77.51	72.42
6300	65.02	56.11	67.41	59.55	73.20	68.46
10000	60.20	51.38	62.59	54.86	68.09	63.76
16000	54.58	45.79	56.82	49.34	61.95	58.01
25000	48.25	39.73	50.23	42.98	55.00	51.28

C.4. Aviat Pitts S-2C NPDs

Table 19: Aviat Pitts S-2C NPDs in SEL at M1 [Left]

	Aviat Pitts S-2C NPDs at M1 [Left]: SEL (dB(A))			
Distance (ft)	High Speed	Low Speed	Accelerating	Inverted
200	89.59	75.79	90.00	91.44
400	85.42	71.38	85.80	87.37
630	82.54	68.33	82.88	84.56
1000	79.44	65.13	79.72	81.53
2000	74.33	60.12	74.45	76.45
4000	68.41	54.85	68.24	70.33
6300	63.85	51.19	63.37	65.47
10000	58.43	47.16	57.49	59.60
16000	51.89	42.52	50.34	52.50
25000	44.48	37.34	42.43	44.53

Table 20: Aviat Pitts S-2C NPDs in SEL at M2 [Center] (Used in INM Modeling)

	Aviat Pitts S-2C NPDs at M2 [Center]: SEL (dB(A))			
Distance (ft)	High Speed	Low Speed	Accelerating	Inverted
200	91.73	74.78	89.12	92.30
400	87.42	70.35	84.90	88.22
630	84.41	67.24	81.97	85.40
1000	81.17	63.90	78.81	82.33
2000	75.87	58.60	73.67	77.17
4000	69.89	53.00	67.83	70.96
6300	65.40	49.11	63.42	66.06
10000	60.17	44.87	58.25	60.20
16000	53.98	40.08	52.10	53.13
25000	47.06	34.84	45.18	45.14

Table 21: Aviat Pitts S-2C NPDs in SEL at M3 [Right]

	Aviat Pitts S-2C NPDs at M3 [Right]: SEL (dB(A))			
Distance (ft)	High Speed	Low Speed	Accelerating	Inverted
200	89.48	73.21	86.89	90.90
400	85.40	68.92	82.79	86.85
630	82.59	65.95	79.98	84.06
1000	79.58	62.76	76.95	81.04
2000	74.63	57.68	71.95	76.00
4000	68.85	52.15	66.08	69.95
6300	64.35	48.17	61.51	65.19
10000	58.97	43.68	56.06	59.49
16000	52.48	38.53	49.46	52.60
25000	45.23	33.00	42.01	44.82

C.5. American Champion Decathlon NPDs

Table 22: American Champion Decathlon NPDs in SEL at M1 [Left]

	American Champion Decathlon NPDs at M1 [Left]: SEL (dB(A))		
Distance (ft)	High Speed	Low Speed	Accelerating
200	88.88	76.19	88.54
400	84.77	71.94	84.43
630	81.93	69.07	81.60
1000	78.88	66.06	78.56
2000	73.85	61.27	73.61
4000	68.05	55.93	67.99
6300	63.61	52.01	63.78
10000	58.37	47.56	58.92
16000	52.09	42.36	53.14
25000	44.95	36.55	46.58

Table 23: American Champion Decathlon NPDs in SEL at M2 [Center]

	American Champion Decathlon NPDs at M2 [Center]: SEL (dB(A))		
Distance (ft)	High Speed	Low Speed	Accelerating
200	87.10	72.44	86.00
400	82.97	68.37	81.88
630	80.12	65.58	79.04
1000	77.05	62.60	75.98
2000	72.02	57.79	70.99
4000	66.28	52.48	65.29
6300	61.92	48.67	60.97
10000	56.82	44.43	55.90
16000	50.69	39.55	49.85
25000	43.75	34.05	43.02

Table 24: American Champion Decathlon NPDs in SEL at M3 [Right]

	American Champion Decathlon NPDs at M3 [Right]: SEL (dB(A))		
Distance (ft)	High Speed	Low Speed	Accelerating
200	84.68	71.48	84.21
400	80.59	67.34	80.11
630	77.78	64.47	77.28
1000	74.77	61.37	74.23
2000	69.86	56.20	69.21
4000	64.25	50.19	63.40
6300	60.01	45.66	58.95
10000	55.03	40.47	53.69
16000	49.07	34.56	47.37
25000	42.33	28.26	40.27

C.6. Spectral Classes

Table 25: Spectral Classes for Aerobatic Aircraft

Aircraft	Spectral Classes Approach	Departure	Level/Afterburner
Edge	215	110	112
Extra	215	112	112
Sukhoi	215	109	112
Pitts	215	109	112
Decathlon	215	109	112

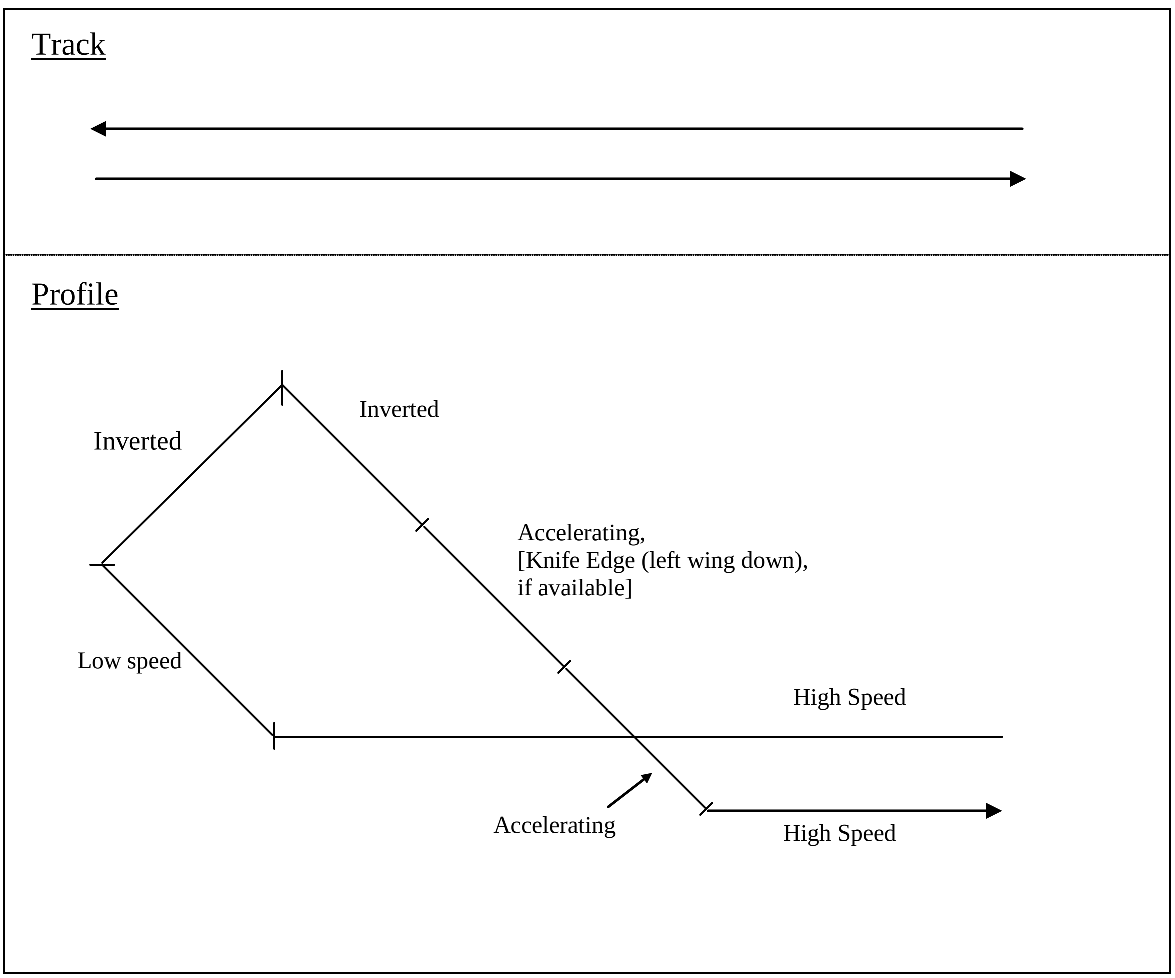

Figure 15: Half Cuban Eight Flight Path Modeling in INM

Appendix D. Data Analysis Summary

The analysis of the aerobatic aircraft noise data was separated into two major tasks: the evaluation of the level-flight event data, and the comparison of the modeled results generated by INM with measured noise data for the full aerobatic sequences.

The LAMAX values for all 82 level-flight events are plotted in Figure 16 through 20 according to aircraft type. The LAMAX metric was used for this comparison, so that the loudest noise events could be used as a basis of comparison between different types of level-flight events. For the Edge and the Sukhoi, the loudest of the six types of level-flight events were the knife edge events with the left wing down (94-97 dB(A) at M2 [Center] for the Edge, and 88-90 dB(A) at M2 [Center] for the Sukhoi). For the remaining aircraft, both the high speed and accelerating events were the loudest types of maneuvers (85-87 dB(A) at M2 [Center] for the Extra, 80-82 dB(A) at M2 [Center] for the Pitts, and 80-82 dB(A) at M2 [Center] for the Decathlon). For all five aircraft, the low speed events were the quietest of all six maneuvers (around 70-71 dB(A) at M2). By looking at the noise levels at M1 [Left], M2 [Center] and M3 [Right] separately for each event, M2 always resulted in the loudest noise levels due to its closer proximity to the aircraft during the level-flight events. The data also indicates a difference between the noise levels at M1 [Left] and M3 [Right], which can be attributed to aircraft directivity and to constant, relatively high cross winds coming from the West[27].

The level-flight data for all five aircraft were also compared against each other for each of the six event types. Overall, the Edge was the loudest of the five aircraft, closely followed by the Sukhoi. Although it varied slightly by event type, the Extra was typically the third loudest aircraft, then the Pitts. For all event types, the Decathlon was the quietest aircraft. This pattern was also reflected in the NPD data.

The measured noise levels were then compared to results generated by INM for the level-flight events for the Extra, Pitts and Sukhoi aircraft. The results are plotted alongside the level-flight event data in Figure 17 for the Extra, Figure 18 for the Sukhoi and Figure 19 for the Pitts. To enhance this comparison, the difference between the modeled results and the average measured results for each of the six types of level-flight events are present in Figures 21 through 23. For the Pitts and the Sukhoi, this comparison shows good agreement between measured and modeled data for all of the maneuver types, with an average difference within +/-2 dB for each maneuver type. The Extra also shows good agreement between measured and modeled data for all of the maneuver types, with an average difference +/- 3 dB for each maneuver type.

Measured noise levels were also compared to results generated by INM for the five aerobatic sequences. Since the main concern is with the overall noise produced by an aerobatic sequence, SEL values for each sequence were calculated and compared with corresponding measured data. The results are plotted in Figures 1 through 6, at the beginning of this technical memorandum. A detailed discussion of those results has already been presented.

Given the measured SEL data for each aerobatic sequence, rough estimates of the day-night average sound levels (L_{dn} or DNL) due to those sequences can be made. In Tables 26 through 28, the estimated DNL values are presented for each aircraft, based on the loudest measured aerobatic

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[27] The cross winds were in compliance with the meteorological criteria in FAR 36 Appendix G.

sequence for that aircraft repeated multiple times during daytime hours[28]. It is important to note that these estimated DNL values are based solely on the measured aerobatic routines, and did not take into account aircraft approaches/landings, aircraft departures/takeoffs, variations on the aerobatic routine, nighttime operations, other aircraft, or other noise sources. A detailed discussion of those results has already been presented.

[28] DNL has a 10 dB penalty associated with nighttime noise levels.

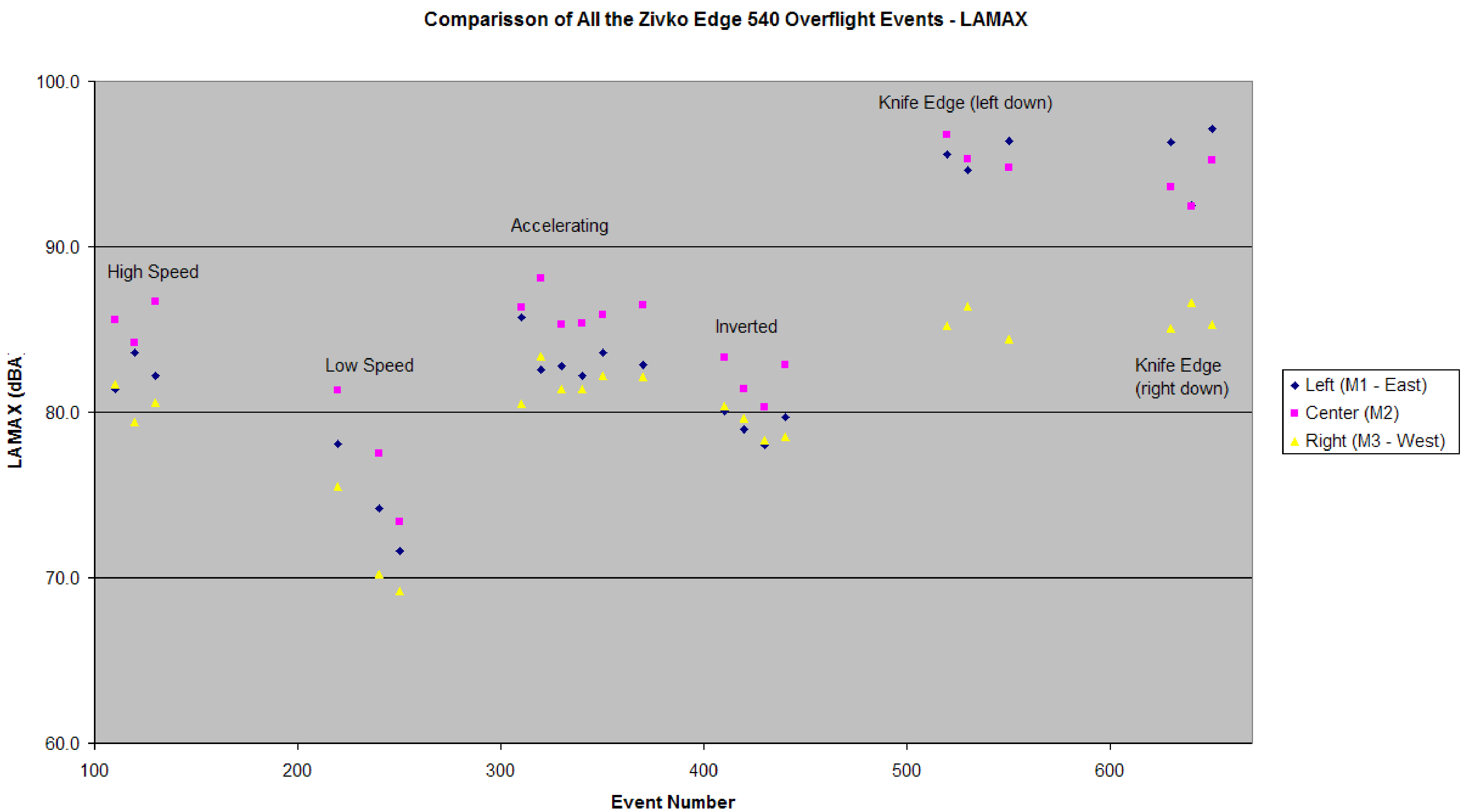

Figure 16: Comparison of Zivko Edge 540 Level-Flight Events – LAMAX

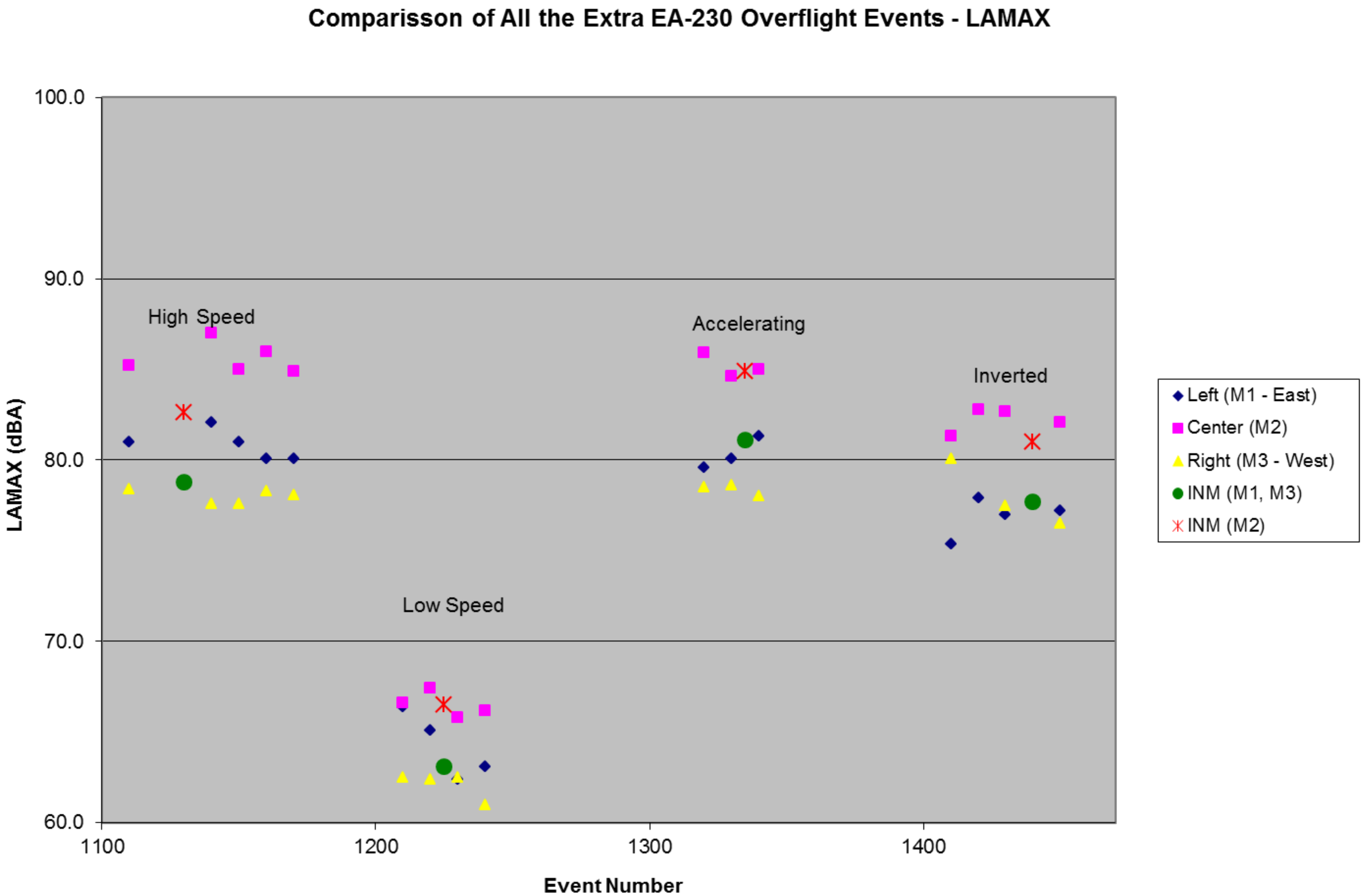

Figure 17: Comparison of Extra EA-230 Level-Flight Event with Corresponding INM Results – LAMAX

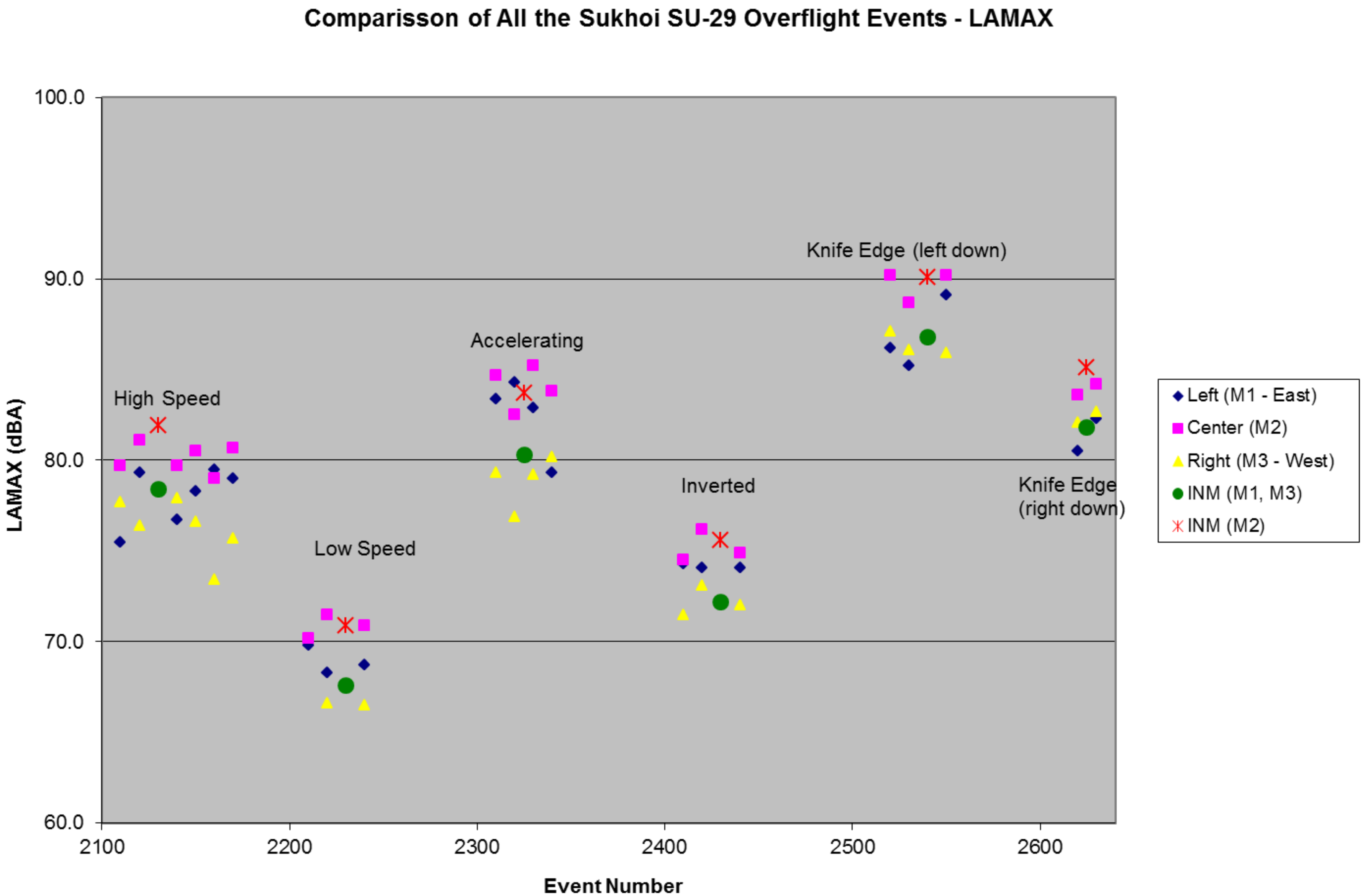

Figure 18: Comparison of Sukhoi SU-29 Level-Flight Event with Corresponding INM Results – LAMAX

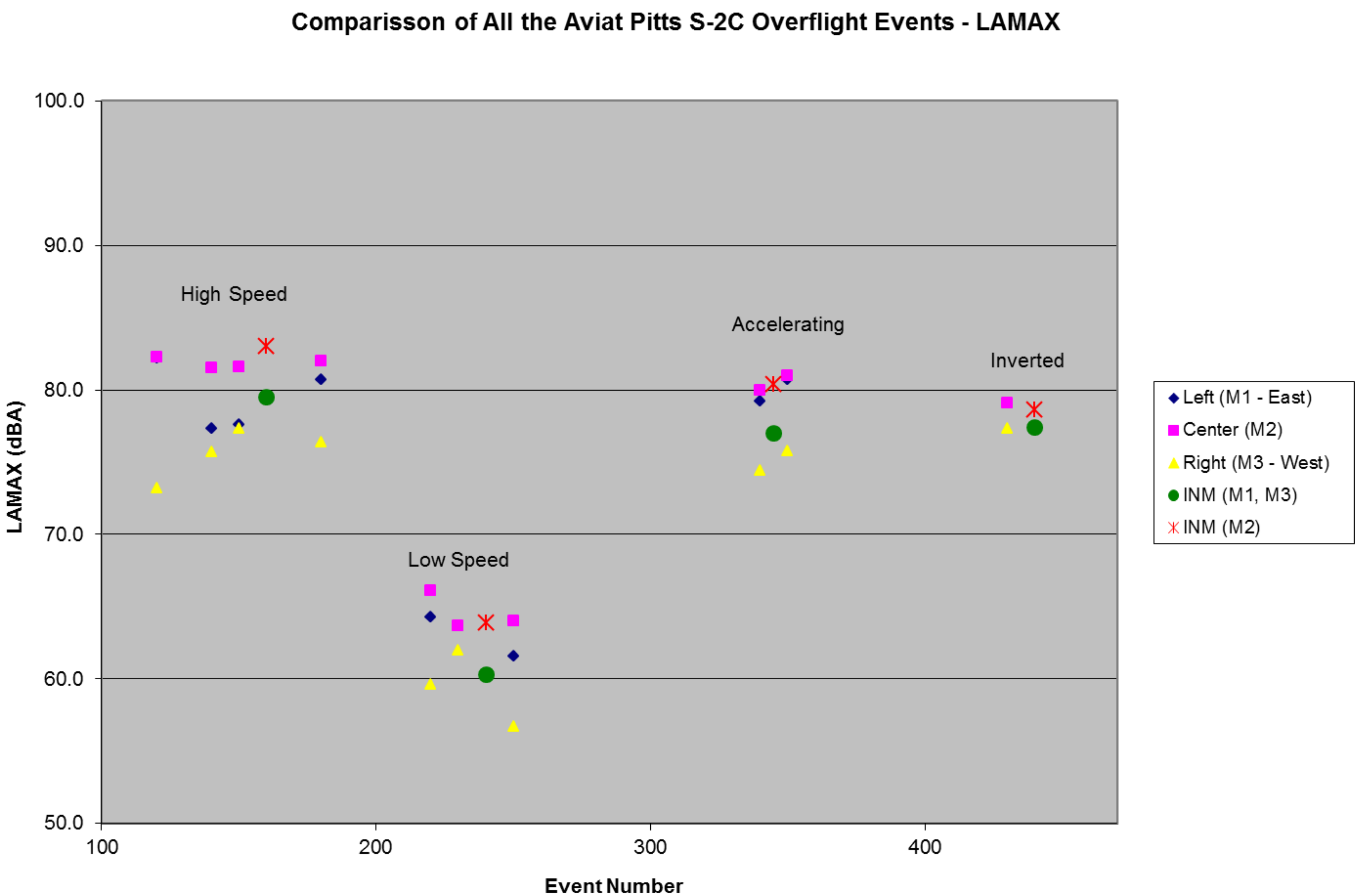

Figure 19: Comparison of Aviat Pitts S-2C Level-Flight Event with Corresponding INM Results – LAMAX

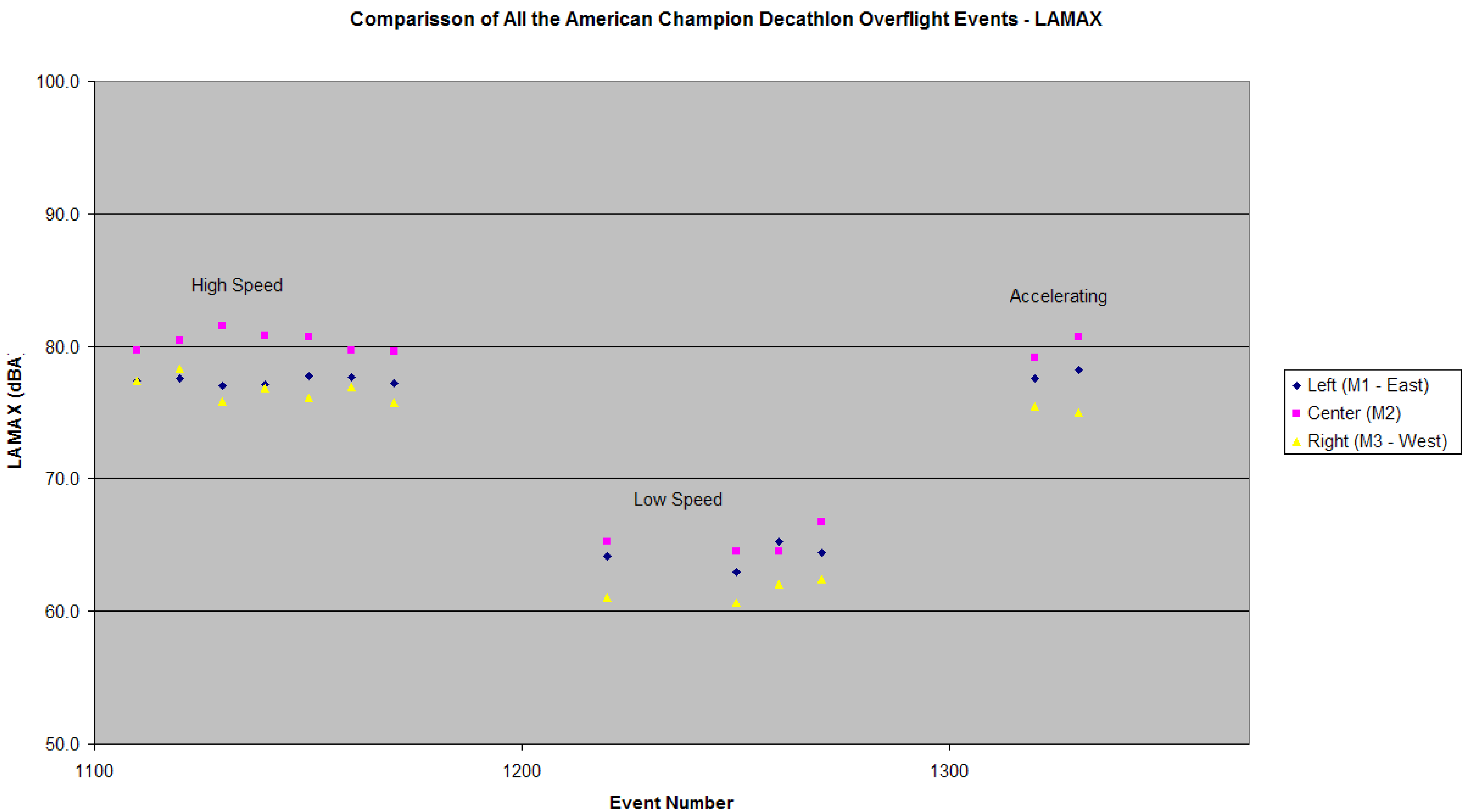

Figure 20: Comparison of Sukhoi SU-29 Level-Flight Event with Corresponding INM Results – LAMAX

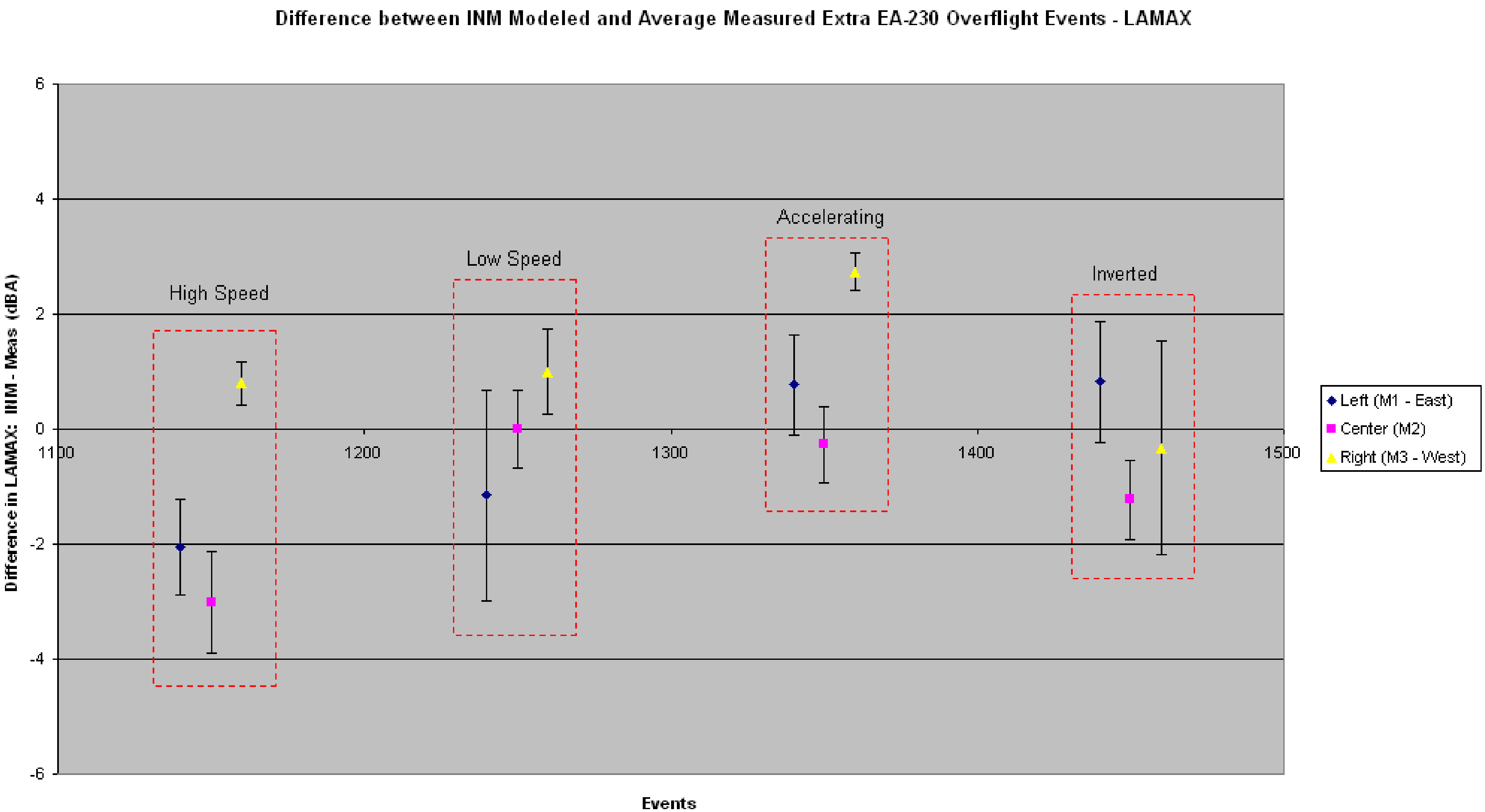

Figure 21: Difference between INM Modeled and Average Measured Results for the Extra EA-230 Level-Flight Events – LAMAX[29]

[29] The error bars represent one standard deviation over each type of level-flight event at each microphone.

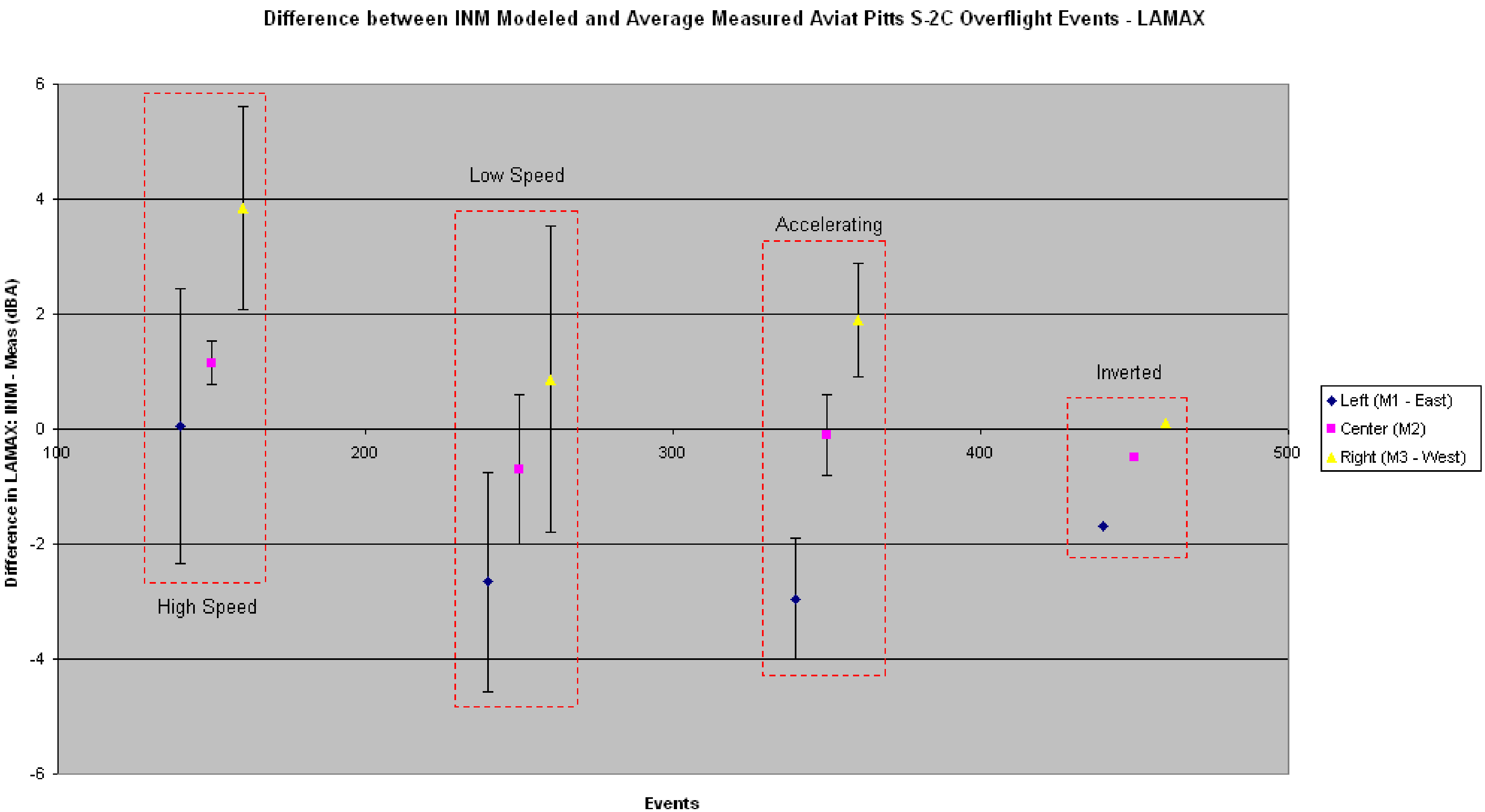

Figure 22: Difference between INM Modeled and Average Measured Results
for the Aviat Pitts S-2C Level-Flight Events – LAMAX

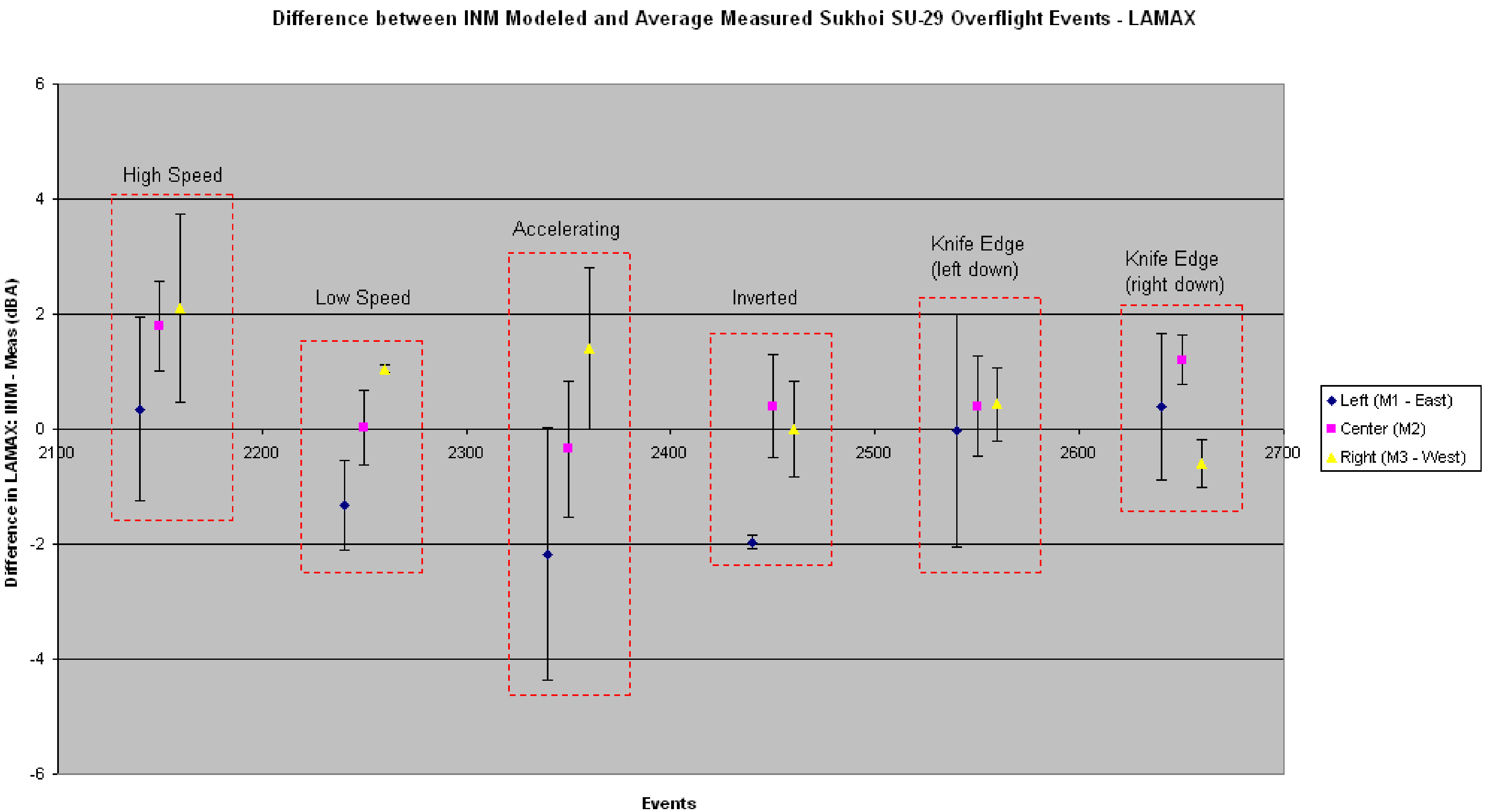

Figure 23: Difference between INM Modeled and Average Measured Results
for the Sukhoi SU-29 Level-Flight Events – LAMAX

Table 26: Estimated DNL values for the Extra EA-230

	DNL (dB(A))				
Number of Sequences	M1 (-500 ft)	M2 (0 ft)	M4 (660 ft)	M5 (1320 ft)	M7 (5496 ft)
1	39.2	39.4	36.7	34.3	25.5
2	42.2	42.4	39.7	37.3	28.5
5	46.1	46.3	43.6	41.2	32.4
10	49.2	49.4	46.7	44.3	35.5
15	50.9	51.1	48.4	46.0	37.2
20	52.2	52.4	49.7	47.3	38.5
50	56.1	56.3	53.6	51.2	42.4

Table 27: Estimated DNL values for the Aviat Pitts S-2C

	DNL (dB(A))				
Number of Sequences	M1 (-500 ft)	M2 (0 ft)	M4 (660 ft)	M5 (1320 ft)	M7 (5496 ft)
1	40.8	41.8	40.4	38.4	28.7
2	43.8	44.8	43.4	41.4	31.7
5	47.8	48.8	47.4	45.4	35.7
10	50.8	51.8	50.4	48.4	38.7
15	52.5	53.5	52.1	50.1	40.4
20	53.8	54.8	53.4	51.4	41.7
50	57.8	58.8	57.4	55.4	45.7

Table 28: Estimated DNL values for the Sukhoi SU-29

	DNL (dB(A))				
Number of Sequences	M1 (-500 ft)	M2 (0 ft)	M4 (660 ft)	M5 (1320 ft)	M7 (5496 ft)
1	39.8	39.3	37.8	35.8	27.9
2	42.8	42.3	40.8	38.8	30.9
5	46.8	46.3	44.8	42.8	34.9
10	49.8	49.3	47.8	45.8	37.9
15	51.6	51.1	49.6	47.5	39.7
20	52.8	52.3	50.8	48.8	40.9
50	56.8	56.3	54.8	52.8	44.9

Date: October 17, 2012 (updated November 9, 2012)

Subject: Approval of Aerobatic Practice Area (APA) noise equivalent methodology

Attachment 2

Aircraft List

The range of aerobatic aircraft represented in INM for this analysis is presented below. If a certificate of waiver is requested for an aircraft not on the list below, prior written approval by AEE is needed before the report in Attachment 1 can be used.

Aircraft Name	**Engine**		**Aircraft Name**	**Engine**
Aero Vodochody L39C	Ivchenko AI-25TL turbofan 16.87 kN (3,792 lbf)		MiG 15 UTi	Klimov VK-1 turbojet, 26.5 kN (5,950 lbf
American Champion 8KAB Decathelon	Lycoming AEIO-360-H1B CSU, 180 hp (134.2 kW)		North American A3	Allison V-1710-87 liquid-cooled piston V12 engine, 1,325 hp (988 kW)
American Champion Citibria	Lycoming O-320-A2B, 150 hp (111.9 kW)		North American P5 Mustang	Packard V-1650-7 liquid-cooled supercharged V-12, 1,490 hp (1,111 kW at 3,000 rpm;[76] 1,720 hp (1,282 kW) a WEP
Aviat Eagle	Lycoming AEIO-360-A1D, 200 hp (149 kW)		North American T2	Wright R-1820 single row radial 1425 hp
Cap 232	Lycoming AEI0-540-L1 B5D air-cooled flat-six, 22 kW (300 hp)		North American T6	Pratt & Whitney R-1340-AN-1 Wasp radial engine, 600 hp (450 kW)
Dornie alpha jet	SNECMA Turbomeca Larzac 04-C5 turbofans, 13.24 kN (2,976 lbf) each		P-47	Pratt & Whitney R-2800-59 twin-row radial engine, 2,535 hp (1,890 kW)
de Havilland DHC-1B Chipmunk	de Havilland Gipsy Major 1C (145 hp, 108 kw)		Piper J-3	Continental A-65-8 air-cooled flat four, 65 hp (48 kW) at 2,350 rpm
Edge 540	Modified Lycoming AEIO-540 Hartzell composite, 3 blade, 254 kW (340 hp)		Pitts S-2	Textron Lycoming AEIO-540-D4A5 flat-six air cooled piston engine, 260 hp (19 kW)
Extra 300	Lycoming AEIO-540-L1B5 MT-Propeller composite propeller (3- or 4-blade), 224 kW (300 hp)		RV-4	Lycoming O-320, O-360 or IO-360, 150-180hp (110-135 kW)

F-15	Pratt & Whitney F100-100 or −220 afterburning turbofans		RV-6	Lycoming O-320 or Lycoming O-360 fixed pitch or constant speed, 150-180h (112-134 kW)
F-16	F110-GE-100 afterburning turbofan		RV-7	Lycoming O-320 or Lycoming O-360 Constant Speed or Fixed Pitch, 160 to 200 hp (119 to 149 kW)
Giles 202	Lycoming AEIO-360-A1E piston engine, 235 hp ()		RV-8	Lycoming O-320, Lycoming O-360 or Lycoming IO-360 fixed pitch or constant speed, 150-200hp (112-149 kW)
Great Lakes 2T	Lycoming engine		Stearman	radial engine
Grob G120	Lycoming AEIO-540-D4D5 6-cylinder, horizontally opposed engine, 194 kW (260 hp)		Steen Skybol	Lycoming HO-360-B1B piston, 180 hp (130 kW)
Grumman 7F7	Pratt & Whitney R-2800-34W "Double Wasp" radia engines, 2,100 hp (1,566 kW) each		Sukhoi 31	Vedeneyev M-14PF, 294 kW (400 hp)
Grumman F8F Bearca	Pratt & Whitney R-2800-34W "Double Wasp" two-row radial engine, 2,100 h (1,567 kW)		Super solutio	Pratt & Whitney R-1340 Radial, 535 hp (399 kW)
Hawker Sea Fury	Bristol Centaurus XVIIC 18-cylinder twin-row radial engine, 2,480 hp (1,850 kW)		Yak 52	Vedeneyev M-14P 9-cylinder radial engine, 268 kW (360 hp)
Lazer 230	piston engine		Yak 55	Vedeneyev M14P 9-cylinder radial engine, 268.5 kW (360.1 hp)
Lockheed P-38	Allison V-1710-111/113 V-12 piston engine, 1,725 hp [N 7] (1,194 kW) each		Zlin 242	Avia M 137A inverted 6 cylinder inline engine, 134 kW (180 hp)

Attachment 3

Applying the Volpe Report for APAs