DOT/FAA/AEE/2012-07
DOT-VNTSC-FAA-12-08.II

ANALYSIS OF MODELING CUMULATIVE NOISE FROM SIMULTANEOUS FLIGHTS

VOLUME 2: SUPPLEMENTAL ANALYSIS

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December 2012

Final Report

U.S. Department of Transportation

Federal Aviation Administration

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE December 2012	3. REPORT TYPE Final Report

4. TITLE AND SUBTITLE
Analysis of Modeling Cumulative Noise from Simultaneous Flights; Volume 2: Supplemental Analysis

5. FUNDING NUMBERS
FP01 (JD7RC),
FA4SC3 (KJ200)

6. AUTHOR(S)

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Department of Transportation
Research and Innovative Technology Administration
John A. Volpe National Transportation Systems Center
Environmental Measurement and Modeling Division, RVT-41
Cambridge, MA 02142-1093

8. PERFORMING ORGANIZATION REPORT NUMBER
DOT-VNTSC-FAA-12-08.II

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Department of Transportation
Federal Aviation Administration
Western-Pacific Region
Special Programs Staff, AWP-1SP
Lawndale, CA 90261

U.S. Department of Transportation
Federal Aviation Administration
Office of Environment and Energy, AEE-100
Washington, DC 20591

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
DOT/FAA/AEE/2012-07

11. SUPPLEMENTARY NOTES

FAA Program Managers: Barry Brayer and Keith Lusk (AWP, Western Pacific Regional Office, Special Programs Staff); Rebecca Cointin, Bill He (AEE, Office of Environment and Energy, Noise Division)

12a. DISTRIBUTION/AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

This is the second of two volumes of the report on modeling cumulative noise from simultaneous flights. This volume examines the effect of several modeling input cases on Percent Time Audible results calculated by the Integrated Noise Model. The cases presented in this volume include changes to ambient noise input type as well as changes to sampling duration for ambient inputs. The results are compared with those presented in the Volume 1 report.

14. SUBJECT TERMS

Aircraft Noise, Noise Prediction, Noise Model Comparison, Simultaneous Aircraft Overflight, Integrated Noise Model, Time Compression, Time Audible, Audibility

15. NUMBER OF PAGES
46

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

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

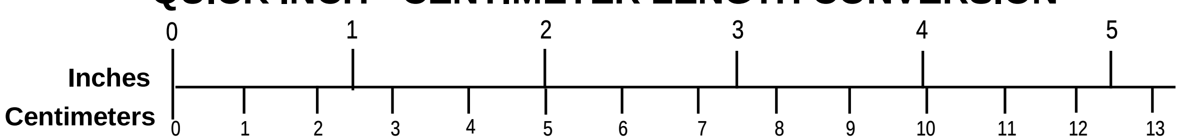
VOLUME (APPROXIMATE)

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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1 INTRODUCTION

The Federal Aviation Administration Office of Environment and Energy's (FAA AEE) Aviation Environmental Design Tool (AEDT) and Integrated Noise Model (INM) are integrated noise models which predict cumulative noise for aircraft operations but do not take into account flight scheduling. These methods can result in overpredictions when calculating cumulative, time-based noise metrics for simultaneously occurring flights because noise from these flights are accounted for independently.

In Volume 1 of this analysis[*] "*Analysis of Modeling Cumulative Noise from Simultaneous Flights; Volume 1: Analysis at Four National Parks*",[1] two methods were presented to better account for noise from simultaneously occurring aircraft in AEDT/INM, known as "time compression algorithms." The performance of these algorithms was evaluated using several National Park noise model studies, and conclusions were made regarding the applicability of the time compression algorithms for simultaneous aircraft modeling over a variety of modeling scenarios in AEDT/INM.

The results of the previous analysis showed:

- The proposed Time Compression algorithm for use in the FAA's INM[†] outperformed the original time compression algorithm when compared to measured data;
- Both time compression algorithms outperformed the baseline case with no time compression; and
- The proposed algorithm showed poorer performance for helicopter and high altitude jet aircraft.

Volume 2 of this analysis focuses on an additional analysis to better characterize the performance of the Time Compression algorithms when modeling simultaneously occurring flights in AEDT/INM. Section 2 of this report focuses on investigating the effects of the modeling input assumptions. Section 3 investigates other modeling factors such as modeling of high-altitude jet aircraft over long distances. Conclusions from this analysis and recommendations regarding modeling simultaneously-occurring flights with time compression in AEDT/INM are presented in Section 4along with recommendations for future work intended to further improve simultaneous aircraft event modeling in AEDT/INM.

[*] Volume 1 of this analysis was originally delivered as a letter report entitled "Analysis of Modeling Cumulative Noise from Simultaneous Flights; Final Report" on January 5, 2011. It has since been reissued as Draft Technical Report "Analysis of Modeling Cumulative Noise form Simultaneous Flights; Volume 1: Analysis at Four National Parks".

[†] All modeling for this effort was performed in INM 7.0b.

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2 ANALYSIS OF MODELING INPUT ASSUMPTIONS

This section focusses on analyses conducted to examine the modeling input assumptions (i.e., duration of each overflight event and ambient input, as well as the ambient acoustic data represented by the ambient input files used in the INM studies) used in the previous analysis. These assumptions are likely to have had varying contributions to the differences between the measured and modeled results.

2.1 Modeling Duration

In accordance with FAA Part 150,[2] an average annual day is typically used to represent long-term average conditions for an airport. Because air tour aircraft activity over National Parks is generally seasonal, analyses are performed to be representative for the season (summer and/or winter) when air tours (the noise source of interest for ATMPs) occurs, not an entire year. Thus, the previous analysis utilized an average day (12 hours from 7 AM to 7 PM) of aircraft operations (air tour and commercial jet overflights) during the peak month (PMAD), along with averaged ambient data for the season. It was recommended at the conclusion of the previous analysis that additional analysis be performed to see if ambient data representing different (shorter) time periods would improve the comparisons between the measured and modeled results.

This analysis included noise measurements and the corresponding INM studies at three National Parks: Grand Canyon National Park (GCNP), Lake Mead National Recreational Area (LMNRA), and Great Smoky Mountains National Park (GRSM).[*] Detailed inputs for the specific time periods include:

1. The FAA's Enhanced Traffic Management System (ETMS) was queried for aircraft operational data that occurred within a specified time period that could be correlated with a field observer present at a site. Overflight operations were selected with the time period of interest being shortened to correspond directly to the observation period in each study park: two sets for the LMNRA 2004 study; three sets for the GRSM 2006 study; and a single set for the GCNP 2007 study, where observer log periods for nine measurement sites were chosen to be concurrent[†]. Operations were then further subdivided into two sets: one containing all aircraft operations[‡], and the other only including commercial overflight operations, and excluding fixed-wing and helicopter air tour operations.
2. The observer log data for specified time periods were used and not aggregated into an average for the site as a whole.

[*] All three of these studies were also included in the previous analysis. The Zion National Park (ZION) study was excluded from this secondary analysis due to several issues with the study described in the previous letter report.

[†] Two GCNP sites included in the previous analysis, G054 and G057, did not have observer-log data corresponding to the study time window of interest.

[‡] Because time period specific data were not available for the fixed-wing and helicopter air tour operations, average daily air tour operations were used in this analysis.

Table 1 provides an overview of the site locations and specific time periods (or "sessions") modeled during this analysis. To allow for comparison with the previous analysis, the modeled dates were kept consistent for the second analysis. Site and time-window selection for the second analysis was mainly influenced by the availability of corresponding observer log data.

Table 1. Site modeling time and duration for secondary analysis

Park Name	Site Name, Session	Session Date	Session Start Time-End Time (Local)	Session Duration (Hours)
GCNP 2007	All Sites (9)	8/10/2007	1400-1800	4
GRSM 2006	Noland (AM)	6/7/2006	0900-1300	4
GRSM 2006	Noland (PM)	6/7/2006	1400-1800	4
GRSM 2006	Parsons (PM)	6/13/2006	1440-1840	4
LMNRA 2004	Indian Pass (AM)	5/14/2004	1100-1300	2
LMNRA 2004	Indian Pass (PM)	5/14/2004	1400-1600	2

The results of the modeling for a specific time period (or "session-based modeling") showed that when considering the high altitude operations in each of these studies, INM predicts a larger number of audible, modeled, high-altitude jet events than were observed. On average only one in four events modeled as audible by the INM was marked in the observer log for these three parks analyses[*]. Table 2 presents the total number of aircraft operations modeled in the session-length study, as compared to the number of aircraft operations predicted as audible in INM, and the count of aircraft reported in the observer log.

[*] Some Parks in this analysis include observer data collected through in situ observer logging (or field observations), while other Parks had off-site observer logging. For the purposes of ATMP related research, off-site observer logging is considered to be fundamentally equivalent to in situ observer logging[3].

Table 2. Number of aircraft operations by measurement site: Total[*] vs. modeled and observed

		Number of Operations, All Aircraft				Number of Operations, High- Altitude Jets			
Park Name and Year	**Site Name, Session**	**Total**	**Audible Modeled**	**Observed**	**Percentage Of Modeled Events Observed**	**Total**	**Audible Modeled**	**Observed**	**Percentage Of Modeled Events Observed**
GCNP 2007	G010	808	70	26	37%	434	67	18	27%
GCNP 2007	G015	808	96	40	42%	434	90	32	36%
GCNP 2007	G031	808	72	106	147%	434	64	5	8%
GCNP 2007	G032	808	79	40	51%	434	72	16	22%
GCNP 2007	G033	808	108	36	33%	434	103	29	28%
GCNP 2007	G053	808	79	17	22%	434	75	8	11%
GCNP 2007	G055	808	67	113	169%	434	89	10	11%
GCNP 2007	G056	808	71	36	51%	434	66	3	5%
GCNP 2007	G058	808	103	113	110%	434	95	6	6%
GRSM 2006	Noland (AM)	416.95	89	75	84%	409	75	55	73%
GRSM 2006	Noland (PM)	478.95	96	62	65%	471	82	38	46%
GRSM 2006	Parsons (PM)	446.95	127	61	48%	439	119	46	39%
LMNRA 2004	Indian Pass (AM)	518.21	72	80	111%	361	71	48	68%
LMNRA 2004	Indian Pass (PM)	1800.58	418	77	18%	1614	412	45	11%

[*] Total number of flights as reported by ETMS, plus reported Air Tour activity (actual activity in GCNP, percent of total reported activity in LMNRA and GRSM)

2.2 Variation of Ambient Type

The following four types of "ambient" characterizations are typically used by the FAA and NPS in environmental analyses related to transportation noise in the parks:

- *Existing Ambient:* The composite, all-inclusive sound associated with a given environment, excluding only the analysis system's electrical noise (i.e., aircraft-related sounds are included);
- *Existing Ambient Without Source of Interest (*or *"Traditional" Ambient):* The composite, all-inclusive sound associated with a given environment, excluding the analysis system's electrical noise and the sound source of interest, in the case of the Air Tour Management Plan (ATMP) program, commercial air tour aircraft;
- *Existing Ambient Without All Aircraft* (or *"Cumulative" Ambient*, for its use in assessing cumulative impacts): The composite, all-inclusive sound associated with a given environment, excluding the analysis system's electrical noise and the sounds produced by the sound source of interest, in this case, all types of aircraft (i.e. commercial air tours, commercial jets, general aviation aircraft, military aircraft, and agricultural operations); and
- *Natural Ambient:* The natural sound conditions found in a study area, including all sounds of nature (i.e., wind, streams, wildlife, etc.), and excluding all human and mechanical sounds.

The analysis in Section 2.1 utilized the *Existing Ambient Without the Source of Interest*, as did the previous analysis[1.]. Since ambient data type directly influences audibility computations and since a variety of different ambient types have been used in the past for different Parks analyses, modeling was performed with additional ambient types to determine their effect. The ambient data were calculated using the L_{50} noise metric, which represents the level exceeded 50% of the time during the measurement period at a given location.

The creation of ambient input data for environmental analysis in INM was based on estimates of the ambient acoustic condition at a specific site, and modified for the above ambient characterizations by excluding the contribution of certain sources, using data gathered in the acoustic observer logs corresponding to that site. Except for the Existing Ambient, the computation of the above ambient types is challenging because different sound sources often overlap in both frequency and amplitude; there is currently no practical method to separate out acoustic energy of different sound sources (i.e., human-caused sounds imbedded with natural sounds). Using the data in the acoustic observer logs, different characterizations of ambient can be *estimated* from the sound level data. This method was developed by performing a detailed data analysis working closely with the NPS, in comparing several approaches of estimating of the Natural Ambient.[3]

Figure 1 provides an example of ambient type variation across the frequencies of interest. These ambient spectra were generated from the session-long measurement taken at GCNP 2007 site G032 during the 1400-1800 observation period used in this study. The Equivalent Auditory System Noise (EASN)[4] spectrum, a one-third octave band representation of the threshold of human hearing, is provided for reference.

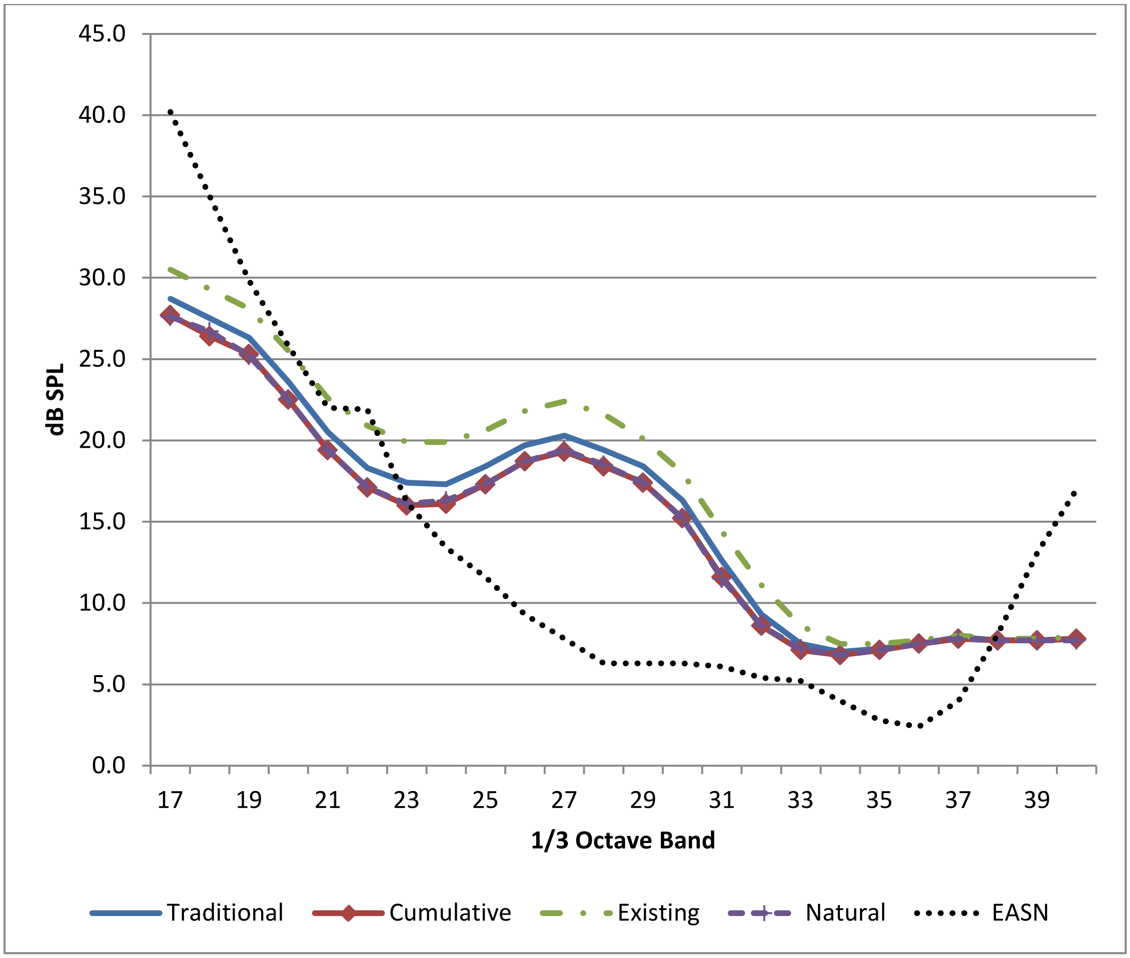

Figure 1. Comparison of ambient type, GCNP 2007 Site G032, session-length sample.

Ambient spectra, filtered with respect to EASN, are shown in Figure 2. The filtering process minimizes low-frequency differences in the ambient spectra, where human sensitivity is lowest. Differences in the middle of the frequency range are preserved.

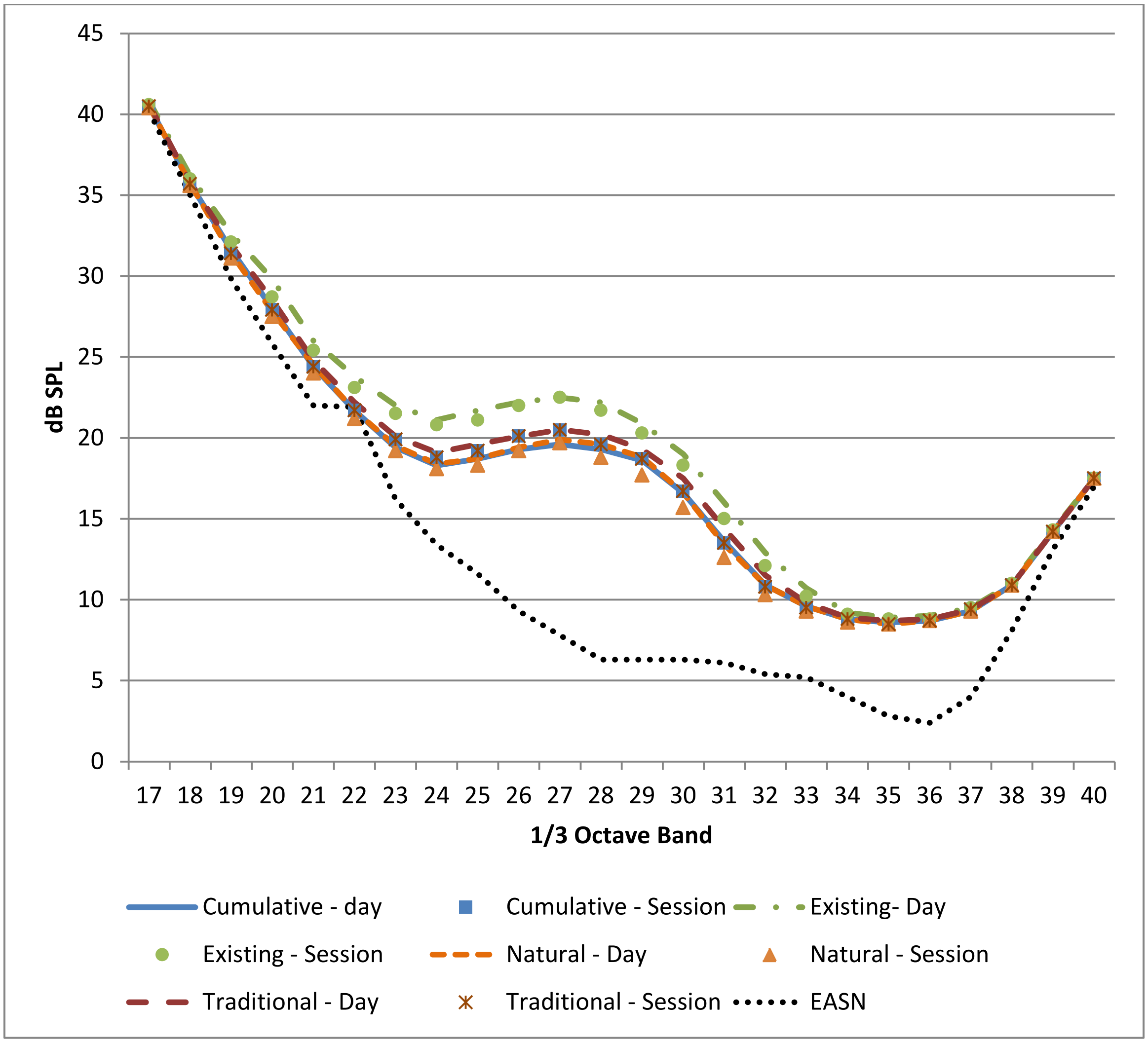

Figure 2. Comparison of EASN-modified ambient type, GCNP 2007 Site G032

Averaged %TAUD results across all sites modeled with the different ambient types are presented in Table 3. The results show corresponding %TAUD values increase as the amount of human-caused sounds decrease in the ambient type. This trend is intuitive since the lower the ambient sound level, the more aircraft sounds should be audible. However, the audibility increase is not substantial.

Table 3. Difference from observed %TAUD, all aircraft, varying ambient type and sampling duration; averaged across all parks*

		Existing L_{50}			Traditional L_{50}			Cumulative L_{50}			Natural L_{50}		
Ambient sampling duration	**Time Compression**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Session-long	Average	34.3	23.8	18.6	34.7	26.4	21.8	35.3	27.5	23.2	35.7	28.3	24.3
	Standard Deviation	19.1	16.0	15.4	18.8	17.6	16.9	18.3	17.2	16.5	18.1	16.8	16.1
	Median	40.0	27.2	21.2	40.0	27.2	21.2	40.0	27.2	21.2	40.0	30.3	25.7
Day-long (7AM-7PM)	Average	34.8	26.5	21.5	35.1	27.9	23.7	35.6	27.6	23.6	35.8	28.7	25.0
	Standard Deviation	18.7	17.1	16.4	18.5	17.4	16.8	18.2	16.6	16.4	18.1	17.2	16.8
	Median	40.0	27.2	21.2	40.0	29.7	24.5	40.0	30.6	23.8	40.0	31.2	26.2
Study-long	Average	N/A	N/A	N/A	34.5	27.0	22.3	N/A	N/A	N/A	N/A	N/A	N/A
	Standard Deviation	N/A	N/A	N/A	19.9	19.8	19.5	N/A	N/A	N/A	N/A	N/A	N/A
	Median	N/A	N/A	N/A	36.4	28.1	22.4	N/A	N/A	N/A	N/A	N/A	N/A

* Results for each study park are presented in the Appendices.

2.3 Variation of Ambient Duration

The analysis in Section 2.1 utilized ambient data based on measurements taken over the full deployment at each of the analysis locations. Based on long-term ambient data collected in separate studies by the Volpe Center[5] and the National Park Service,[6] the FAA and NPS have jointly agreed that a minimum 25-day measurement period would be conducted in order for the ambient data to be considered representative of a particular season, e.g., summer. To more closely model specific ambient conditions during observation, two new sets of input data were developed; one based on the "Existing Ambient Without Air Tours" data collected for the 7AM-7PM period on the modeled day, and one based on the same data, but during the period of observation detailed in Table 1. The results modeled using the two new ambient data sets were compared with the study-long "Existing Ambient Without Air Tours" ambient input file from the original modeling effort.

Average results for all three parks studies using different ambient durations are shown in Table 4 through Table 6. The LMNRA 2004 results show larger discrepancies between measured and modeled data for both day-long and session-long ambient input data (see Table 4); this is likely due to the large variation in the shorter ambient inputs with respect to the study-long average, due to transient wind conditions during the observation period (see Figure 3). Results for GRSM 2006 show slightly poorer performance in absolute difference as the ambient input sample length is reduced, although standard deviation is slightly improved (see Table 5). Slight overall improvement is seen in the GCNP 2007 results as the ambient input is restricted toward the observation period (see Table 6).

Table 4. Difference in measured and modeled time audible for LMNRA 2004– Traditional Ambient, all aircraft

	LMNRA 2004 (Month-long Ambient)			LMNRA 2004 (day-long Ambient)			LMNRA 2004 (session-long Ambient) (2 hours)		
	Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Average (2 sites)	36.4	23.6	16.2	36.4	34.6	31.0	36.4	26.5	20.4
Standard Deviation	5.3	13.0	13.9	5.3	7.0	9.1	5.3	16.3	19.2
Median	36.4	23.6	16.2	36.4	34.6	31.0	36.4	26.5	20.4

Table 5. Difference in measured and modeled time audible for GRSM 2006– Traditional Ambient, all aircraft

	GRSM 2006 (Month-long Ambient)			GRSM 2006 (Day-long Ambient)			GRSM 2006 (Session-long Ambient) (4 hours)		
	Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Average (3 sites)	25.9	16.1	10.0	32.7	20.4	13.9	31.0	19.4	12.9
Standard Deviation	22.6	22.8	21.6	16.6	19.6	19.0	17.7	20.2	19.5
Median	17.6	7.4	1.9	0.3	2.0	2.4	21.0	9.2	3.4

Table 6. Difference in measured and modeled time audible for GCNP 2007– Traditional Ambient, all aircraft

	GCNP 2007 (Month-long Ambient)			GCNP 2007 (Day-long Ambient)			GCNP 2007 (Session-long Ambient) (4 hours)		
	Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Average (9 sites)	36.5	30.6	26.8	35.6	28.9	25.4	35.6	28.7	25.1
Standard Deviation	21.5	20.4	19.5	22.0	18.9	17.4	22.0	18.5	16.8
Median	40.1	32.8	26.0	40.0	29.8	24.3	40.0	29.8	24.3

Similar results were seen for the three parks studies, when only noise from overflights was analyzed, as shown in Table 7 through Table 9. As seen above, variations in the ambient condition during observation at LMNRA likely caused poorer model performance when analyzed with the session-long ambient input. Similarly, the results from GRSM may show the effects of short-term changes in ambient condition. Full results for all sites are presented in Appendix A through Appendix F.

Table 7. Difference in Measured and Modeled Time Audible for LMNRA 2004 - Traditional Ambient, overflight events only

	LMNRA 2004 (Month-long Ambient)			LMNRA 2004 (Day-long Ambient)			LMNRA 2004 (Session-long Ambient) (2 hours)		
	Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)		
Time Compression	None	Original	Proposed	None	Original	Proposed	None	Original	Proposed
Average (2 sites)	11.8	4.0	-0.2	35.3	23.5	17.4	26.2	15.0	9.8
Standard Deviation	38.1	28.2	25.3	43.2	33.1	30.3	56.1	41.6	37.5
Median	11.8	4.0	-0.2	35.3	23.5	17.4	26.2	15.0	9.8

Table 8. Difference in Measured and Modeled Time Audible for GRSM 2006 - Traditional Ambient, overflight events only

	GRSM 2006 (Month-long Ambient)			GRSM 2006 (Day-long Ambient)			GRSM 2006 (Session-long Ambient) (4 hours)		
	Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)		
Time Compression	None	Original	Proposed	None	Original	Proposed	None	Original	Proposed
Average (3 sites)	20.3	12.9	8.0	27.1	17.0	11.7	25.2	15.9	10.7
Standard Deviation	6.3	6.1	6.0	10.4	6.9	6.4	8.8	6.7	6.4
Median	20.4	11.7	6.5	1.9	1.9	2.6	28.9	18.4	12.3

Table 9. Difference in measured and modeled time audible for GCNP 2007 - Traditional Ambient, overflight events only

	GCNP 2007 (Month-long Ambient)			GCNP 2007 (Day-long Ambient)			GCNP 2007 (Session-long Ambient) (4 hours)		
	Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)		
Time Compression	None	Original	Proposed	None	Original	Proposed	None	Original	Proposed
Average (9 sites)	54.8	42.3	36.5	51.4	40.2	34.7	50.2	39.5	34.0
Standard Deviation	13.9	10.7	10.2	12.0	9.6	9.2	11.6	9.1	8.7
Median	53.1	38.4	33.7	55.0	42.5	37.3	51.3	41.7	36.9

Some sensitivity is seen in results when using short ambient source periods. Variations that would likely average out in a month-long set of ambient data had greater effects in these shorter time-scales. Some variation in %TAUD, as compared to that calculated with study-long ambient, could be attributed to the fact that the ambients were created from short samples.

Session-long ambient input data also illuminate the effect on observer sensitivity to local ambient conditions during observation; this can be observed at LMNRA 2004 site L07, where the AM observation session corresponded to a substantially lower ambient noise condition compared with the PM session or the day-long average. Results for %TAUD at site L07 varied by approximately 20% from the AM to PM session. However, ambient duration seems to have a nominal effect on the overall accuracy of modeled results. When averaged across all sites, results using the study-, day-, or session-long Traditional ambient were within 2% TAUD of each other.

Additionally, initial results show that wind condition at the observation site has a noticeable correspondence with the magnitude of difference between observed and modeled results. For the nine sites in the GCNP 2007 study, only three sites (Dragon (G031), Hermit Trail/Dripping Springs (G055) and Hermit Rest Trailhead Parking (G058),had observer-reported wind audibility below 50%TAUD during the modeled time period. These sites also showed the minimum difference, across all ambient time scales, in %TAUD between observed and modeled results. This indicates that wind noise could be adversely impacting observed time audible results. Currently, wind effects are not taken into account in the noise computations in AEDT/INM[*]; neither in the noise propagation computations and adjustments, nor in the computation of the ambient data[†].

[*] Although not factored into the noise computations, headwind is taken into account when computing aircraft performance in INM/AEDT.

[†] For a measurement sight dominated by windy conditions, wind noise may contribute to the average ambient noise levels in the INM/AEDT ambient files. However, wind noise is not specifically targeted or accounted for in the ambient data.

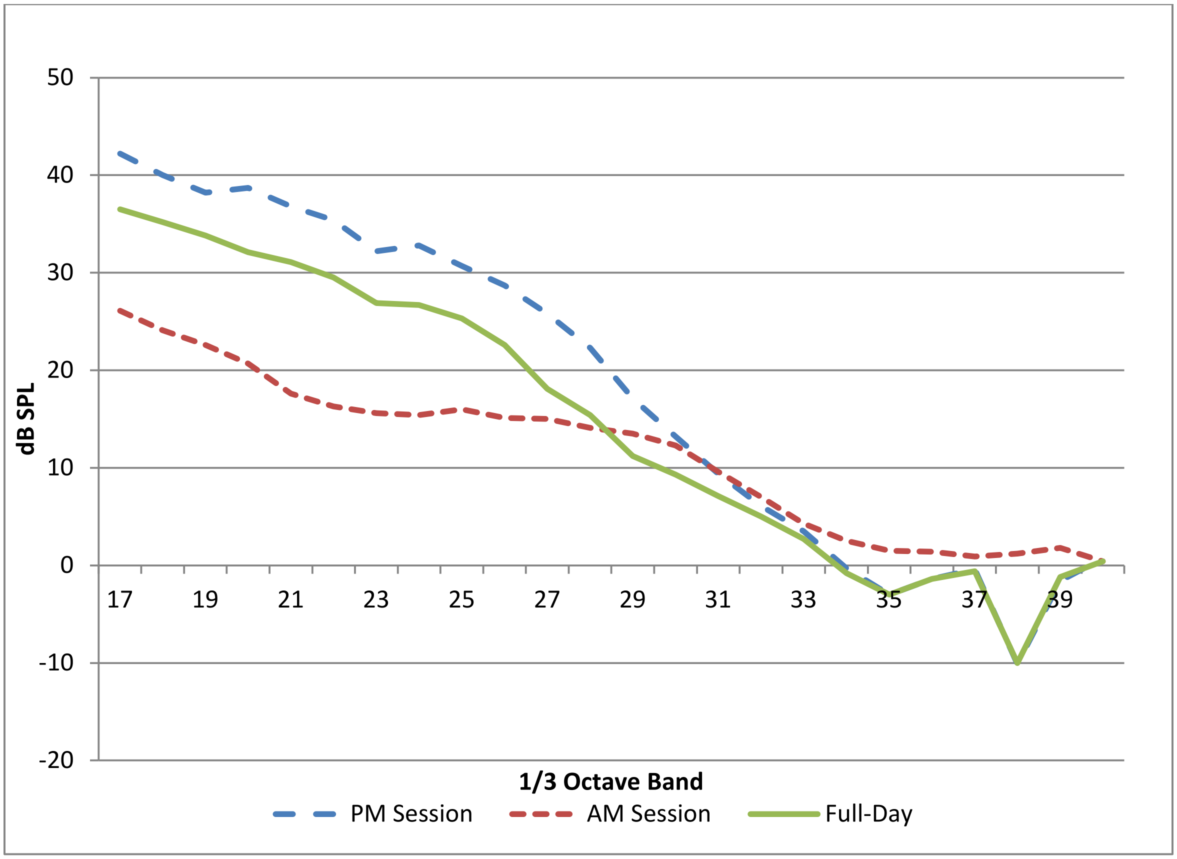

Figure 3. Session-long vs. day-long Traditional Ambient spectra, LMNRA 2004 Site L07

Minimal differences are seen between %TAUD results from studies using the study-long averaged Traditional and either the session- or day-long ambient input files. Averaged across all study sites, differences in %TAUD are small, with differences not exceeding 4% TAUD. Average differences from observed Time Audible ranged from 21.8% for All Aircraft using the proposed algorithm to 43.9% for Overflight events using a Daylong Traditional ambient and no Time Compression.

Table 10. Difference in %TAUD, study-long vs. session- and day-long Traditional Ambient

		Time Compression Type		
	Ambient Sampling Duration	**None**	**Standard**	**Proposed**
All Aircraft	Session-long ambient	-0.5	0.4	0.3
	Day-long ambient	-0.9	-1.0	-1.6
High-Altitude overflight	Session-long ambient	-2.0	-0.1	0.8
	Day-long ambient	-4.0	-1.7	-0.6

The GCNP site with outlying data, G032, showed substantial deviation from the results at other GCNP sites. Analysis of the study-long vs. session-long ambient spectra shows that lower ambient levels at this site during the observer logging session may be the cause of the noticeable increases in %TAUD at this location, compared with smaller differences at G010, for example (see Figure 4 and Figure 5).

Given the close correspondance of averaged results from all ambient sampling durations, the use of study-long ambient inputs is recommended. However, in cases where there are significant differences in measurement conditions during observer logging, analysis of short-term ambient spectra may offer supplemental information.

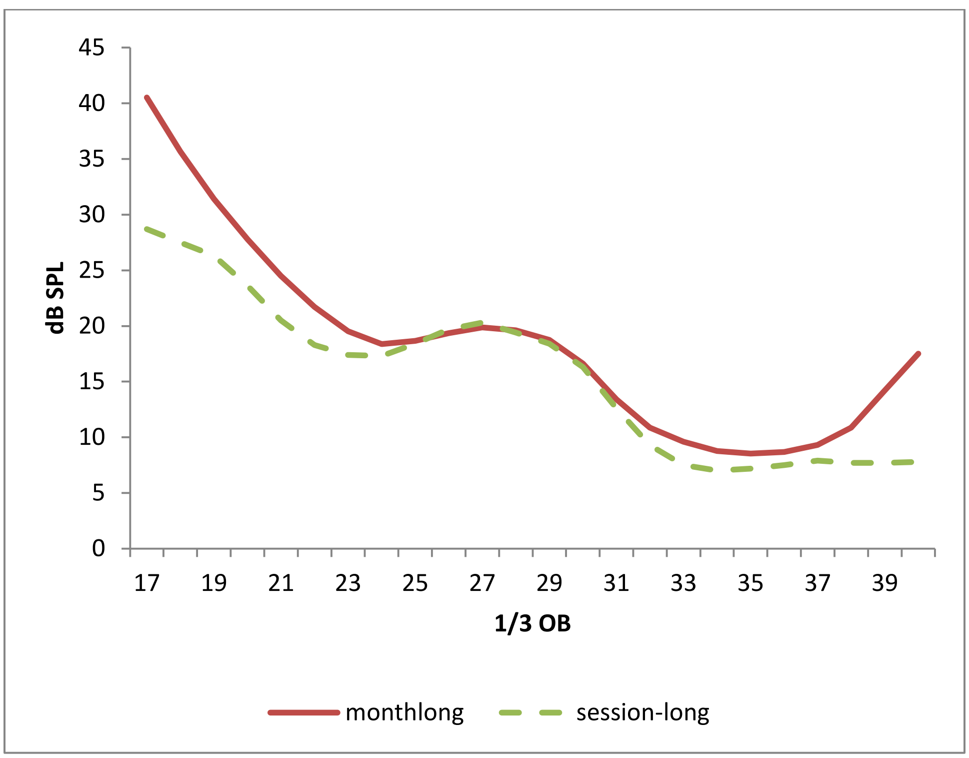

Figure 4. Month-long vs. session-long Traditional Ambient spectra, GCNP 2007 Site G032

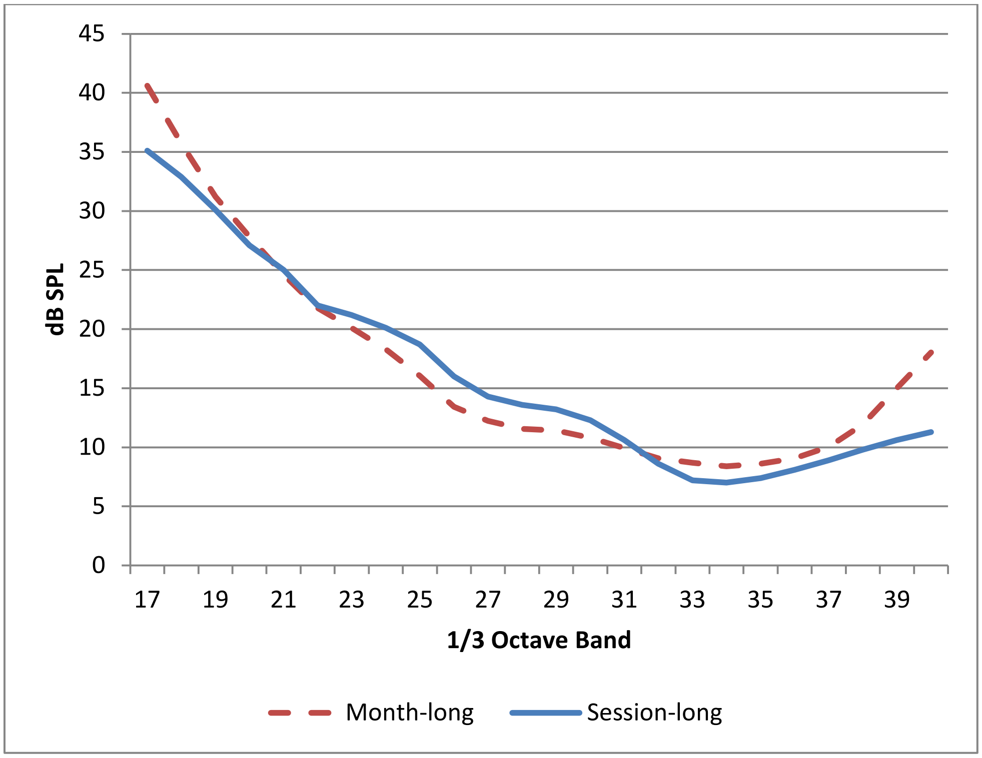

Figure 5. Study-long vs. session-long Traditional Ambient spectra, GCNP 2007 Site G010

3 REVIEW OF OTHER MODELING FACTORS

In addition to the duration and ambient data inputs, aircraft source data also impact the audibility computations in AEDT/INM. These impacts can be attributed to measured and modeled differences in the actual enroute aircraft flying in the National Parks, and the long distance noise propagation methodology used to determine the noise at a receiver due to an enroute aircraft. Both of these factors are investigated in this analysis.

3.1 Review of Enroute Aircraft Source Data

The INM was originally designed to model noise from aircraft operations in the vicinity of airports, typically below 10,000 feet. Noise in the vicinity of airports is typically dominated by aircraft departure noise, and noise from high altitude aircraft overflights is often assumed to have a negligible effect under these conditions. For areas outside the vicinity of airports, such as in the case of many National Parks, there is limited research on both source noise definition and propagation effects for enroute aircraft overflights traveling at speeds 400 to 600 knots. While INM does allow users to model high-altitude jet aircraft, it does not include cruise-specific source noise data, nor does it take into account the changes in meteorological effects over the course of those long propagation distances.[7]

The aircraft source and performance data in INM are based on aircraft approach and departure operations below 10,000 ft altitude for most aircraft, as specified in SAE-AIR-1845.[8] These data are operation specific. If overflight source noise data are not available, then INM uses departure source noise data when modeling aircraft operations (the aircraft specific departure noise-power-distance data and a default departure spectral class[9] of spectral class 126). Due to the limited amount of available spectral data for many aircraft, the same default spectral data are used to represent different aircraft. For this reason, all aircraft events above 10,000 ft AFE[*] were modeled with six substitution aircraft in INM, that were shown to have reasonable performance at high altitudes.[10] These aircraft are: the Boeing 737-300, Boeing 737-700, Boeing 777-200, Airbus A320, Embraer EMB-145 and Boeing MD-83. With only the six substitution aircraft deemed reasonable for high altitude overflight modeling, these substitution aircraft could potentially contribute to the differences seen between the measured and modeled results.

Research by Booz Allan Hamilton and Georgia Institute of Technology, as part of the FAA's Partnership for Air Transportation Noise and Emissions Reduction (PARTNER) Project 2,[11] may allow for the expansion of existing source noise datasets to more accurately model overflight operations in future versions of AEDT/INM. This work (currently under review) provides a methodology to predict enroute aircraft noise based on engine operational parameters and aerodynamic effects, including shock cell noise, for several common commercial jet aircraft classes represented in AEDT.[12]

[*] In INM, the 10,000 ft AFE (above field elevation) limit assumes an altitude buffer, due the wide range of airport elevations being modeled. Therefore, the equivalent limit at mean sea level (MSL) is 18,000 ft MSL.

3.2 Review of Noise Propagation Modeling Methodology

The INM models noise propagation with noise-power-distance (NPD) aircraft source data and a series of noise adjustments to those data. The NPD data fixed-wing aircraft consists of a set of decibel levels for various combinations of noise metrics, aircraft engine power states and slant distances from observer to aircraft*. The NPDs are developed according to methods described in SAE-AIR-1845 and the INM Version 7.0 Technical Manual,[13] and take into account spherical spreading and atmospheric absorption at the ten distances on the NPD curves (ranging from 200 ft to 25,000 ft). To obtain noise levels that lie between thrust values or between distance values on the NPDs, linear interpolation on thrust and logarithmic interpolation on distance are used, and extrapolation is used to obtain levels outside of the bounding thrust or distances values. The NPD method was originally implemented in INM instead of a propagation algorithm, because (1) it was less computationally intensive; (2) INM was originally developed for modeling at short distances up to 25,000 ft; and (3) logarithmic interpolation and extrapolation from NPD distances produce reasonable results over short distances dominated by spherical spreading, which is a logarithmic function with distance†.

It was suggested in the review of the preliminary analysis that this NPD propagation method may be underestimating propagation losses over long distances, and that this underestimation could contribute significantly to the difference between the measured and modeled audibility results for National Parks studies, which are often dominated by high-altitude aircraft events with long propagation distances. The NPD extrapolation method can overpredict aircraft noise at long propagation distances, because it does not take into account changes in atmospheric absorption. While this effect is minimal at short distances (up to 25,000 ft), where extrapolation produces conservative results, it has a more pronounced effect at larger distances. This directly impacts the time audible computations in INM because although the aircraft-specific spectral class data account for spherical spreading and atmospheric absorption over the propagation distance, they are then calibrated to the extrapolated L_{ASmx} NPDs, which do not.

Potentially more realistic methods for modeling long distance noise propagation would be (a) to include a more advanced propagation method (such as ray tracing, or the Parabolic Equation), or (b) to supplement the NPD data by including spherical spreading and atmospheric absorption effects directly at distances beyond 25,000 ft, which are already accounted for at short distances in the SAE-AIR-1845 simplified method for generating NPDs. While the implementation of a more advanced propagation method would require a complete restructuring, along with a significant development and testing effort, before it could be implemented in a publically-released version of AEDT/INM, the implementation of spherical spreading and atmospheric

* The helicopter noise-distance data in INM and AEDT (also referred to as NPDs) are similar to the fixed-wing NPDs, with the following differences: helicopter NPDs are delineated according to operational mode instead; helicopter NPDs are not interpolated on between multiple operational modes, and helicopter NPDs come in sets of three curves for the dynamic operational modes.

† The distance between consecutive points on the NPD curves range from 200 ft to 9,000 ft.

absorption effects at distances beyond 25,000 ft could be accomplished through a series of noise adjustments added to the existing AEDT/INM code.

The implementation of these adjustments, for long propagation distances, within INM and AEDT was investigated as part of FAA PARTNER Project 2 research at Pennsylvania State University. The proposed methodology[14] involved the recalculation of Noise-Power-Distance curves from the AEDT/INM fleet with adjustments based on assigned spectral class and a more complex atmospheric –dependent absorption loss. The adjustments could be accomplished through direct adjustments of the existing NPDs with spherical spreading and atmospheric absorption effects at distances beyond 25,000 ft, or a database of modified NPD curves could be calculated with these effects for enroute slant distances from 35,000 to 135,000 feet. Improvements to the accuracy of NPDs over these long slant distances should allow for better prediction of the effects of enroute aircraft operations. The research showed that atmospheric conditions, particularly humidity, have a strong influence on noise contours at the ground; implementing a layered-atmosphere approach to more closely represent local atmospheric profiles could correspond to large improvements in model performance. Additionally, the research highlighted the impact of atmospheric refraction and wind direction on long-range vertical propagation. These effects are not currently considered in AEDT, but were shown to have strong effects on model results.

To investigate this effect, a propagation method utilizing spherical spreading and atmospheric absorption was compared to the NPD extrapolation method at long distances up to 50 nautical miles (NMI) for a sample aircraft source (see Figure 6)[*]. For this example, the proposed propagation method was approximately 1 dB L_{ASmx} less than the NPD extrapolation method at 5 NMI from the source, and that difference increased with distance (a difference of 6 dB was seen at 10 NMI, 15 dB at 20 NMI and 37 dB at 50 NMI). In this example, the proposed propagation method results in noise levels dropping below 0 dB L_{ASmx} at distances beyond 20 NMI from the aircraft source, whereas the current NPDs result in noise levels above 0 dB L_{ASmx} at 50 NMI. Such a difference in noise levels at long propagation distances could have a significant impact of aircraft audibility over long distances. While these results make intuitive sense, they have not been validated against field measurements, since a comprehensive validation data set is not currently available.

[*] The sample aircraft source was based on an aircraft-specific spectral class extrapolated to 25,000 ft and then calibrated to the corresponding 25,000 NPD value.

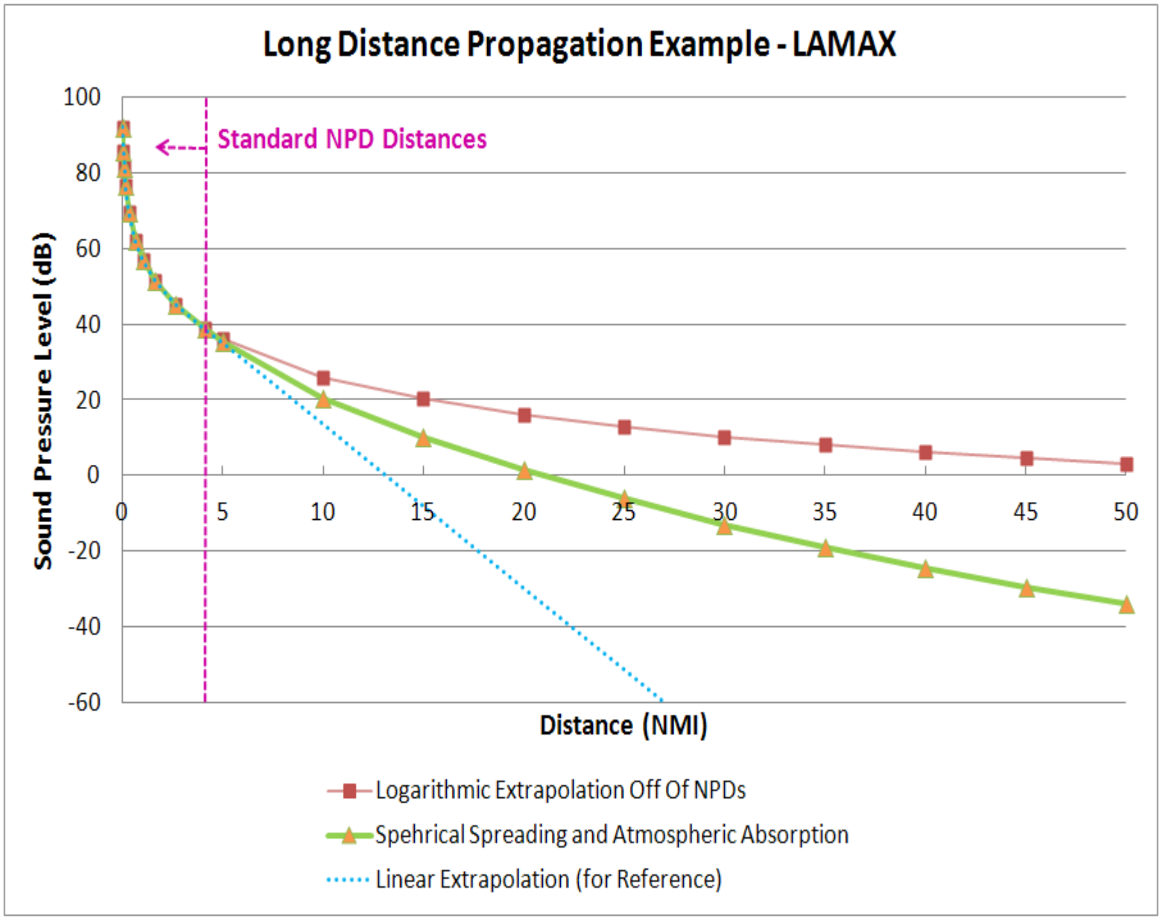

Figure 6. Comparison of long-distance propagation calculation methods for a sample aircraft

An improvement in the long distance propagation methodology could have a significant impact on the audibility computations in INM and AEDT, regardless of which time compression algorithm is used. This would impact noise from both high altitude and air tour events, both of which could have long lateral propagation distances in a National Park study. For example, in the secondary analysis, 27.2% of the events (560 aircraft operations) at GCNP that contribute to time audible have propagation distances greater than 60,000 ft. Likewise, 18.6% of the events (834 aircraft operations) at LMNRA and 42.7% of the events (457 aircraft operations) at GRSM that contribute to time audible have propagation distances greater than 60,000 ft. While more detailed propagation methods are explored for future model improvements to AEDT in the long term[15, 16, 17], a significant improvement in noise modeling over long distances could be achieved by implementing spherical spreading and atmospheric absorption as long distance propagation adjustments in the INM and AEDT in the interim.

Ongoing research, taking place at Pennsylvania State University, Georgia Institute of Technology and the Volpe Center, also seeks to develop methods to improve the accuracy of both source data of aircraft in cruise, and long-distance, vertical propagation from high altitudes. The techniques developed in this research may offer better modeling of noise from overflight segments, and could have a substantial effect on the accuracy of Percent Time Audible calculations, regardless of the time compression method employed.

Coupled with implementation of spherical spreading and atmospheric absorption adjustments to better model long-distance, horizontal propagation, the enroute algorithms in development could provide marked improvements. However, without an appropriate validation dataset, the effects of current practices or future improvements are largely speculative.

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4 CONCLUSIONS AND FUTURE WORK

This supplemental analysis serves to reinforce the conclusions of the previous analysis[1]; mainly, that the proposed time compression algorithm consistently outperforms the current one and no time compression cases across a variety of ambient conditions and measurement time scales. Additionally, the issues identified previously that may have a negative effect on algorithm performance are still in force. The modeling of high-altitude jet aircraft, the effects of measurement site location, geometry, and land cover, and performance issues with helicopter modeling could all contribute to the variance seen between modeled and measured results.

As described above, ongoing research, prompted by recommendations from the preliminary analysis, may produce methods to improve model performance within the given AEDT/INM framework in the near future. Improvements in the modeling of high-altitude aircraft events should have a positive effect on %TAUD results, particularly in environments where they are a dominant noise source.

The small sample size of this study makes larger conclusions about the accuracy of results for short modeling periods difficult. Low numbers of observer-log hours relative to park measurement duration for the study parks allow for variation from a single session to be amplified relative to their overall effect on the average study. Several large Parks studies were undertaken during 2010 and 2011 in Grand Canyon, Zion, and Glacier National Parks, and these could provide additional measurement and associated observation data for further study. These Dose-Response studies focused on gathering copious observer data alongside long-duration one-third octave-band measurements.[18] Additional analysis and modeling of the GCNP2007 measurements is possible as well, including off-site observer logging of the continuously recorded audio. These data could allow for a better understanding of model performance for discrete time periods and events; coupled with improvements to enroute event modeling from Pennsylvania State and Georgia Institute of Technology's research, improvements beyond the results from the proposed algorithm are possible.

Critical to developing a better understanding of model performance is the development of a verification and validation dataset. Test plans have been developed for simultaneous overflight measurements of both fixed-wing propeller and helicopter aircraft, and it may be possible to combine existing National Parks measurement datasets with corresponding commercial jet position and operational data to begin validating both time compression and long-distance propagation results.

In the meantime, the use of the proposed Time Compression algorithm for audibility analyses in AEDT and INM should be considered. The proposed algorithm will allow for immediate improvement in modeled %TAUD results. Further improvements to the models notwithstanding, the increase in accuracy provided by the proposed algorithm merit its use, specifically in National Parks analyses.

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APPENDIX A. %TAUD RESULTS, ALL AIRCRAFT EVENTS

Table 11. %TAUD results, all aircraft events, LMNRA 2004

LMNRA 2004		Existing L_{50}			Traditional L_{50}			Cumulative L_{50}			Natural L_{50}		
Site	**Ambient Time Scale**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Indian Pass	Session (11 AM – 1 PM)	100.0	74.0	66.2	100.0	82.3	74.2	100.0	89.9	82.4	100.0	98.2	94.4
	Day (7 AM – 7 PM)	100.0	89.1	81.5	100.0	97.0	92.0	100.0	98.8	95.7	100.0	99.9	99.1
Indian Pass	Session (2 PM – 4 PM)	100.0	96.8	91.8	100.0	97.9	93.8	100.0	99.8	98.4	100.0	100.0	99.7
	day (7a-7p)	100.0	97.4	92.9	100.0	99.4	97.3	100.0	99.9	99.0	100.0	100.0	99.8

Table 12. %TAUD results, all aircraft events, GRSM 2006

GRSM 2006		Existing L_{50}			Traditional L_{50}			Cumulative L_{50}			Natural L_{50}		
Site	**Ambient Time Scale**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Noland	Session (9 AM – 1 PM)	100.0	90.7	83.4	100.0	91.2	83.9	100.0	92.8	86.0	100.0	92.9	86.1
	Day (7 AM – 7 PM)	100.0	90.9	83.6	100.0	91.6	84.5	100.0	80.0	71.9	100.0	93.2	86.5
Noland	Session (2 PM – 6 PM)	62.9	52.3	46.7	64.8	53.4	47.6	69.3	56.0	50.0	71.3	57.2	51.0
	Day (7 AM – 7 PM)	62.5	52.0	46.4	64.0	52.9	47.3	69.3	56.0	50.0	71.3	57.2	51.0
Parson	Session (2:40 PM – 6:40 PM)	68.8	55.7	49.7	72.6	57.9	51.6	76.2	59.8	53.3	79.6	61.6	54.8
	Day (7 AM – 7 PM)	76.5	60.0	53.4	78.6	61.1	54.4	81.2	62.4	55.6	81.2	62.4	55.6

Table 13. %TAUD results, all aircraft events, GCNP 2007

GCNP 2007		Existing L_{50}			Traditional L_{50}			Cumulative L_{50}			Natural L_{50}		
Site	**Ambient Time Scale**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
G010	Session (2 PM – 6 PM)	61.7	51.5	46.0	61.7	51.5	46.0	61.7	51.5	46.0	61.7	51.5	46.0
	Day (7 AM – 7 PM)	61.7	51.5	46.0	61.7	51.5	46.0	61.7	51.5	46.0	61.7	51.5	46.0
G015	Session (2 PM – 6 PM)	100.0	99.5	97.5	100.0	99.5	97.5	100.0	99.5	97.5	100.0	99.5	97.5
	Day (7 AM – 7 PM)	100.0	99.5	97.5	100.0	99.5	97.5	100.0	99.5	97.5	100.0	99.5	97.5
G031	Session (2 PM – 6 PM)	100.0	95.2	89.3	100.0	100.0	99.6	100.0	100.0	99.6	100.0	100.0	99.8
	Day (7 AM – 7 PM)	100.0	96.6	91.4	100.0	100.0	99.7	100.0	100.0	99.8	100.0	100.0	99.8
G032	Session (2 PM – 6 PM)	74.2	58.7	52.3	74.2	58.7	52.3	74.2	58.7	52.3	74.2	58.7	52.3
	Day (7 AM – 7 PM)	74.2	58.7	52.3	74.2	58.7	52.3	74.2	58.7	52.3	74.2	58.7	52.3
G033	Session (2 PM – 6 PM)	86.9	65.1	58.0	86.9	65.1	58.0	86.9	65.1	58.0	86.9	65.1	58.0
	Day (7 AM – 7 PM)	86.9	65.1	58.0	86.9	65.1	58.0	86.9	65.1	58.0	86.9	65.1	58.0
G053	Session (2 PM – 6 PM)	60.7	50.9	45.5	60.7	50.9	45.5	60.7	50.9	45.5	60.7	50.9	45.5
	Day (7 AM – 7 PM)	60.7	50.9	45.5	60.7	50.9	45.5	60.7	50.9	45.5	60.7	50.9	45.5
G055	Session (2 PM – 6 PM)	100.0	100.0	99.8	100.0	100.0	99.8	100.0	100.0	99.8	100.0	100.0	99.8
	Day (7 AM – 7 PM)	100.0	100.0	99.8	100.0	100.0	99.8	100.0	100.0	99.8	100.0	100.0	99.8
G056	Session (2 PM – 6 PM)	100.0	77.3	69.3	100.0	96.1	90.7	100.0	96.1	90.7	100.0	95.6	90.0
	Day (7 AM – 7 PM)	100.0	94.0	87.6	100.0	97.6	93.2	100.0	97.9	93.9	100.0	97.9	93.8
G058	Session (2 PM – 6 PM)	100.0	100.0	99.8	100.0	100.0	99.8	100.0	100.0	99.8	100.0	100.0	99.8
	Day (7 AM – 7 PM)	100.0	100.0	99.8	100.0	100.0	99.8	100.0	100.0	99.8	100.0	100.0	99.8

APPENDIX B. %TAUD RESULTS, OVERFLIGHT EVENTS

Table 14. %TAUD results, overflight events, LMNRA 2004

LMNRA 2004		Existing L_{50}			Traditional L_{50}			Cumulative L_{50}			Natural L_{50}		
Site	**Ambient Time Scale**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Indian Pass	Session (11 AM – 1 PM)	20.6	20.3	18.6	26.8	25.8	23.5	36.4	33.7	30.5	47.9	42.3	38.0
	Day (7 AM – 7 PM)	35.1	32.7	29.6	45.0	40.3	36.2	53.9	46.5	41.6	66.7	54.5	48.6
Indian Pass	Session (2 PM – 4 PM)	100.0	73.3	65.5	100.0	78.5	70.4	100.0	86.5	78.6	100.0	93.0	86.3
	day (7a-7p)	100.0	75.0	67.1	100.0	81.0	72.9	100.0	89.2	81.7	100.0	95.2	89.4

Table 15. %TAUD results, overflight events, GRSM 2006

GRSM 2006		Existing L_{50}			Traditional L_{50}			Cumulative L_{50}			Natural L_{50}		
Site	**Ambient Time Scale**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Noland	Session (9 AM – 1 PM)	51.3	44.7	40.1	52.1	45.3	40.6	56.0	47.9	42.8	56.1	47.9	42.9
	Day (7 AM – 7 PM)	51.6	44.9	40.3	53.2	46.0	41.2	38.2	35.2	31.8	57.0	48.6	43.4
Noland	Session (2 PM – 6 PM)	53.6	46.3	41.5	55.2	47.4	42.4	59.1	49.9	44.6	60.8	51.0	45.6
	Day (7 AM – 7 PM)	53.3	46.1	41.3	54.5	46.9	42.0	59.1	49.9	44.6	60.8	51.0	45.6
Parson	Session (2:40 PM – 6:40 PM)	65.3	53.7	47.9	68.9	55.8	49.7	72.2	57.7	51.4	75.2	59.3	52.8
	Day (7 AM – 7 PM)	72.6	57.8	51.6	74.4	58.9	52.5	76.7	60.1	53.5	76.7	60.1	53.5

Table 16. %TAUD results, overflight events, GCNP 2007

GCNP 2007		Existing L_{50}			Traditional L_{50}			Cumulative L_{50}			Natural L_{50}		
Site	**Ambient Time Scale**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
G010	Session (2 PM – 6 PM)	58.9	49.7	44.5	58.9	49.7	44.5	58.9	49.7	44.5	58.9	49.7	44.5
	Day (7 AM – 7 PM)	58.9	49.7	44.5	58.9	49.7	44.5	58.9	49.7	44.5	58.9	49.7	44.5
G015	Session (2 PM – 6 PM)	76.4	59.9	53.4	76.4	59.9	53.4	76.4	59.9	53.4	76.4	59.9	53.4
	Day (7 AM – 7 PM)	76.4	59.9	53.4	76.4	59.9	53.4	76.4	59.9	53.4	76.4	59.9	53.4
G031	Session (2 PM – 6 PM)	20.8	20.5	18.7	53.0	45.9	41.1	53.0	45.9	41.1	69.8	56.3	50.2
	Day (7 AM – 7 PM)	23.7	23.1	21.1	59.9	50.4	45.0	65.6	53.8	48.1	71.0	57.0	50.8
G032	Session (2 PM – 6 PM)	37.0	34.2	30.9	37.0	34.2	30.9	37.0	34.2	30.9	37.0	34.2	30.9
	Day (7 AM – 7 PM)	37.0	34.2	30.9	37.0	34.2	30.9	37.0	34.2	30.9	37.0	34.2	30.9
G033	Session (2 PM – 6 PM)	79.2	61.4	54.7	79.2	61.4	54.7	79.2	61.4	54.7	79.2	61.4	54.7
	Day (7 AM – 7 PM)	79.2	61.4	54.7	79.2	61.4	54.7	79.2	61.4	54.7	79.2	61.4	54.7
G053	Session (2 PM – 6 PM)	58.0	49.2	44.0	58.0	49.2	44.0	58.0	49.2	44.0	58.0	49.2	44.0
	Day (7 AM – 7 PM)	58.0	49.2	44.0	58.0	49.2	44.0	58.0	49.2	44.0	58.0	49.2	44.0
G055	Session (2 PM – 6 PM)	68.6	55.6	49.6	68.6	55.6	49.6	68.6	55.6	49.6	68.6	55.6	49.6
	Day (7 AM – 7 PM)	68.6	55.6	49.6	68.6	55.6	49.6	68.6	55.6	49.6	68.6	55.6	49.6
G056	Session (2 PM – 6 PM)	51.8	45.1	40.4	58.3	49.4	44.2	58.3	49.4	44.2	57.9	49.1	43.9
	Day (7 AM – 7 PM)	55.0	47.3	42.3	62.2	51.8	46.3	63.3	52.5	46.9	63.0	52.3	46.7
G058	Session (2 PM – 6 PM)	68.5	55.6	49.6	68.5	55.6	49.6	68.5	55.6	49.6	68.5	55.6	49.6
	Day (7 AM – 7 PM)	68.5	55.6	49.6	68.5	55.6	49.6	68.5	55.6	49.6	68.5	55.6	49.6

APPENDIX C. DIFFERENCE IN %TAUD (MODELED- MEASURED), ALL AIRCRAFT EVENTS

Table 17. %TAUD results (modeled – measured), all aircraft events, LMNRA 2004

LMNRA 2004		Existing L_{50}			Traditional L_{50}			Cumulative L_{50}			Natural L_{50}		
Site	**Ambient Time Scale**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Indian Pass	Session (11 AM – 1 PM)	32.6	6.6	-1.2	32.6	14.9	6.8	32.6	22.5	15.0	32.6	30.8	27.0
	Day (7 AM – 7 PM)	32.6	21.7	14.1	32.6	29.6	24.6	32.6	31.4	28.3	32.6	32.5	31.7
Indian Pass	Session (2 PM – 4 PM)	40.1	36.9	31.9	40.1	38.0	33.9	40.1	39.9	38.5	40.1	40.1	39.8
	day (7a-7p)	40.1	37.5	33.0	40.1	39.5	37.4	40.1	40.0	39.1	40.1	40.1	39.9

Table 18. %TAUD results (modeled – measured), all aircraft events, GRSM 2006

GRSM 2006		Existing L_{50}			Traditional L_{50}			Cumulative L_{50}			Natural L_{50}		
Site	**Ambient Time Scale**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Noland	Session (9 AM – 1 PM)	51.4	42.1	34.8	51.4	42.6	35.3	51.4	44.2	37.4	51.4	44.3	37.5
	Day (7 AM – 7 PM)	51.4	42.3	35.0	51.4	43.0	35.9	51.4	31.4	23.3	51.4	44.6	37.9
Noland	Session (2 PM – 6 PM)	18.7	8.1	2.5	20.6	9.2	3.4	25.1	11.8	5.8	27.1	13.0	6.8
	Day (7 AM – 7 PM)	18.3	7.8	2.2	19.8	8.7	3.1	25.1	11.8	5.8	27.1	13.0	6.8
Parson	Session (2:40 PM – 6:40 PM)	17.2	4.1	-1.9	21.0	6.3	0.0	24.6	8.2	1.7	28.0	10.0	3.2
	Day (7 AM – 7 PM)	24.9	8.4	1.8	27.0	9.5	2.8	29.6	10.8	4.0	29.6	10.8	4.0

Table 19. %TAUD results (modeled – measured), all aircraft events, GCNP 2007

GCNP 2007		Existing L_{50}			Traditional L_{50}			Cumulative L_{50}			Natural L_{50}		
Site	**Ambient Time Scale**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
G010	Session (2 PM – 6 PM)	40.0	29.8	24.3	40.0	29.8	24.3	40.0	29.8	24.3	40.0	29.8	24.3
	Day (7 AM – 7 PM)	40.0	29.8	24.3	40.0	29.8	24.3	40.0	29.8	24.3	40.0	29.8	24.3
G015	Session (2 PM – 6 PM)	40.1	39.6	37.6	40.1	39.6	37.6	40.1	39.6	37.6	40.1	39.6	37.6
	Day (7 AM – 7 PM)	40.1	39.6	37.6	40.1	39.6	37.6	40.1	39.6	37.6	40.1	39.6	37.6
G031	Session (2 PM – 6 PM)	11.7	6.9	1.0	11.7	11.7	11.3	11.7	11.7	11.3	11.7	11.7	11.5
	Day (7 AM – 7 PM)	11.7	8.3	3.1	11.7	11.7	11.4	11.7	11.7	11.5	11.7	11.7	11.5
G032	Session (2 PM – 6 PM)	40.0	24.5	18.1	40.0	24.5	18.1	40.0	24.5	18.1	40.0	24.5	18.1
	Day (7 AM – 7 PM)	40.0	24.5	18.1	40.0	24.5	18.1	40.0	24.5	18.1	40.0	24.5	18.1
G033	Session (2 PM – 6 PM)	56.9	35.1	28.0	56.9	35.1	28.0	56.9	35.1	28.0	56.9	35.1	28.0
	Day (7 AM – 7 PM)	56.9	35.1	28.0	56.9	35.1	28.0	56.9	35.1	28.0	56.9	35.1	28.0
G053	Session (2 PM – 6 PM)	46.6	36.8	31.4	46.6	36.8	31.4	46.6	36.8	31.4	46.6	36.8	31.4
	Day (7 AM – 7 PM)	46.6	36.8	31.4	46.6	36.8	31.4	46.6	36.8	31.4	46.6	36.8	31.4
G055	Session (2 PM – 6 PM)	8.3	8.3	8.1	8.3	8.3	8.1	8.3	8.3	8.1	8.3	8.3	8.1
	Day (7 AM – 7 PM)	8.3	8.3	8.1	8.3	8.3	8.1	8.3	8.3	8.1	8.3	8.3	8.1
G056	Session (2 PM – 6 PM)	69.2	46.5	38.5	69.2	65.3	59.9	69.2	65.3	59.9	69.2	64.8	59.2
	Day (7 AM – 7 PM)	69.2	63.2	56.8	69.2	66.8	62.4	69.2	67.1	63.1	69.2	67.1	63.0
G058	Session (2 PM – 6 PM)	7.5	7.5	7.3	7.5	7.5	7.3	7.5	7.5	7.3	7.5	7.5	7.3
	Day (7 AM – 7 PM)	7.5	7.5	7.3	7.5	7.5	7.3	7.5	7.5	7.3	7.5	7.5	7.3

APPENDIX D. DIFFERENCE IN %TAUD (MODELED- MEASURED), OVERFLIGHT EVENTS

Table 20. %TAUD results (modeled – measured), overflight events, LMNRA 2004

LMNRA 2004		Existing L_{50}			Traditional L_{50}			Cumulative L_{50}			Natural L_{50}		
Site	**Ambient Time Scale**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Indian Pass	Session (11 AM – 1 PM)	-19.7	-20.0	-21.7	-13.5	-14.5	-16.8	-3.9	-6.6	-9.8	7.6	2.0	-2.3
	Day (7 AM – 7 PM)	-5.2	-7.6	-10.7	4.7	0.0	-4.1	13.6	6.2	1.3	26.4	14.2	8.3
Indian Pass	Session (2 PM – 4 PM)	65.9	39.2	31.4	65.9	44.4	36.3	65.9	52.4	44.5	65.9	58.9	52.2
	day (7a-7p)	65.9	40.9	33.0	65.9	46.9	38.8	65.9	55.1	47.6	65.9	61.1	55.3

Table 21. %TAUD results (modeled – measured), overflight events, GRSM 2006

GRSM 2006		Existing L_{50}			Traditional L_{50}			Cumulative L_{50}			Natural L_{50}		
Site	**Ambient Time Scale**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Noland	Session (9 AM – 1 PM)	14.3	7.7	3.1	15.1	8.3	3.6	19.0	10.9	5.8	19.1	10.9	5.9
	Day (7 AM – 7 PM)	14.6	7.9	3.3	16.2	9.0	4.2	1.2	-1.8	-5.2	20.0	11.6	6.4
Noland	Session (2 PM – 6 PM)	27.3	20.0	15.2	28.9	21.1	16.1	32.8	23.6	18.3	34.5	24.7	19.3
	Day (7 AM – 7 PM)	27.0	19.8	15.0	28.2	20.6	15.7	32.8	23.6	18.3	34.5	24.7	19.3
Parson	Session (2:40 PM – 6:40 PM)	27.9	16.3	10.5	31.5	18.4	12.3	34.8	20.3	14.0	37.8	21.9	15.4
	Day (7 AM – 7 PM)	35.2	20.4	14.2	37.0	21.5	15.1	39.3	22.7	16.1	39.3	22.7	16.1

Table 22. %TAUD results (modeled – measured), overflight events, GCNP 2007

GCNP 2007		Existing L_{50}			Traditional L_{50}			Cumulative L_{50}			Natural L_{50}		
Site	**Ambient Time Scale**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
G010	Session (2 PM – 6 PM)	43.9	34.7	29.5	43.9	34.7	29.5	43.9	34.7	29.5	43.9	34.7	29.5
	Day (7 AM – 7 PM)	43.9	34.7	29.5	43.9	34.7	29.5	43.9	34.7	29.5	43.9	34.7	29.5
G015	Session (2 PM – 6 PM)	49.7	33.2	26.7	49.7	33.2	26.7	49.7	33.2	26.7	49.7	33.2	26.7
	Day (7 AM – 7 PM)	49.7	33.2	26.7	49.7	33.2	26.7	49.7	33.2	26.7	49.7	33.2	26.7
G031	Session (2 PM – 6 PM)	16.6	16.3	14.5	48.8	41.7	36.9	48.8	41.7	36.9	65.6	52.1	46.0
	Day (7 AM – 7 PM)	19.5	18.9	16.9	55.7	46.2	40.8	61.4	49.6	43.9	66.8	52.8	46.6
G032	Session (2 PM – 6 PM)	23.7	20.9	17.6	23.7	20.9	17.6	23.7	20.9	17.6	23.7	20.9	17.6
	Day (7 AM – 7 PM)	23.7	20.9	17.6	23.7	20.9	17.6	23.7	20.9	17.6	23.7	20.9	17.6
G033	Session (2 PM – 6 PM)	55.0	37.2	30.5	55.0	37.2	30.5	55.0	37.2	30.5	55.0	37.2	30.5
	Day (7 AM – 7 PM)	55.0	37.2	30.5	55.0	37.2	30.5	55.0	37.2	30.5	55.0	37.2	30.5
G053	Session (2 PM – 6 PM)	51.3	42.5	37.3	51.3	42.5	37.3	51.3	42.5	37.3	51.3	42.5	37.3
	Day (7 AM – 7 PM)	51.3	42.5	37.3	51.3	42.5	37.3	51.3	42.5	37.3	51.3	42.5	37.3
G055	Session (2 PM – 6 PM)	60.3	47.3	41.3	60.3	47.3	41.3	60.3	47.3	41.3	60.3	47.3	41.3
	Day (7 AM – 7 PM)	60.3	47.3	41.3	60.3	47.3	41.3	60.3	47.3	41.3	60.3	47.3	41.3
G056	Session (2 PM – 6 PM)	49.3	42.6	37.9	55.8	46.9	41.7	55.8	46.9	41.7	55.4	46.6	41.4
	Day (7 AM – 7 PM)	52.5	44.8	39.8	59.7	49.3	43.8	60.8	50.0	44.4	60.5	49.8	44.2
G058	Session (2 PM – 6 PM)	63.5	50.6	44.6	63.5	50.6	44.6	63.5	50.6	44.6	63.5	50.6	44.6
	Day (7 AM – 7 PM)	63.5	50.6	44.6	63.5	50.6	44.6	63.5	50.6	44.6	63.5	50.6	44.6

APPENDIX E. DIFFERENCE IN %TAUD (STUDY-LONG – SESSION OR DAYLONG AMBIENT), TRADITIONAL AMBIENT, ALL AIRCRAFT EVENTS

Table 23. %TAUD results (study-long – session or daylong ambient), all aircraft, LMNRA 2004

LMNRA 2004		Existing L_{50}			Traditional L_{50}			Cumulative L_{50}			Natural L_{50}		
Site	**Ambient Time Scale**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Indian Pass	Session (11 AM – 1 PM)	-19.7	-20.0	-21.7	-13.5	-14.5	-16.8	-3.9	-6.6	-9.8	7.6	2.0	-2.3
	Day (7 AM – 7 PM)	-5.2	-7.6	-10.7	4.7	0.0	-4.1	13.6	6.2	1.3	26.4	14.2	8.3
Indian Pass	Session (2 PM – 4 PM)	65.9	39.2	31.4	65.9	44.4	36.3	65.9	52.4	44.5	65.9	58.9	52.2
	day (7a-7p)	65.9	40.9	33.0	65.9	46.9	38.8	65.9	55.1	47.6	65.9	61.1	55.3

Table 24. %TAUD results (study-long – session or daylong ambient), all aircraft, GRSM 2006

GRSM 2006		Existing L_{50}			Traditional L_{50}			Cumulative L_{50}			Natural L_{50}		
Site	**Ambient Time Scale**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Noland	Session (9 AM – 1 PM)	14.3	7.7	3.1	15.1	8.3	3.6	19.0	10.9	5.8	19.1	10.9	5.9
	Day (7 AM – 7 PM)	14.6	7.9	3.3	16.2	9.0	4.2	1.2	-1.8	-5.2	20.0	11.6	6.4
Noland	Session (2 PM – 6 PM)	27.3	20.0	15.2	28.9	21.1	16.1	32.8	23.6	18.3	34.5	24.7	19.3
	Day (7 AM – 7 PM)	27.0	19.8	15.0	28.2	20.6	15.7	32.8	23.6	18.3	34.5	24.7	19.3
Parson	Session (2:40 PM – 6:40 PM)	27.9	16.3	10.5	31.5	18.4	12.3	34.8	20.3	14.0	37.8	21.9	15.4
	Day (7 AM – 7 PM)	35.2	20.4	14.2	37.0	21.5	15.1	39.3	22.7	16.1	39.3	22.7	16.1

Table 25. %TAUD results (study-long – session or daylong ambient), all aircraft, GCNP 2007

GCNP 2007		Existing L_{50}			Traditional L_{50}			Cumulative L_{50}			Natural L_{50}		
Site	**Ambient Time Scale**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
G010	Session (2 PM – 6 PM)	43.9	34.7	29.5	43.9	34.7	29.5	43.9	34.7	29.5	43.9	34.7	29.5
	Day (7 AM – 7 PM)	43.9	34.7	29.5	43.9	34.7	29.5	43.9	34.7	29.5	43.9	34.7	29.5
G015	Session (2 PM – 6 PM)	49.7	33.2	26.7	49.7	33.2	26.7	49.7	33.2	26.7	49.7	33.2	26.7
	Day (7 AM – 7 PM)	49.7	33.2	26.7	49.7	33.2	26.7	49.7	33.2	26.7	49.7	33.2	26.7
G031	Session (2 PM – 6 PM)	16.6	16.3	14.5	48.8	41.7	36.9	48.8	41.7	36.9	65.6	52.1	46.0
	Day (7 AM – 7 PM)	19.5	18.9	16.9	55.7	46.2	40.8	61.4	49.6	43.9	66.8	52.8	46.6
G032	Session (2 PM – 6 PM)	23.7	20.9	17.6	23.7	20.9	17.6	23.7	20.9	17.6	23.7	20.9	17.6
	Day (7 AM – 7 PM)	23.7	20.9	17.6	23.7	20.9	17.6	23.7	20.9	17.6	23.7	20.9	17.6
G033	Session (2 PM – 6 PM)	55.0	37.2	30.5	55.0	37.2	30.5	55.0	37.2	30.5	55.0	37.2	30.5
	Day (7 AM – 7 PM)	55.0	37.2	30.5	55.0	37.2	30.5	55.0	37.2	30.5	55.0	37.2	30.5
G053	Session (2 PM – 6 PM)	51.3	42.5	37.3	51.3	42.5	37.3	51.3	42.5	37.3	51.3	42.5	37.3
	Day (7 AM – 7 PM)	51.3	42.5	37.3	51.3	42.5	37.3	51.3	42.5	37.3	51.3	42.5	37.3
G055	Session (2 PM – 6 PM)	60.3	47.3	41.3	60.3	47.3	41.3	60.3	47.3	41.3	60.3	47.3	41.3
	Day (7 AM – 7 PM)	60.3	47.3	41.3	60.3	47.3	41.3	60.3	47.3	41.3	60.3	47.3	41.3
G056	Session (2 PM – 6 PM)	49.3	42.6	37.9	55.8	46.9	41.7	55.8	46.9	41.7	55.4	46.6	41.4
	Day (7 AM – 7 PM)	52.5	44.8	39.8	59.7	49.3	43.8	60.8	50.0	44.4	60.5	49.8	44.2
G058	Session (2 PM – 6 PM)	63.5	50.6	44.6	63.5	50.6	44.6	63.5	50.6	44.6	63.5	50.6	44.6
	Day (7 AM – 7 PM)	63.5	50.6	44.6	63.5	50.6	44.6	63.5	50.6	44.6	63.5	50.6	44.6

APPENDIX F. DIFFERENCE IN %TAUD (STUDYLONG – SESSION OR DAYLONG AMBIENT), TRADITIONAL AMBIENT, OVERFLIGHT EVENTS

Table 26. %TAUD results (study-long – session or daylong ambient), overflight events, LMNRA 2004

LMNRA 2004		Existing L_{50}			Traditional L_{50}			Cumulative L_{50}			Natural L_{50}		
Site	**Ambient Time Scale**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Indian Pass	Session (11 AM – 1 PM)	-19.7	-20.0	-21.7	-13.5	-14.5	-16.8	-3.9	-6.6	-9.8	7.6	2.0	-2.3
	Day (7 AM – 7 PM)	-5.2	-7.6	-10.7	4.7	0.0	-4.1	13.6	6.2	1.3	26.4	14.2	8.3
Indian Pass	Session (2 PM – 4 PM)	65.9	39.2	31.4	65.9	44.4	36.3	65.9	52.4	44.5	65.9	58.9	52.2
	day (7a-7p)	65.9	40.9	33.0	65.9	46.9	38.8	65.9	55.1	47.6	65.9	61.1	55.3

Table 27. %TAUD results (study-long – session or daylong ambient), overflight events, GRSM 2006

GRSM 2006		Existing L_{50}			Traditional L_{50}			Cumulative L_{50}			Natural L_{50}		
Site	**Ambient Time Scale**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Noland	Session (9 AM – 1 PM)	14.3	7.7	3.1	15.1	8.3	3.6	19.0	10.9	5.8	19.1	10.9	5.9
	Day (7 AM – 7 PM)	14.6	7.9	3.3	16.2	9.0	4.2	1.2	-1.8	-5.2	20.0	11.6	6.4
Noland	Session (2 PM – 6 PM)	27.3	20.0	15.2	28.9	21.1	16.1	32.8	23.6	18.3	34.5	24.7	19.3
	Day (7 AM – 7 PM)	27.0	19.8	15.0	28.2	20.6	15.7	32.8	23.6	18.3	34.5	24.7	19.3
Parson	Session (2:40 PM – 6:40 PM)	27.9	16.3	10.5	31.5	18.4	12.3	34.8	20.3	14.0	37.8	21.9	15.4
	Day (7 AM – 7 PM)	35.2	20.4	14.2	37.0	21.5	15.1	39.3	22.7	16.1	39.3	22.7	16.1

Table 28. %TAUD results (study-long – session or daylong ambient), overflight events, GCNP 2007

GCNP 2007		Existing L_{50}			Traditional L_{50}			Cumulative L_{50}			Natural L_{50}		
Site	**Ambient Time Scale**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
G010	Session (2 PM – 6 PM)	43.9	34.7	29.5	43.9	34.7	29.5	43.9	34.7	29.5	43.9	34.7	29.5
	Day (7 AM – 7 PM)	43.9	34.7	29.5	43.9	34.7	29.5	43.9	34.7	29.5	43.9	34.7	29.5
G015	Session (2 PM – 6 PM)	49.7	33.2	26.7	49.7	33.2	26.7	49.7	33.2	26.7	49.7	33.2	26.7
	Day (7 AM – 7 PM)	49.7	33.2	26.7	49.7	33.2	26.7	49.7	33.2	26.7	49.7	33.2	26.7
G031	Session (2 PM – 6 PM)	16.6	16.3	14.5	48.8	41.7	36.9	48.8	41.7	36.9	65.6	52.1	46.0
	Day (7 AM – 7 PM)	19.5	18.9	16.9	55.7	46.2	40.8	61.4	49.6	43.9	66.8	52.8	46.6
G032	Session (2 PM – 6 PM)	23.7	20.9	17.6	23.7	20.9	17.6	23.7	20.9	17.6	23.7	20.9	17.6
	Day (7 AM – 7 PM)	23.7	20.9	17.6	23.7	20.9	17.6	23.7	20.9	17.6	23.7	20.9	17.6
G033	Session (2 PM – 6 PM)	55.0	37.2	30.5	55.0	37.2	30.5	55.0	37.2	30.5	55.0	37.2	30.5
	Day (7 AM – 7 PM)	55.0	37.2	30.5	55.0	37.2	30.5	55.0	37.2	30.5	55.0	37.2	30.5
G053	Session (2 PM – 6 PM)	51.3	42.5	37.3	51.3	42.5	37.3	51.3	42.5	37.3	51.3	42.5	37.3
	Day (7 AM – 7 PM)	51.3	42.5	37.3	51.3	42.5	37.3	51.3	42.5	37.3	51.3	42.5	37.3
G055	Session (2 PM – 6 PM)	60.3	47.3	41.3	60.3	47.3	41.3	60.3	47.3	41.3	60.3	47.3	41.3
	Day (7 AM – 7 PM)	60.3	47.3	41.3	60.3	47.3	41.3	60.3	47.3	41.3	60.3	47.3	41.3
G056	Session (2 PM – 6 PM)	49.3	42.6	37.9	55.8	46.9	41.7	55.8	46.9	41.7	55.4	46.6	41.4
	Day (7 AM – 7 PM)	52.5	44.8	39.8	59.7	49.3	43.8	60.8	50.0	44.4	60.5	49.8	44.2
G058	Session (2 PM – 6 PM)	63.5	50.6	44.6	63.5	50.6	44.6	63.5	50.6	44.6	63.5	50.6	44.6
	Day (7 AM – 7 PM)	63.5	50.6	44.6	63.5	50.6	44.6	63.5	50.6	44.6	63.5	50.6	44.6

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