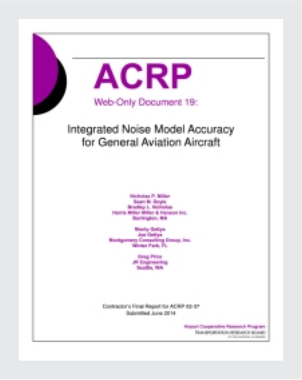

Integrated Noise Model Accuracy for General Aviation Aircraft

DETAILS

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Contents

List of Figures

List of Tables

1 Study Overview and Conclusions

1.1 Goals

The original goals of the project were four:

- Assess INM Accuracy for General Aviation (GA) Aircraft – How well do INM calculated values of GA aircraft SEL values match measured SEL for selected types of GA aircraft? [1]
- Identify Causes of Discrepancies – When INM calculated SEL do not agree with measured values, what are the likely causes of these discrepancies?
- Identify Potential Solutions – Having identified likely causes of discrepancies, what solutions can be developed generally for GA aircraft that will minimize inaccuracies of modeled results?
- Identify Implementation Steps – How should the solutions be implemented

1.2 Approach

This final report addresses all goals. Section 3 identifies the total sample of aircraft from which specific aircraft would be selected for detailed analysis. Section 4 uses national flight operations data and aircraft certification levels to compute the discrepancies for each aircraft of the total sample – how much the INM computed Sound Exposure Level of each aircraft differed from that measured by permanent noise monitoring systems at six airports. Section 5 uses the discrepancies to rank-order the aircraft and to identify those that, if realistically modeled in the INM would most improve DNL computations across most airports. Section 6 selected the most important aircraft to examine in detail, and Section 7 described the analysis that identified the causes of error. Section 8 offers and tests two solutions that will correct the GA jet departure profiles and, for the tests, eliminates the errors of the INM modeling. Section 9 describes two approaches that could be used to apply the findings of this study to the GA jet INM database and suggests a single approach. Section 9 also describes approaches and estimated costs for the two approaches. Section 2 describes the state of the practice of modeling GA aircraft through a literature search and a survey of INM users.

1.3 Results

1.3.1 General

The analysis focused on INM accuracy in modeling operations of GA jets. The study compared INM produced sound exposure levels and climb profiles with measured sound exposure levels and radar reported climb profiles. Modeled jet departures have discrepancies much more significant the modeled arrivals. The over-riding source of error in the INM modeling of GA jet aircraft departures is use of maximum takeoff thrust in the INM rather than the commonly used derated thrust, generally referred to as the "Assumed Temperature Method," ATM. The report offers in Section 8 two primary solutions to producing the ATM departure for a jet aircraft. A first (called ATM1) is to use manufacturer provided reduced thrust departure data, possibly supplemented with operator information. The preferred data are revised coefficients for the INM-internal performance computation equation (see Equation 1, page 53). Alternative data would include start of takeoff thrust, together with altitudes and amount of changes to

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[1] SEL is a measure of the total sound energy of a single flyover. It is the basis for computation of DNL. Hence, if the modeled SELs for important aircraft types equal, on average, the SEL of the measurements, then modeled DNL will be an accurate representation of the actual noise exposure, assuming other variables, such as number of operations, flight tracks and runway utilization are realistic.

climb thrust which are then used to modify INM departure data. With this approach, it is desirable to have empirical radar climb data and, if possible, noise monitoring data to verify correct modeling of these changed profiles. Section 8 describes this process in detail and successfully applies it to two aircraft: GIV and LEAR35.

A second approach (ATM2) is to use the INM directly to develop the ATM departure profile. The approach mimics that used by pilots to select a derated thrust appropriate for a given airport and runway and uses the physics built into the INM. For a specific aircraft, the INM is run at a higher temperature (the assumed temperature) than that used for modeling the airport. (The pilot uses the runway length to determine a derated thrust that produces the maximum safe length of takeoff roll for the runway; the INM uses the assumed temperature to compute the length of takeoff roll.) The resulting fixed profile point procedure is then run again in the INM as a user defined profile at the airport's modeled temperature (usually an annual average). Radar data would be useful here as well for verification. For modeling, absent radar data, the actual length of takeoff roll used at the airport can be used to compare with the length computed at the assumed temperature. Iterations of the assumed temperature will be required until the modeled takeoff roll matches the actual roll length. This approach was applied successfully to three aircraft: GIV, LEAR35, and the CNA560E.

1.3.2 Specific

Sources of discrepancies in INM modeled GA jet departure sound levels are of two related types. The discrepancy is due to INM thrust values that are significantly different from thrust used, and this incorrect thrust in turn not only causes the noise produced to be incorrect, but creates an altitude climb profile that is, for almost all GA jets analyzed, higher than the reality as reported by radar data. These two effects of too high sound levels and too high altitudes interact, and result in the INM produced sound level generally being higher than measured, but it may also be equal to or lower than measured. Higher INM thrust means higher sound level while higher altitude means lower sound level. Thus correcting discrepancies is a balance between lowering thrust and lowering altitude in the INM to match measured data.

In this study, GA aircraft were first selected for determining discrepancies using the contribution of each aircraft type to total fleet noise. Aircraft that contributed at least 1% of the total fleet noise were identified, Section 3.4. Section 4 describes how discrepancies were determined and Section 5 gives the discrepancies in decibel effect relative to measured results. Section 6 rank-orders the aircraft in terms of contribution to fleet-wide discrepancies and identifies the ten jet aircraft types most important to correct for modeling accurate departure fleet noise (Figure 5) and for modeling accurate arrival fleet noise (Figure 6). Correcting the ten jet aircraft departures would improve fleet departure noise accuracy by up to 2.5 dB and correcting the 5 arrival aircraft would improve fleet arrival noise by up to 1 dB. Section 7 examines three of the ten jet departure aircraft types and three of the five arrival aircraft to determine the details of the causes of the errors, and to suggest solutions. Because the departures result in the most significant errors, and have the greatest potential for improving INM accuracy, the remainder of the analysis focuses on solutions for the departure types.

Through conversations and information from pilots and working with Gulfstream staff, incorporation of Assumed Temperature Method (ATM) departures was identified as the proper solution for correcting the departure discrepancies. Sufficient information was collected on the Gulfstream 4, the Lear 35 and the Cessna Citation 550[2] to test two ATM methods that could be used to provide corrected input into the

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[2] The report notes that both Cessna pilot data and communications with the Cessna manufacturer indicated that Cessna does not use reduced power departures. The radar data however, when compared with the INM standard maximum power takeoff profile, show a more gradual climb profile. The ATM procedure as tested with the INM in Section 8 and shown in Figure 30 resulted in a match of both profile and noise levels with the measured data.

INM. The two ATM methods, ATM1 and ATM2, described briefly above in Section 1.3.1and in detail in Section 8 both show promise, but this study recommends that ATM2 be implemented as a modeling procedure for INM users, Section 9. It requires less information than ATM1, uses the strengths of the INM (proper physics including aircraft departure performance response to changes in temperature and altitude), and the information that is required (typical length of takeoff roll at the airport) can be acquired at the airport being modeled.

ATM1 requires a detailed and lengthy effort, contacting the manufacturers of each of the ten important aircraft types, six of which are no longer manufactured, or surveying pilots of each aircraft type to determine use of thrust settings on departure, locations / altitudes of cutbacks, and generally full development of either the INM equation coefficients, or a universal standard profile to be applied nationally to all GA jet operations of the ten aircraft types. The most efficient would be if manufacturers could provide the necessary equation coefficients. Then modeling the derated thrust departures would be a process similar to modeling the standard maximum thrust departures. This study's experience of developing and applying ATM1 leads to the conclusion that the costs of development including the need to find methods for validating the profiles suggest the simpler ATM2 is the best method to implement.

ATM2 implementation is recommended to be a procedure followed by an INM modeler. The procedure will guide the modeler through the steps of using the INM to produce the assumed temperature (derated thrust) takeoff procedure. The procedure will reference specific files in the INM that provide the data for input into the final modeling of the airport. As suggested above, the procedure will direct the user to choose an assumed temperature for the aircraft, run the INM for that temperature, identify the resultant profile points, input them into the INM and run at the temperature appropriate for the airport. In the INM files from this second run, the modeler will find the takeoff roll length that results and compare that length with actual lengths of takeoffs at the airport. If the INM length is not within an identified margin of error of the actual length, the user will change the temperature (increase if the modeled length is too short, decrease if the modeled length is too long) and repeat the process until an acceptable modeled takeoff roll length is found.

Development of the ATM2 procedure will first require testing that procedure on the remaining seven identified aircraft types, the other three having been tested as described in Section 8.2.2. In these tests, altitude and sound level will be compared with the radar and sound monitoring data available from the present study. The goal is to further validate the procedure and, most importantly, identify any issues with the noise database for each aircraft. As described in Section 8.3, the ATM tests on the Lear 35 showed that, almost certainly, the incorrect engine type was being used for that aircraft in the INM database. If such is the case for any of the other aircraft types, the issue needs to be corrected if a viable ATM2 procedure is to be provided to INM users.

1.3.3 Conclusions

Discrepancies in INM modeling of GA jets result of over-estimation of average fleet departure noise exposure by about 3 dB and of arrival noise exposure by about 1 ¼ dB. Correction of the INM inputs of ten jet departures will eliminate about 2 ½ dB of the departure discrepancy and correction of five jet arrivals will eliminate about 1 dB of the arrival discrepancy.

The analysis focuses on correcting the GA jet departure procedures. Two identified methods, ATM1 and ATM2, based on actual pilot procedures for conducting reduced thrust departures, are described and tested. Though both result in realistic departure profiles and sound levels, ATM1 requires involvement with manufacturers and possibly pilots and will be time consuming to develop, the other, ATM2, uses the INM to produce the best departure profile by choosing a correct temperature adjustment.

Though many factors other than use of thrust can affect aircraft departure operations and hence climb rates and sound levels, it is the use of thrust that has the most effect in performance. Use of flaps, drag coefficient, airspeed, aircraft weight and pressure altitude all can affect performance. However, these factors have generally been included in the INM computations, and using the ATM2 procedure takes full advantage of these factors to the extent they are included in the INM. Further, errors in these other factors have minimal effect on computed results.[3]

A final note is that commercial jet departure operations commonly use reduced or derated thrust. Two other ACRP studies, 02-55, Enhanced AEDT Modeling of Aircraft Arrival and Departure Profiles, and 02-41, Estimating Takeoff Thrust Settings for Airport Emissions Inventories, are examining current takeoff thrust procedures. Eventually, some standardization across all jet aircraft reduced thrust departures could be thought desirable, though from the findings of this study, the possibility of consistency is judged remote. Commercial jet aircraft continuously record all engine and flight parameters, providing the types of data pursued in this study. GA jets rarely have on-board equipment to record such data, and hence the techniques for developing appropriate departure profiles will for the foreseeable future be very different for GA jets and commercial jets.

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[3] A sensitivity analysis of Equation 1 showed possible variations in the speed and altitude had little effect on total thrust.

2 State of the Practice: How are GA Aircraft Being Modeled?

This state of the practice section documents the results of two efforts to determine current noise modeling practice for GA aircraft: Section 2.1a literature search; Section 2.2a web-based survey of Integrated Noise Model (INM) users. Harris Miller Miller & Hanson Inc. (HMMH) completed the literature review, and HMMH and Montgomery Consulting Group (MCG) worked together to produce and distribute the survey and summarize the results.

2.1 Literature Review

The literature review was a broad search of published information to identify additional data on the noise levels produced by GA aircraft or on how GA aircraft noise is modeled. The search yielded eight published articles or reports, which provided limited information useful for the analysis of the modeling of noise generated by GA aircraft. The following paragraphs summarize these publications and their potential utility for this project. The ***bold italic text*** at the end of each summary gives the usefulness of the information to this project. Documents reviewed are listed in Appendix A.

2.1.1 “Review of Integrated Noise Model (INM) Equations and Processes”

Forsyth, D.W., *NASA/CR-2003-212414,* May 2003

The FAA's Integrated Noise Model (INM) relies on the methods of the SAE AIR-1845 "Procedure for the Calculation of Airplane Noise in the Vicinity of Airports" issued in 1986. Simplifying assumptions for aerodynamics and noise calculation were made in the SAE standard and the INM. One the objectives of this study of interest to modeling GA aircraft was the test of some of the simplified assumptions against Boeing source data, but the testing was related to variations in only weight, atmospheric conditions and flap retraction schedule. Generally, the INM equation A1 assumptions appear to predict the corrected net thrust to ±2% of Boeing determined performance. It must be said, however, that the report assumes the reader has an in-depth understanding of engine performance and provides more information than can easily be summarized here. ***For the current study, when we examine modifying aircraft coefficients, the results suggest only that the form of equation A1 of SAE AIR-1845 is reasonable and that aircraft weight and flap retraction should be considered for alteration (if physically reasonable).***

2.1.2 “Assessment of Tools for Modeling Aircraft Noise in the National Parks”

Fleming, G.G., K.J. Plotkin, C.J. Roof, B.J. Ikelheimer, D.A. Senzig, FICAN, March 18, 2005

Because the main aircraft types of concern in the National Parks context are tour aircraft, this study might have suggested useful modeling issues to include. The first objective of the study was to evaluate the performance of two aircraft noise models, the FAA’s INM and NMSim (a model evolved from a study for the NATO Committee on the Challenges of Modern Society) for modeling the noise produced by tour aircraft over national parks. A second objective was to examine the usability of each model, i.e., ease of operation, runtime, data input / output availability, etc. Because high altitude jet aircraft also produce noise audible in parks, field measurements of some of these overflights were also conducted and are reported in appendices. ***In general, the study focuses on comparing calculations of audibility over long distances for propeller and rotary wing aircraft of the type used for air tours. None of these comparisons are judged applicable to the present assessment of INM accuracy in computing standard noise metrics for GA aircraft in the vicinity of airports.***

2.1.3 “Fitchburg Municipal Airport Noise Measurement Study: Summary of Measurements, Data and Analysis”

Reherman, C.N., C.L. Roof, G.G. Fleming, D.A. Senzig, D.R. Read, C.S.Y. Lee, DOT-VNTSC-FAA-03-09, November 2005

This document reports on the measurement and analysis of the noise produced by six aircraft: Maule M-7-235C, Piper Twin Comanche PA-30, Piper Navajo Chieftain PA-31-350, Piper Warrior PA-28-161, Beech 1900D, Eurocopter EC-130 Helicopter, and the Robinson R-22 Helicopter. It describes the planning and execution of the measurements made at Fitchburg Municipal Airport in Fitchburg, Massachusetts. Additionally, the data reduction procedures and data adjusted to standard conditions are presented. These aircraft, with the possible exception of the Beech 1900D are unlikely to be in the list of GA aircraft proposed for evaluation – they are unlikely to be significant contributors to GA aircraft produced noise exposure because we expect the GA jets to dominate noise exposure wherever they operate. Appendix A of the report includes a clear description of the calculation of INM coefficients for the 1900D using the measured and the manufacturer supplied data. ***The information contained in this reference for the Beech 1900D aircraft, should there be sufficient noise data from the monitoring systems / airports used in this INM GA aircraft accuracy study could provide a check on the potential errors in our determination of discrepancies.***

2.1.4 “Integrated Noise Model (INM) Noise Contour Comparison: Version 7.0 vs. 6.2a”

He, B., R. Cointin, E. Boeker, E. Dinges, C. Roof, FAA-AEE-07-01, October 2007

This report was intended to provide a general sense of noise level changes expected by using INM version 7.0 rather than previous version 6.2a. Four different airport studies were run, modifying, one at a time, terrain effects, lateral attenuation and bank angle as implemented in 7.0. One of the four was a “Large GA” airport, likely with the noise dominated by jets. Each was run with variations in headwind component and temperature. Results were examined in terms of DNL contours and their areas and LAMAX. Interestingly, the changes in contour area were, for most of the cases, greatest for the Large GA airport. No rigorous analysis was conducted, however, to isolate specific reasons for any changes, but the report suggests that the change in lateral attenuation is the dominant factor affecting the increase in DNL contours. We note that lateral attenuation is built into INM and is generic by aircraft type – e.g., for under-wing or for fuselage mounted engines. It is our intention to explore only the aircraft specific variables, and not the general means by which the INM uses those specifics in the computation of noise exposure. ***The information provided in this reference is judged non-applicable to the present assessment of INM accuracy in computing standard noise metrics for GA aircraft in the vicinity of airports***.

2.1.5 “Sensitivity of the FAA integrated noise model to input parameters”

Gaja, E., G. Clemente, A. Reig, *Applied Acoustics*, Volume 66 Issue 3, March 2005

The study conducted a sensitivity analysis of INM computations as they might be affected by errors in input information. It analyzed the effects of variations in aircraft weight, speed, flaps ID, climb rate and altitude on INM computed SEL. Not surprisingly, weight is the primary factor affecting SEL during takeoff since it affects climb rate and altitude. On approach, flaps ID is also important. This study was reviewed in hopes that it would shed light on engine and aerodynamic coefficients, which we have proposed to alter in our study of INM accuracy for GA aircraft. It did not. However, the importance of weight confirms our approach in the Modified Work Plan, page 9, to determine the effects on INM accuracy by modifying an aircraft’s weights. ***The information on the effects of weight confirms the***

value of our approach, but the study provides no information directly applicable to our assessment of INM accuracy in computing standard noise metrics for GA aircraft.

2.1.6 “Error Sensitivity Analysis of the Integrated Noise Model”

Restrick, K., EEC Note: EEC/ENV/2002/006, 28/06/2002

This report was reviewed because, under the expanded work plan, we proposed under “Identify causes of discrepancies: modification of INM input” to “Modify Coefficients,” page 9 of the plan. This is one of the few studies that reports on input error sensitivity. Though there is sufficient information to believe the effort was thorough, the text explanations leave much to be desired and it is not possible to easily connect all the analysis steps and the results. Thirteen aircraft types were run through the analysis for six flight segments.

The study presents a method for analyzing and calculating the effect of errors in the inputs to each of the equations used within INM. The most influential variables are found to be aircraft weight, local pressure, and a number of aircraft flap and engine coefficients. The coefficients examined are:

Aerodynamic –

B – Ground roll flap coefficient (multiplied by weight, thrust to get ground roll)
C – Takeoff flap coefficient (multiplied by sq. root of weight gives climb CAS, Calibrated Airspeed)
D – Landing flap coefficient (multiplied by sq. root of weight gives approach CAS)
R – Drag coefficient to lift coefficient for a given flap setting (landing gear retracted) (for a given configuration and airspeed, used with weight and segment thrust and to give climb angle for the segment)

Engine corrected net thrust equation –

E – Constant
F – Constant multiplying calibrated airspeed
G – Constant multiplying pressure altitude, h (height above MSL at ISA for performance); in some cases there are two G constants, one multiplying h, one multiplying h squared
H – Constant multiplying ambient air temperature at plane

Interpreting the average percent errors in report Table 3, it appears that in descending order of importance, errors in aircraft weight and in coefficients R, E and F, are likely to have the greatest effect on aircraft position. Presumably, since they all relate to power required / delivered by the aircraft, they may also have the greatest influence on computed noise level. ***The information contained in this report will be useful to our analysis in that we will consider the results in prioritizing the modification of variables to determine their effect on resulting INM computed GA aircraft noise levels.***

2.1.7 “The Mosquito Effect: Community Reaction to Noise from a General Aviation Airport”

Lloyd, D., Inter-noise 2000, Nice, France, 2730 August 2000

This study determined the reaction of residents to aircraft noise from Jandakot, a GA airport having about 1100 daily aircraft operations. The results of the study were compared with the expected responses calculated using the Australian Noise Exposure Forecast (ANEF) system. The response of 330 residents was determined by conducting a social survey in the areas within the INM computed ANEF contours out to 10 ANEI (approximately 45 DNL). The results of the survey indicated that reaction to light aircraft noise was approximately 7 ANEF units higher than predicted by a 1982 National Acoustics Laboratory survey of residents living around five major Australian airports. Validation of the INM ANEF contours showed that actual noise levels from aircraft overflights were 3 ANEF units higher than the computed ANEF levels. When taking into consideration the actual noise, it was concluded that the reaction to aircraft noise from this airport was 4 ANEF units higher than would be expected for major airports. This would suggest that a 4 ANEF adjustment should be considered when planning for residential land use around GA airports. However, it should be noted that the difference of 4 ANEF units which has been found at Jandakot, while statistically significant, is not outside the bounds of variation between airports which would have been expected from results at major airports from the 1982 NAL study. It appears from examination of the tarmac in Google Earth and from reading a description of the airport that it is primarily, if not exclusively, an airport of propeller aircraft operations***. It is interesting as a data point for the hypothesis that annoyance is higher for low noise, large numbers of aircraft than for loud less frequent jet aircraft, but has probable little relevance for the present study.***

2.1.8 "Simplified Computation Procedure for Assessment of the Noise Load in the Vicinity of Sport Airfields"

Sandor, H., 2006 Annual Report, KTI Institute for Transport Sciences Nonprofit Limited, Hungary ISSN: 1789-4042, pp. 5157

Hungary is apparently complying with the European Noise Directive, 2002/49/EC, that requires EU members to create noise maps, provide the information to the public and establish Noise Action Plans to reduce numbers of people exposed to excessive noise. The method for airports has been judged as too complicated and too precise for "sport airfields," which we take to mean low use GA airports. This study describes a method to determine "noise loads" (noise exposure) as a function of distance from the runway / flight track and of the number of operations at a sport airfield. It provides graphs that can be used knowing any two of the three variables of number of operations per 16 hours (maybe they only operate during daylight), distance and noise load, to derive the third***. The method has no direct application to our study.***

2.2 INM User Survey

The INM user survey was completed to determine how GA aircraft noise modelers currently use the INM, collect input data, validate the model and determine noise exposure from GA aircraft at a variety of airports, from strictly GA to large hub commercial airports. The survey was conducted using a web-based provider.[4] The survey process had three steps that generated the responses:

1. Development of the database of INM users
2. Design of the survey questionnaire
3. Execution of the questionnaire

A brief summary of the method for the respective steps is described in the following three sections. The survey results are presented and discussed in Section 2.2.4. The questionnaire is provided in Appendix B.

2.2.1 Development of database INM users

Potential INM users including airport, airline industry, and state and federal agency users were identified and compiled from the following sources:

- HMMH proprietary lists of HMMH-hosted INM Training Workshop attendees from 2001-2011

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[4] SurveyMonkey™

- LinkedIn[5] INM User Group
- Airport Consultants Council (ACC)[6] database of firms identified as providing noise compatibility consulting
- Known INM modelers HMMH and MCG contact lists
- Internet research conducted by MCG – determined that most potential INM users were already included in the above lists

Combined, the initial potential U.S. and international INM users lists contained 483 contacts. Since the user database contained e-mails from 2001 – 2011, it was expected that many of the e-mails would bounce (discontinued e-mail addresses). If the e-mail address was non-existent, MCG attempted to resolve the user contact information by locating the contact at another organization or contact address (i.e., firm had been acquired, contact had moved to another firm, etc.). MCG received 123 "bounced" e-mails upon execution of the survey.

The final database of potential INM user names consisted of 256 potential U.S. users and 104 potential international users. Appendix C summarizes the types of users surveyed and responding.

2.2.2 Questionnaire development

HMMH in combination with MCG constructed the survey. Two separate survey questionnaires were developed, a survey of the potential U.S. users and a survey for potential international users. The U.S. and international user surveys were slightly different ("FAA" as an organization applies to only the U.S.), and are provided separately to permit analysis of differences in GA aircraft modeling approach, if any. An online software application, SurveyMonkey™, was used to execute the questionnaire. The questionnaire included twelve questions with multiple choice responses and/or text fillable user input. The survey began requesting the type of user based on their organization and asked whether they modeled GA aircraft using the INM (those who did not model GA aircraft exited the survey). The survey then focused on model input data sources, how they modeled GA aircraft and whether they have compared and/or used noise measurement data to validate or modify the model. The survey ended by asking the participant whether they could be contacted for further questioning. The twelve survey questions and summary of responses are provided in Section 2.2.4.2.

2.2.3 Questionnaire execution

The survey commenced on December 6, 2011 with the original invitation to complete the online survey, and was followed-up with reminder e-mails on December 13 and December 20, 2011. A final reminder e-mail advised recipients that survey data collection would conclude on December 23, 2011. The following summarizes the INM user participation:

- 121 U.S. users responded to the 261[7] queries (46.4% response rate)
- 35 international users responded to the 99[8] queries (35.4% response rate)

2.2.4 Summary of responses

The following two sections summarize the responses, first as generalizations, then more specifically in tables.

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[5] LinkedIn is a business oriented social network, http://www.linkedin.com/ (accessed 2 February 2012)

[6] ACC is an international trade association that represents private businesses involved in the development and operations of airports and related facilities, http://www.acconline.org/ (accessed 2 February 2012)

[7] Note that 256 emails were sent, but five were forwarded by recipients to others who were the INM users.

[8] Of the 104 originally identified emails, in subsequent emails, 5 addresses thought valid ultimately bounced.

2.2.4.1 Summary Generalizations

The following summary percentages are based on the number of respondents who answered each specific question. Except for question 1, which was answered by 97 from the U.S. and by 38 international participants, each question was answered by 61 to 71 U.S. respondents and by 21 to 29 international respondents. In this section, percentages have been rounded.

For both U.S. and international respondents, their division among organizations was similar with about 55% consultant, 23% government and 12% airport personnel.[9]

For respondents who model GA aircraft more often than rarely, about 1 ½ times as many U.S. respondents model GA aircraft as compared with international respondents, or about 69% of U.S. compared with 45% of international respondents. U.S. respondents report modeling all aircraft types about equally with a slight tendency toward piston props, while the international respondents report modeling turbojets slightly more often than modeling the other two types.

For determining how to model existing fleet mixes, a wide range of resources are used, particularly in the U.S. There is a clear preference for interviews, while use of permanent noise and operations monitoring systems and radar data combined represent a close second for international respondents.

For determining future fleet mixes, all respondents report primary use of airport and consultant forecasts, while U.S. respondents also make frequent use of the current fleet adjusted by the Terminal Area Forecast or other federal forecasts.

The weather data that are used are predominantly annual averages, though international respondents make heavy use of seasonal averages and long term (decades of) historical data.

Though half or fewer of the respondents modify GA aircraft data for modeling, of those who do, modifications are more often to the profiles of altitude, speed or thrust. Respondents report that modifications to weights or noise-power-distance curves are made about half as often as they are made to profiles. Occasionally spectral classes are altered.

Well over half the respondents find they need to model GA aircraft types not in the INM database, and generally do so by substituting other INM aircraft types. A few also develop user defined.

While most respondents never or rarely compare modeled GA aircraft noise levels with measured levels, about 40% report doing so.

Finally, though most respondents report never adjusting computed GA aircraft noise levels using measured data, 27% to 28% report doing so.

2.2.4.2 Specific Responses by Question

The following tables provide more detail on respondent answers to the twelve questions. They compare U.S. and international responses. The percentages shown were used to develop the previous section's generalizations. Percentages are based on answers of "rarely" which is for these tables the sum of "never" and "rarely" in the answers. "Mostly" is the sum of the responses of "occasionally" or more frequently. The intent is to emphasize those respondents who fairly frequently take the action in question versus those who almost never do. In this way, the "mostly" responses can be considered to be from

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[9] For these generalizations and the following section, respondents who marked "other," and who could clearly be categorized as government, consultant or airport were included in the totals for those types of organizations.

those who are very familiar with modeling GA aircraft and who best represent the state of the practice for using the INM to model GA aircraft.

Question #1		
What best describes your organization?		
Answer Summary	**U.S. Respondents**	**Int'l Respondents**
Airport	13.1%	11.9%
FAA - U.S./CAA - Int.	14.0%	4.8%
Military	1.9%	2.4%
Other Government	6.5%	16.7%
Consultant	55.1%	54.8%
Other	9.3%	9.5%
Other responses:	Noise Committee Member, Manufacturer, University, Research & Development Center	Research Center, Air Navigation Services Provider, University, Airline

Question #2		
Do you model GA aircraft with the INM?		
Answer Summary	**U.S. Respondents**	**Int'l Respondents**
Rarely (once/year or less)	31.0%	55.2%
Mostly (>twice/year)	69.0%	44.8%

Question #3				
For airports where you use the INM to model GA aircraft, what have been the predominant GA aircraft types?				
Answer Summary	**U.S. Respondents**		**Int'l Respondents**	
	Rarely	**Mostly**	**Rarely**	**Mostly**
Turbojets	45%	31%	29%	38%
Turboprops	34%	34%	34%	33%
Piston-engine props	21%	36%	37%	29%

Question #4				
What data sources have you used for estimating types of GA aircraft to model EXISTING noise?				
Answer Summary	**U.S. Respondents**		**Int'l Respondents**	
	Rarely	**Mostly**	**Rarely**	**Mostly**
Enhanced Traffic Management System Count	24%	14%	19%	13%
Radar data	19%	18%	19%	13%
Perm. Noise & Ops. Monitoring Systems	22%	16%	15%	22%
Interviews FBO, Tower, Based Operator(s)	8%	28%	13%	38%
Commercial Available Sources	18%	18%	23%	6%
Other	9%	8%	10%	9%
Other responses:	Master Plans, Observation, INM database, Internal data, Airport sponsor, Fictional ops. data (for education), FAA databases, Demand forecasts, NextGen data		Consultant data, ANP Database, Internet search	

Question #5				
What data sources have you used for estimating types of GA aircraft to model FUTURE noise?				
Answer Summary	**U.S. Respondents**		**Int'l Respondents**	
	Rarely	**Mostly**	**Rarely**	**Mostly**
Fleet TAF Adjusted or federal sources	36%	44%	65%	17%
Airport/Consult. forecast	21%	48%	6%	74%
Other	43%	7%	29%	9%
Other responses:	Socioeconomic data, Internal forecasts, Fictional ops. data (for education), Aviation forecast trends, Primary users input, Airport Managers, Letters of Interest		Internet search, Other consultants, Interviews with major operators and FBO's	

Question #6				
What data do you use to specify weather conditions?				
Answer Summary	**U.S. Respondents**		**Int'l Respondents**	
	Rarely	**Mostly**	**Rarely**	**Mostly**
Annual Average	6%	67%	0%	48%
Seasonal Average	71%	19%	67%	41%
Other (specify below)	23%	14%	33%	11%
Other responses:	Actual data, Consultant Wind Study, Design day, Daily, Single-event conditions, Specific day/time periods, Fictional ops. data (for education purposes), Metric-specific time periods		Actual weather data of the last 30 years, Actual weather cases, 20 year averages	

Question #7				
Have you ever modified INM provided GA aircraft data?				
Answer Summary	**U.S. Respondents**		**Int'l Respondents**	
	Rarely	**Mostly**	**Rarely**	**Mostly**
Takeoff weights	35%	20%	33%	24%
Departure/Arrival alt-speed-thrust	26%	44%	23%	48%
Noise-Power-Dist curve	31%	24%	35%	19%
Other	8%	11%	9%	10%
Other responses:	Substitute aircraft types within INM database, Spectral class for user-defined aircraft, Spectral class based on internal noise estimates, Investigate performance coefficients		Situation changes and factoring of movement numbers	

Question #8		
Have you needed to model a GA aircraft that is not in the INM database?		
Answer Summary	**U.S. Respondents**	**Int'l Respondents**
Rarely	37.7%	28.6%
Mostly	62.3%	71.4%

Question #9				
When you have wanted to model a GA aircraft not in the standard INM database, have you:				
Answer Summary	**U.S. Respondents**		**Int'l Respondents**	
	Rarely	**Mostly**	**Rarely**	**Mostly**
Excluded it - modeling	50%	6%	45%	3%
Used INM standard sub	5%	43%	14%	38%
Assigned standard type	9%	36%	14%	41%
Developed user defined	36%	15%	27%	19%

Question #10		
Have you compared INM modeled GA aircraft noise with measured noise?		
Answer Summary	**U.S. Respondents**	**Int'l Respondents**
Rarely	61.0%	61.9%
Mostly	39.0%	38.1%

Question #11		
Have you adjusted INM modeled GA aircraft noise using measured noise?		
Answer Summary	**U.S. Respondents**	**Int'l Respondents**
Rarely	88.1%	85.7%
Mostly	11.9%	14.3%

Question #12		
May we contact you directly if we have additional questions?		
Answer Summary	**U.S. Respondents**	**Int'l Respondents**
Yes, provided name	41.2%	47.4%

2.3 Recommendations

The literature review provides useful information about how modifications of coefficients used within the INM might be made to the GA aircraft database, should that be a useful approach to improving computed results. However, the literature provided no information on comparisons of GA aircraft modeled results using the INM with measured values or any information about current modeling procedures or methods.

The user survey, however, suggests that current INM modeling of GA aircraft noise would benefit, probably significantly in reductions of modeling effort, cost of modeling, and in uniformity of results if:

1. More GA aircraft types were provided as standard types in the INM database
2. Clear methods were provided / described for:
    a. Selecting substitution standard INM GA aircraft types for those types not specifically included in the INM database
    b. Modifying departure altitude and thrust profiles, as described in Section 8 and as recommended in Section 9.

3 GA Aircraft Types Selected for Evaluation

3.1 Introduction

To begin the analysis of INM modeling accuracy of GA aircraft, Task 2 developed two comprehensive lists, one of GA jets and one of propeller aircraft for initial evaluation. This section describes the method used to develop the comprehensive lists.

3.2 Sources Used for Operations and Noise Data

The operations data we used to develop the lists consist of 84 days of GA operations from the FAA's Enhanced Traffic Management System Counts (ETMSC) website[10]. The sample comprises seven days of data from each of the 12 months spanning July of 2010 through June of 2011. Each record in the data provides the type of aircraft by FAA designator[11], the origin and destination airport, and the dates and hours of the departure and arrival.

The noise level for each jet arrival and departure was derived from the aircraft noise certification data in Appendix 1 of FAA Advisory Circular 36-1H[12]. In cases where the FAA data did not contain noise levels for a particular designator found in the ETMSC data, the analysis utilized noise levels from the European Aviation Safety Agency (EASA) Type-Certificate Data Sheets for Noise (TCDSN)[13]. For propeller aircraft, certification data are not available and estimated A-weighted takeoff and approach noise levels were used from FAA Advisory Circular 36-3H. Note that this means that the noise contributions from jet and propeller aircraft are not directly comparable.

3.3 Determination of Noise Contribution

The jet aircraft operations dataset consisted of 1,587, 230 operations (793,615 unique departure and arrival pairs). Of those, approximately 536,000 operations were flown by jet-powered aircraft not on FAA's air carrier aircraft list[14] and considered to be GA jets, occurred at a US airport, and were matched to available noise certification data. For each of 60 aircraft types remaining in the data sample, a number representing their current relative noise contribution across the country was computed. The propeller dataset provided an estimated 952,163 operations by some 551 aircraft types. We chose the 50 types with the highest number of operations for computations of relative noise contributions.

For the noise contributions we used the following formula:

$$Noise = 10 * \log(N_{Departures} * 10^{(\frac{L_D + w_d}{10})} + N_{Arrivals} * 10^{(\frac{L_A + w_a}{10})})$$

Where, for jet aircraft:

$$L_D = [(Certification\ sideline\ measurement) + (Certification\ takeoff\ \ measurement)]/2$$

$$L_A = Certification\ approach\ measurement$$

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[10] Downloaded from https://aspm.faa.gov/etms/sys/Default.asp, August 17, 2011.

[11] FAA Order JO 7340.2B CHG 3 Ch. 5 Section 1

[12] Downloaded from http://www.faa.gov/about/office_org/headquarters_offices/apl/noise_emissions/aircraft_noise_levels/, July 12, 2011.

[13] Jet Aeroplane Issue 12 downloaded from http://easa.europa.eu/certification/type-certificates/noise.php, July 12, 2011.

[14] FAA Order JO 7210.3W.

For propeller aircraft:

$$L_D = A - \textit{weighted takeoff noise level}$$

$$L_A = A - \textit{weighted approach noise level}$$

And for both aircraft types:

$$w_d, w_a = 10\ \textit{when the operation occurs between 10 PM and 7 AM, else}\ 0$$

The representative jet departure noise level was computed as the average of the certification sideline and takeoff (EASA "flyover") positions. Previous analyses have shown this value to be more consistent with the relative contribution of measured departure noise levels. Note that this averaging is consistent with the quota points systems used by the UK's Department for Transport to limit nighttime noise exposure at the three major London airports and as well as similar systems at Brussels Airport and Madrid-Barajas Airport. The noise levels are weighted using the same ten decibel nighttime penalty as utilized in the Day-Night Average Sound Level (DNL). For jet aircraft, where more than one certification result is available, the median value is used in the calculations.

3.4 Selected GA Aircraft

Table 1 lists the jet aircraft identified using the above criteria of percent of total national annual operations and contribution to total GA jet aircraft sound energy. Note, particularly, column 5. It gives the INM aircraft type that we used for modeling. Types that include an asterisk are "substitutions" – not originally developed for the actual aircraft type. A few aircraft designators show two INM types that were used for modeling. There are several possible methods by which the specific INM type is selected. The data we receive in the associated flight plan may give the aircraft's N (tail) number, in which case the specific aircraft type is found through the FAA registry of N numbers. If there was no N number, and there is more than one possible INM type, then the INM type is assigned randomly in a way that all such assignments will equal the national distribution of the two (or more) possible types.

Table 2 provides similar information for propeller aircraft.

Table 1 List of GA jet aircraft for evaluation

1 Designator	2 Associated Aircraft Types	3 % Noise Contribution	4 % of Ops in 84 Day Sample	5 INM Type Used
H25B	BAe-125-700/800; Hawker 750, 800, 800XP, 900XP	17%	7%	LEAR35*
BE40	Beechjet/Hawker 400	7%	6%	MU3001*
FA50	Dassault Falcon 50, Mystère 50	5%	2%	F10062*
C560	Cessna 560 Citation 5/5 Ultra/5 Ultra Encore	5%	6%	CNA560U CNA560E
GLF4	Gulfstream Aerospace G-1159C Gulfstream 4/4SP/SRA-4	5%	6%	GIV
C56X	Cessna 560XL Citation Excel	4%	5%	CNA560XL
LJ45	Learjet 45	4%	4%	LEAR35*
C550	Cessna 550, S550, 552 Citation 2/S2/Bravo	4%	6%	CNA500 CNA55B
C525	Cessna 525 Citation Jet, Citation CJ1	3%	5%	CNA525C
C650	Cessna 650 Citation 3/6/7	3%	2%	CIT3
F2TH	Dassault Falcon 2000	3%	3%	CL600*
CL60	Canadair CL-600 Challenger 600/601/604	2%	4%	CL600 CL601
LJ35	Learjet 35, 36	2%	2%	LEAR35
F900	Dassault Falcon 900, Mystère 900	2%	3%	F10062
GLF5	Gulfstream Aerospace G-1159D Gulfstream 5	2%	3%	GV
LJ31	Learjet 31	2%	2%	LEAR35*
PRM1	Hawker Premier 1, 390	1%	2%	LEAR35*
C750	Cessna 750 Citation 10	1%	3%	CNA750*
GALX	IAI 1126 Galaxy, Gulfstream 200	1%	1%	CL600*
C25A	Cessna 525A Citation CJ2	1%	2%	CNA525C*
CL30	Bombardier BD-100 Challenger 300	1%	2%	CL601*
C680	Cessna 680 Citation Sovereign	1%	2%	CNA680
ASTR	IAI 1125 Astra, Gulfstream 100	1%	1%	IA1125
G150	Gulfstream Aerospace Gulfstream G150	1%	1%	IA1125*
C25B	Cessna 525B Citation CJ3	1%	2%	CNA525C
LJ60	Learjet 60	1%	2%	CNA55B*
C501	Cessna 501 Citation 1SP	0%	1%	CNA500*
C510	Cessna 510 Citation Mustang	0%	2%	CNA510
EA50	Eclipse 500	0%	1%	ECLIPSE 500

Notes:
**Indicates an INM standard substitution.*
Two types, column 5, indicate HMMH INM modeling used two, see text.

Table 2 List of GA propeller aircraft for evaluation

1 Designator	2 Associated Aircraft Types	3 % Noise Contribution	4 % of Ops in Sample	5 INM Type
BE20	Hawker Beechcraft Corp 200, 1300 Super King Air, Commuter	23%	7%	DHC6*
BE9L	Hawker Beechcraft Corp 90, A90 to E90 King Air	11%	5%	CNA441*
SR22	Cirrus SR-22	7%	6%	N/A
B350	Hawker Beechcraft Corp B300 Super King Air 350	5%	3%	N/A
BE58	Hawker Beechcraft Corp 58 Baron	5%	4%	BEC58P
PA31	Piper PA-31/31P Navajo, Navajo Chieftain, Chieftain, Pressurized Navajo, Mojave, T-1020	4%	2%	PA31
BE36	Hawker Beechcraft Corp 36 Bonanza (piston)	3%	5%	N/A
BE30	Hawker Beechcraft Corp 300 Super King Air	3%	1%	DHC6*
C421	Cessna 421, Golden Eagle, Executive Commuter	2%	2%	BEC58P*
C182	Cessna 182, Skylane	2%	5%	CNA182
BE55	Hawker Beechcraft Corp 55 Baron	2%	2%	BEC58P*
C310	Cessna 310, T310	2%	2%	BEC58P*
C414	Cessna 414, Chancellor	2%	2%	BEC58P*
C208	Cessna 208 Caravan 1, (Super) Cargomaster, Grand Caravan	2%	1%	CNA208
C441	Cessna 441 Conquest, Conquest 2	2%	1%	CNA441
C210	Cessna 210, T210, (Turbo) Centurion	2%	3%	CNA206*
PA32	Piper PA-32 Cherokee Six, Six, Saratoga, Turbo Saratoga	2%	3%	GASEPV*
C172	Cessna 172, P172, R172, Skyhawk, Hawk XP, Cutlass	2%	9%	CNA172
BE35	Hawker Beechcraft Corp 35 Bonanza	1%	2%	GASEPV*
C340	Cessna 340	1%	1%	BEC58P*
PA34	Piper PA-34 Seneca	1%	1%	BEC58P*
PA46	Piper PA-46-310P/350P Malibu, Malibu Mirage	1%	2%	GASEPV*
SR20	Cirrus SR-20	1%	1%	N/A
PA44	Piper PA-44 Seminole, Turbo Seminole	1%	1%	BEC58P*
BE33	Hawker Beechcraft Corp 33 Debonair, Bonanza	1%	1%	GASEPV*
C206	Cessna 206, P206, T206, TP206, U206, TU206, (Turbo) Super Skywagon, (Turbo) Super Skylane, (Turbo) Skywagon 206, (Turbo) Stationair, (Turbo) Stationair 6	1%	1%	CNA206
P28B	Piper PA-28-201T/235/236	1%	2%	GASEPV*

1 Designator	2 Associated Aircraft Types	3 % Noise Contribution	4 % of Ops in Sample	5 INM Type
	Cherokee, Cherokee Charger/Pathfinder, Dakota, Turbo Dakota			
M20P	Mooney M-20, M-20A/B/C/D/E/F/G/J/L/R/S, Mark 21, Allegro, Eagle, Ranger, Master, Super 21, Chaparral, Executive, Statesman, Ovation, 201, 205, ATS, MSE, PFM (non-turbocharged engine)	1%	3%	GASEPV*
P32R	Piper PA-32R Cherokee Lance, Lance, Saratoga SP/2 HP/2TC, Turbo Saratoga SP	1%	1%	GASEPV*
P28A	Piper PA-28-140/150/151/160/161/180/181 Archer, Cadet, Cherokee, Cherokee Archer/Challenger/Chief/Cruiser/Flite Liner/Warrior, Warrior	0%	3%	PA28 GASEPF*
PA30	Piper PA-30/39 Twin Comanche, Twin Comanche CR, Turbo Twin Comanche	0%	0%	PA30
P46T	Piper PA-46T-500TP Malibu Meridian	N/A	2%	N/A
*Notes: *Indicates an INM standard substitution.*				

4 Detailed Analyses: Overall Description

This section describes the methods used to analyze the measured and modeled SEL values of the aircraft types identified in the previous section. Generally, the analyses focus on the sound levels of the GA jet aircraft operating at the six airports of Table 3.[15] Twelve months of data were used with at least eleven of the twelve months from 2011, depending on airport data availability.

Table 3 Airports providing flight tracking and noise monitoring data

BED	L.G. Hansom Field, MA
BWI	Baltimore/Washington International Thurgood Marshall Airport, MD
DEN	Denver International Airport, CO
FXE	Fort Lauderdale Executive Airport, FL
HPN	Westchester County Airport, NY
VNY	Van Nuys Airport, CA

4.1 Data Base of Measured Jet Aircraft

The aircraft types analyzed and numbers of data points for each are listed in Table 4. These are the 29 jet aircraft types identified in Section 3.4. Each data point represents a valid match of a measured noise event (SEL) at a monitor with a flight track for the aircraft that flew that track.

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[15] Propeller aircraft were also analyzed, but found not sufficiently significant to be corrected, see Appendix D, page 55.

Table 4 Aircraft types evaluated and numbers of useful associated flight track / SEL data points

Order	Designator	Description	INM Aircraft Type Used	Number Data Points	
				Arrival	Departure
1	H25B*	British Aerospace BAe-125-700/800; Hawker 750, 800, 800XP, 900XP	LEAR35*	3790	2045
2	BE40*	Beechjet/Hawker 400	MU3001*	1812	727
3	FA50*	Dassault Falcon 50, Mystère 50	F10062*	373	268
4	C560	Cessna 560 Citation 5/5 Ultra/5 Ultra Encore	CNA560E/U	2090	1571
5	GLF4	Gulfstream Aerospace G-1159C Gulfstream 4/4SP/SRA-4	GIV	5618	3804
6	C56X	Cessna 560XL Citation Excel	CNA560XL	3460	1372
7	LJ45*	Learjet 45	LEAR35*	848	434
8	C550	Cessna 550, S550, 552 Citation 2/S2/Bravo	CNA500/55B	546	435
9	C525	Cessna 525 Citation Jet, Citation CJ1	CNA525C	501	341
10	C650	Cessna 650 Citation 3/6/7	CIT3	395	275
11	F2TH*	Dassault Falcon 2000	CL600*	2300	1133
12	CL60	Canadair CL-600 Challenger 600/601/604	CL600/1	2135	1096
13	LJ35	Learjet 35, 36	LEAR35	2373	1731
14	F900	Dassault Falcon 900, Mystère 900	F10062	349	350
15	GLF5	Gulfstream Aerospace G-1159D Gulfstream 5	GV	2247	1347
16	LJ31*	Learjet 31	LEAR35*	310	260
17	PRM1*	Hawker Premier 1, 390	LEAR35*	310	301
18	C750*	Cessna 750 Citation 10	CNA750*	3642	1853
19	GALX*	IAI 1126 Galaxy, Gulfstream 200	CL600*	1636	896
20	C25A*	Cessna 525A Citation CJ2	CNA525C*	226	142
21	CL30*	Bombardier BD-100 Challenger 300	CL601*	1643	1074
22	C680	Cessna 680 Citation Sovereign	CNA680	1901	653
23	ASTR	IAI 1125 Astra, Gulfstream 100	IA1125	307	121
24	G150*	Gulfstream Aerospace Gulfstream G150	IA1125*	290	202
25	C25B	Cessna 525B Citation CJ3	CNA525C	690	267
26	LJ60*	Learjet 60	CNA55B*	1184	740
27	C501*	Cessna 501 Citation 1SP	CNA500*	73	32
28	C510	Cessna 510 Citation Mustang	CNA510	349	362
29	EA50	Eclipse 500	ECLIPSE500	204	199

*Aircraft types that have an FAA identified substitution aircraft for INM modeling. For example, the H25B is to be modeled with the INM type LEAR35.

4.2 Computing Discrepancies

In analyzing differences between measured and modeled levels, it is not only the discrepancy between these two that has implications for the accuracy of the modeled levels, but also discrepancies in altitude. Analysis of the accuracy of the modeling included combined analysis of these two types of errors.

As described in the Research Plan, all analyses are focused on a single “prototypical monitor” location. This approach is used because not all airports will have monitors at identical track distances from the airport, and accuracy of modeling is most important at locations relatively close to the airport in the general area where DNL 65 dB is likely to occur.[16] By determining average track distances to DNL 65 dB for the study airports, 12,000 feet from the takeoff end (assumed location of brake-release) of the runway for departures and 9,000 feet from landing threshold for arrivals were selected.[17]

4.2.1 Sound Exposure Level Discrepancies

The SEL discrepancy for an aircraft type is the difference between the energy average measured SEL and the energy average modeled SEL.[18] The energy average SEL is the basic metric used to compute DNL, rather than the arithmetic average SEL. For example, a simplified equation for computing DNL is:

$$\mathrm{DNL} = 10 \times \log_{10} \times \left\{ \sum_{i=1}^{D} 10^{\frac{SEL_{d_i}}{10}} + \sum_{i=1}^{N} 10^{\frac{SEL_{n_j}+10}{10}} \right\} - 49.4$$

Where:

SEL_{d_i} = the i^{th} daytime (7 a.m. to 10 p.m.) SEL from the i^{th} aircraft flight,
SEL_{n_j}= the j^{th} nighttime (10 p.m. to 7 a.m.) SEL from the j^{th} aircraft flight,
49.4 = adjustment to DNL (based on number of seconds in 24 hours),
$10^{\frac{SEL_i}{10}}$ = sound “energy” represented by i^{th} SEL.

In other words, it is the “energy” based value that determines DNL. An energy average SEL for a collection of *n* SEL values is:

$$Energy\ Average\ SEL = 10 \times \log_{10} \left\{ 1/n \sum_{i=1}^{n} 10^{\frac{SEL_i}{10}} \right\}$$

Hence from the collection of measured SEL the energy average is computed at the prototypical monitor location and similarly the energy average modeled SEL is computed. The difference of measured minus modeled SEL energy average values is the discrepancy. The calculation of the energy average SEL values at the 12,000 and 9,000 foot track distances is accomplished with linear regression of the energy values of the SEL data.[19]

4.2.2 Altitude Discrepancies

From initial comparisons of the modeled altitude profiles with the flight tracking data altitude profiles, it was clear that there were consistent differences. These differences meant the measured and modeled aircraft are at different slant distances from the noise monitors resulting in an additional sound level discrepancy. For each aircraft flight, the difference in slant distance was determined and used as an adjustment to the modeled SEL. For example, if the measured distance of the flight track from the noise monitor were 800 feet, and the modeled profile resulted in a distance of 1200 feet, the modeled SEL

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[16] DNL 65 dB is the level above which noise sensitive residential areas are considered by FAA to be incompatible with aircraft noise.

[17] A slight adjustment in the arrival distance analysis point was necessary to avoid extrapolation of measured results; i.e., a very small percentage of the data points were from monitors at distances less than about 9,000 feet from threshold.

[18] Throughout the analyses, the discrepancy equals the measured minus the modeled level so that the sign of the discrepancy is the “correction” to the modeled result needed to make it equal to the measured level.

[19] The actual calculation is somewhat more complicated, involving a correction to the linear regression of the SEL values, using a regression of the energies of the residuals.

needed an additional increase in level of approximately +2.7 dB.[20] Once all SEL values for a given aircraft type were adjusted, then the net effect on the energy average modeled SEL was determined.

Measured minus modeled sound exposure levels, the decibel effect of altitude discrepancies, and discrepancies that result if the altitude could be corrected are presented in Section 5.

4.3 Select Aircraft for Additional Analysis

In order to most efficiently improve the INM modeling of GA aircraft, rather than identify all aircraft needing correction and recommend methods for correcting them, as in the original scope, we were directed in the telephone conference of March 8, 2012 to consider first the most significant GA jet aircraft, focusing on those at VNY. Additionally, if propeller aircraft noise is not significant, the Panel agreed they could be ignored, hence, they were, but see Appendix D.

Selecting the most significant aircraft had two steps: 1) determine the effect of correcting each jet aircraft type sequentially on the total GA jet sound energy; 2) define and use a criterion for identifying only the aircraft types that if corrected will provide significant improvement in the total sound energy. Details of these two steps are discussed in Section 6.

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[20] The distance correction was computed using the average adjustment for distance assumed by the INM for the GA jets in this study by type of operation – arrival or departure.

5 Detailed Analysis—Measured versus Modeled Discrepancies

5.1 Departures

For all jet aircraft types evaluated, Table 5 presents the measured and modeled departure SEL values, the discrepancies due to the difference between measured and modeled SEL, the decibel effect of altitude differences and the resultant discrepancy if the altitude could be corrected.[21] Figure 1 and Figure 2 present the measured and modeled SEL values and the altitude corrected discrepancy, respectively.

The measured minus modeled discrepancy is the metric of how well the INM as normally used for modeling differs from the measured reality for that aircraft. The altitude discrepancy shows how the measured minus modeled discrepancy would change if the modeled altitude matched the measured reality, assuming all other variables remained unchanged. However, as will be demonstrated in Section 7, because an aircraft's altitude at any location is determined by the specific values of the aircraft's thrust, speed, weight, drag over lift coefficient and other physical variables, correcting for altitude can be accomplished only by altering some or all of these values. Altering some of these, especially thrust, will alter the aircraft noise level so that the measured minus modeled SEL will change, possibly increasing or decreasing, depending on the specific values assigned to these factors. Additionally, all values used must lie within the acceptable envelope of the aircraft's performance capability. Minimizing both the measured discrepancy and the altitude discrepancy thus requires a balancing of thrust, speed, flap management, climb/descent rate, and changes to these during the aircraft's ascent or descent. This process was followed in Section 7.1 for departures of three aircraft types.

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[21] Altitude effects were determined flight by flight from differences between measured and modeled slant distances from the relevant monitor. The resultant effect shown in the table was the change in total energy, by aircraft type. Note that some flights may not have flown directly over the monitor so that the change in slant distance from the monitor may not have exactly equaled the change in altitude. However, significant monitors were relatively close to the airport so that aircraft tracks had not dispersed much at the monitor location. Additionally, only tracks that were no more than 30 degrees off vertical were used. This 30 degree restriction ensured that ground attenuation effects were not incorporated in either the measured or modeled results. Expand more on altitude correction.

Table 5 Departure discrepancies computed for all aircraft types

Order	Designator	Measured SEL (dB)	Modeled SEL (dB)	Discrepancies		
				Measured minus Modeled (dB)	Effective Altitude Discrepancy (dB)	Discrepancy if Altitude Corrected[22] (dB)
1	H25B*	88.9	94.3	-5.3	-3.1	-8.5
2	BE40*	89.2	93.7	-4.5	-1.8	-6.3
3	FA50*	93.3	92.7	0.7	-2.4	-1.8
4	C560	88.8	93.3	-4.5	-2.4	-6.9
5	GLF4	87.4	83.5	3.9	-3.5	0.4
6	C56X	83.6	84.5	-0.9	-2.1	-3.0
7	LJ45*	85.2	94.2	-9.0	-2.8	-11.7
8	C550	88.8	88.1	0.7	-2.1	-1.4
9	C525	86.3	85.1	1.2	-4.3	-3.1
10	C650	92.2	91.0	1.2	-2.3	-1.1
11	F2TH*	86.8	88.9	-2.1	-2.7	-4.8
12	CL60	84.3	87.6	-3.3	-0.8	-4.1
13	LJ35	86.6	94.1	-7.5	-2.5	-10.1
14	F900	89.9	92.0	-2.2	-2.4	-4.6
15	GLF5	86.8	87.9	-1.1	-2.9	-3.9
16	LJ31*	86.1	93.6	-7.5	-2.4	-9.9
17	PRM1*	86.1	93.4	-7.4	-3.1	-10.4
18	C750*	81.9	83.9	-1.9	0.3	-1.7
19	GALX*	88.0	88.4	-0.4	-2.3	-2.7
20	C25A*	87.9	84.7	3.2	-4.3	-1.0
21	CL30*	85.8	86.2	-0.4	-1.1	-1.5
22	C680	82.6	86.2	-3.6	-2.1	-5.7
23	ASTR	90.1	92.5	-2.4	0.0	-2.4
24	G150*	90.8	92.4	-1.6	0.0	-1.6
25	C25B	83.5	84.6	-1.1	-3.2	-4.3
26	LJ60*	82.5	85.6	-3.1	-2.1	-5.1
27	C501*	87.2	88.9	-1.6	-1.6	-3.2
28	C510	84.5	84.3	0.2	-2.7	-2.5
29	EA50	80.0	76.3	3.7	-3.9	-0.2

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[22] This correction is the total sound level discrepancy that would occur if the airplane flight track were as close to the noise monitor as were the actual flights. It assumes that there are no changes in thrust or speed.

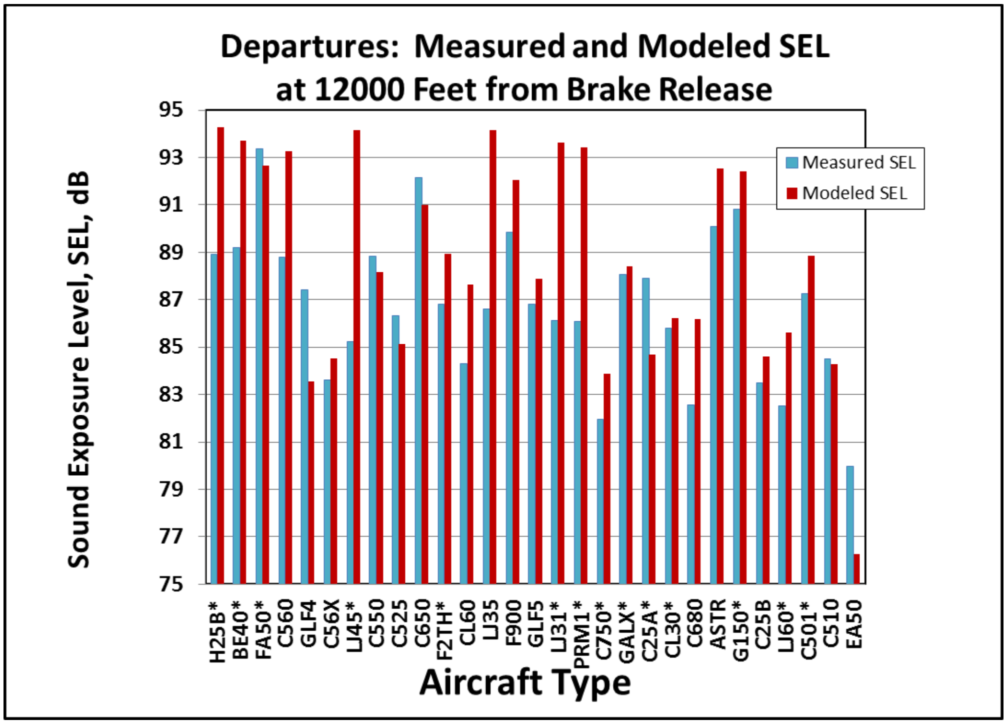

Figure 1 Measured and modeled departure SEL values for the evaluated aircraft

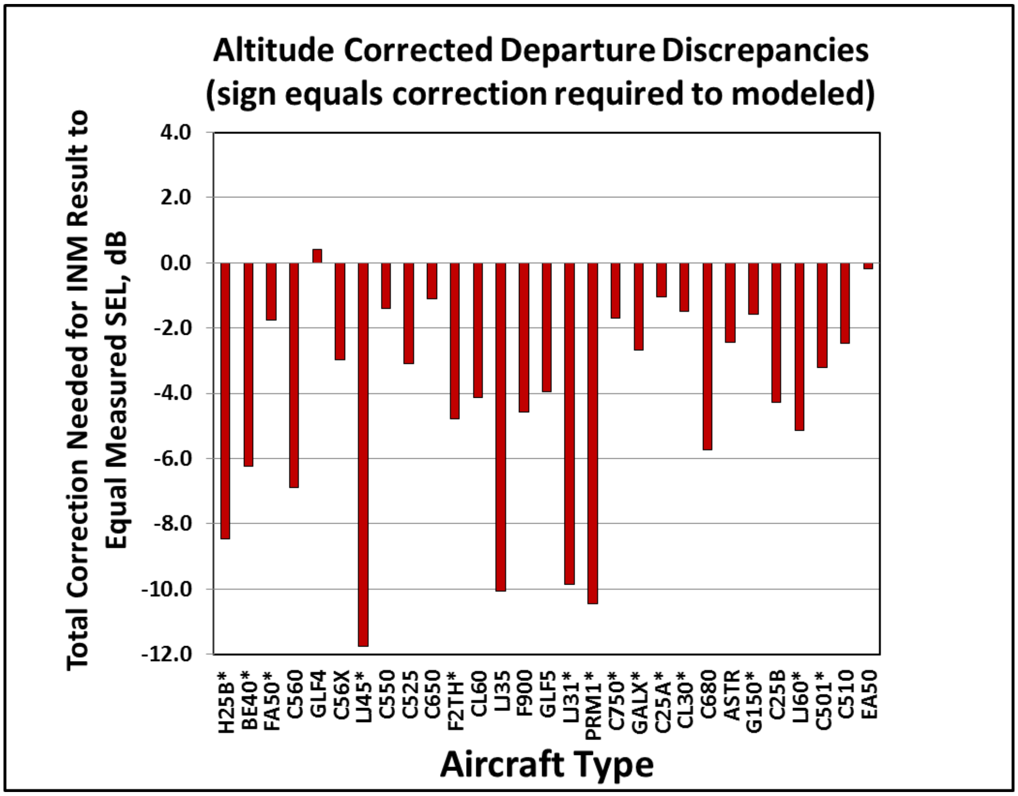

Figure 2 Altitude corrected departure discrepancies for the evaluated aircraft

5.2 Arrivals

For all aircraft types evaluated, Table 6 presents the measured and modeled arrival SEL values, the discrepancies including the difference between measured and modeled SEL, the decibel effect of altitude differences and the resultant discrepancy if the altitude could be corrected. Figure 3 and Figure 4 graphically present the measured and modeled SEL values and the altitude corrected discrepancy, respectively.

Table 6 Arrival discrepancies computed for all aircraft types

Order	Designator	Measured SEL (dB)	Modeled SEL (dB)	Discrepancies		
				Measured minus Modeled (dB)	Effective Altitude Discrepancy (dB)	Discrepancy if Altitude Corrected (dB)
1	H25B*	85.4	85.1	0.3	1.0	1.3
2	BE40*	84.5	84.2	0.3	0.7	0.9
3	FA50*	87.0	88.1	-1.1	1.8	0.7
4	C560	82.5	84.3	-1.9	0.9	-1.0
5	GLF4	85.4	85.6	-0.2	1.2	1.0
6	C56X	85.3	87.8	-2.6	1.0	-1.5
7	LJ45*	84.8	85.0	-0.2	1.2	1.0
8	C550	81.7	85.2	-3.5	0.9	-2.6
9	C525	83.4	82.8	0.6	1.3	1.9
10	C650	84.2	82.1	2.1	0.5	2.6
11	F2TH*	85.2	84.5	0.7	1.2	1.9
12	CL60	84.6	85.4	-0.7	1.0	0.2
13	LJ35	85.4	85.3	0.2	1.1	1.3
14	F900	83.9	88.1	-4.3	1.5	-2.8
15	GLF5	83.0	85.2	-2.2	0.9	-1.3
16	LJ31*	82.2	84.2	-2.0	1.1	-0.9
17	PRM1*	80.5	84.2	-3.7	2.1	-1.6
18	C750*	82.3	87.3	-5.0	1.0	-4.0
19	GALX*	83.7	83.7	0.0	0.8	0.8
20	C25A*	84.4	82.1	2.3	1.3	3.6
21	CL30*	82.6	84.6	-2.0	1.0	-1.0
22	C680	81.7	82.4	-0.7	1.1	0.4
23	ASTR	83.3	81.2	2.1	0.9	2.9
24	G150*	83.4	81.1	2.3	1.0	3.3
25	C25B	82.4	82.2	0.2	1.0	1.2
26	LJ60*	81.6	86.3	-4.7	1.1	-3.5
27	C501*	82.6	81.9	0.7	0.8	1.5
28	C510	79.3	81.8	-2.6	1.3	-1.3
29	EA50	77.9	75.9	2.0	0.9	2.9

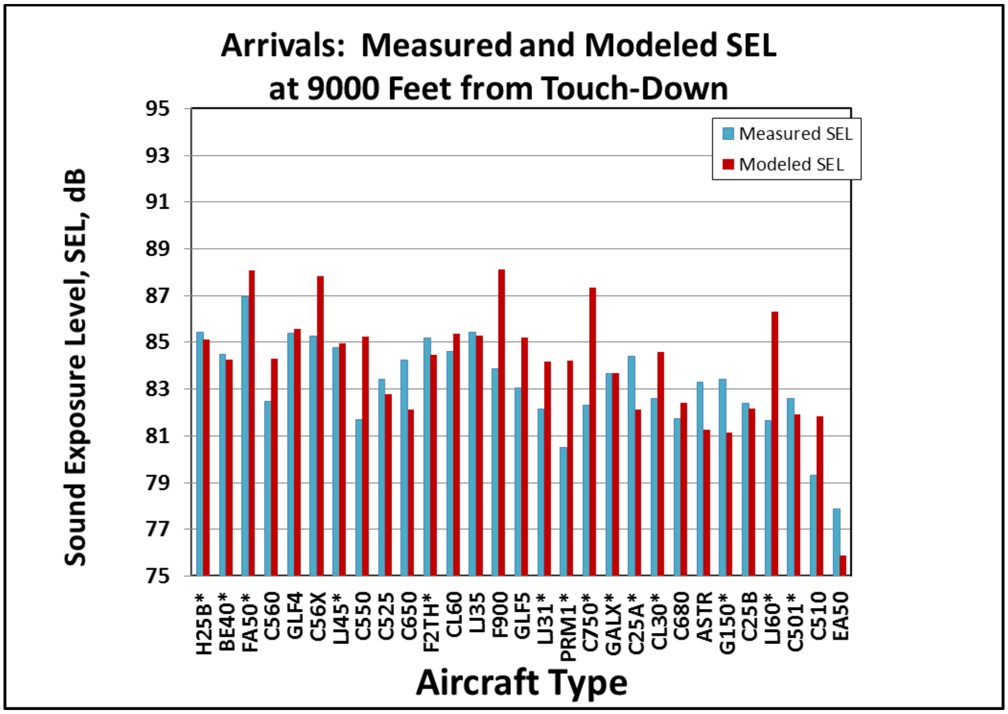

Figure 3 Measured and modeled arrival SEL values for the evaluated aircraft

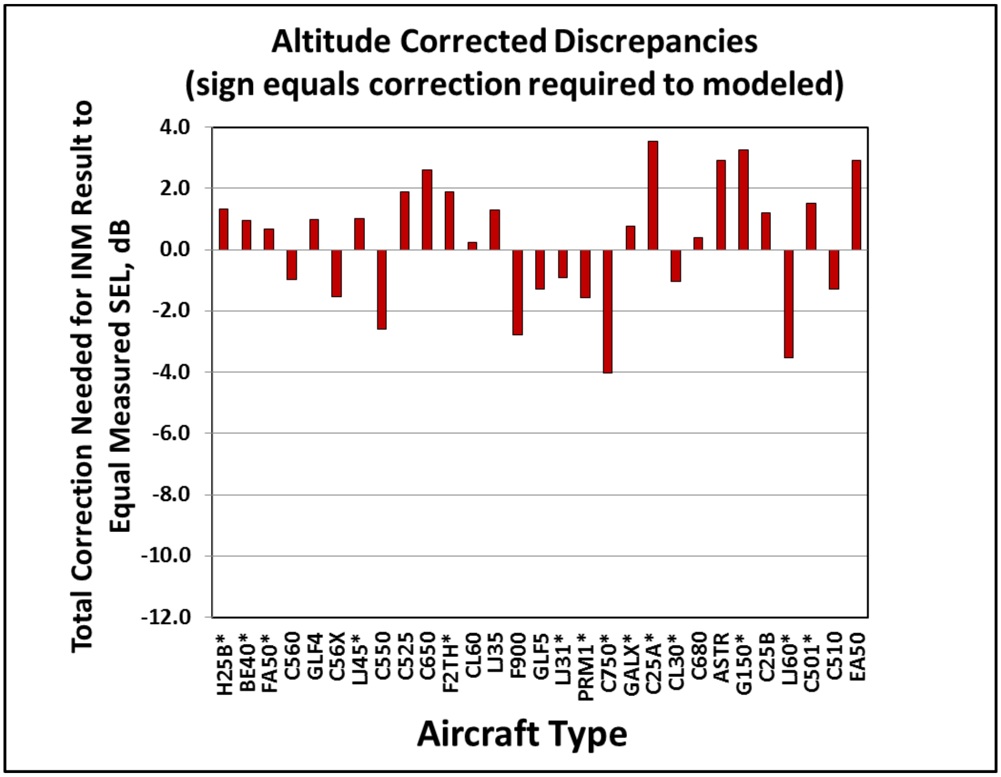

Figure 4 Altitude corrected arrival discrepancies for the evaluated aircraft

5.3 Observations

The INM modeling for almost all aircraft types computes departure SEL values higher than the measured levels (measured minus computed discrepancies are almost all less than zero, Table 5). Correcting for altitude, if it were possible, generally makes the discrepancy more negative because for most aircraft, the INM departure altitudes for the aircraft are higher than actually occurs; see Section 7.1.

Arrival discrepancies are more mixed, with some modeled louder, some quieter. This is not surprising because the INM standard approach is a single descent angle of three degrees. Most descents include level portions and frequent changes of thrust.

6 Detailed Analysis–Select Analysis Aircraft

The goal of selecting specific aircraft for detailed analysis is to identify those aircraft that if modeled correctly (so that INM computed SEL equals measured SEL), total sound energy for the GA fleet would be sufficiently close to the sound energy that would result if all evaluated aircraft could be correctly modeled.

6.1 Effect of Correction on Total Sound Energy

First, separately for departures and arrivals, aircraft types were rank ordered by each one's total sound energy using their measured SEL values and the total number of operations at VNY.[23] Next, total fleet sound energy was computed by summing the energy of all aircraft types, using the modeled SEL and weighting each aircraft type by the annual number of operations at VNY. Finally, starting with the highest total energy aircraft type, we sequentially "corrected" each aircraft type's SEL and computed the change in total fleet sound energy until all aircraft SEL values matched their measured levels. Note that "correction" means the computation of sound energy was changed from using the modeled SEL to using the measured SEL.

6.2 Departures

Figure 5 shows how the total energy was reduced by correcting one aircraft at a time. The aircraft types shown on the horizontal axis are arranged from those with the highest energy contribution (H25B) to those with the lowest energy contribution (C510). The maximum improvement is 2.9 dB if all twenty-nine aircraft could be corrected. The correction to total fleet energy was judged sufficient if the selected aircraft when corrected would provide a result within 0.3 dB of this maximum. The criterion level is shown in Figure 5, and the aircraft selected for detailed analysis are listed in Table 7.

The criterion of 0.3 dB from the maximum reduction possible was based on the following reasoning. In modeling, producing results within 0.5 dB of measured levels would normally be considered very accurate (and unusual), and could have served as a reasonable criterion.[24] However, since it may not be possible to correct any selected aircraft so that modeling produces exactly measured levels, and since it is apparent that measured levels for a given aircraft type may vary from airport to airport, we tightened the criterion to 0.3 dB – thus increasing the number of the selected aircraft types.

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[23] Rank orderings differed insignificantly among VNY, HPN and the total for all airports in our database.

[24] In modeling annual ***commercial*** jet operations, accuracy of modeled results can be ± 2 to ±3 dB of measured DNL and can, with very detailed modeling average within ½ dB across several monitor locations. We have found modeling of commercial jets has been improved considerably over the past decade and is quite accurate, if modeled flight tracks, runway use, etc. are accurate.

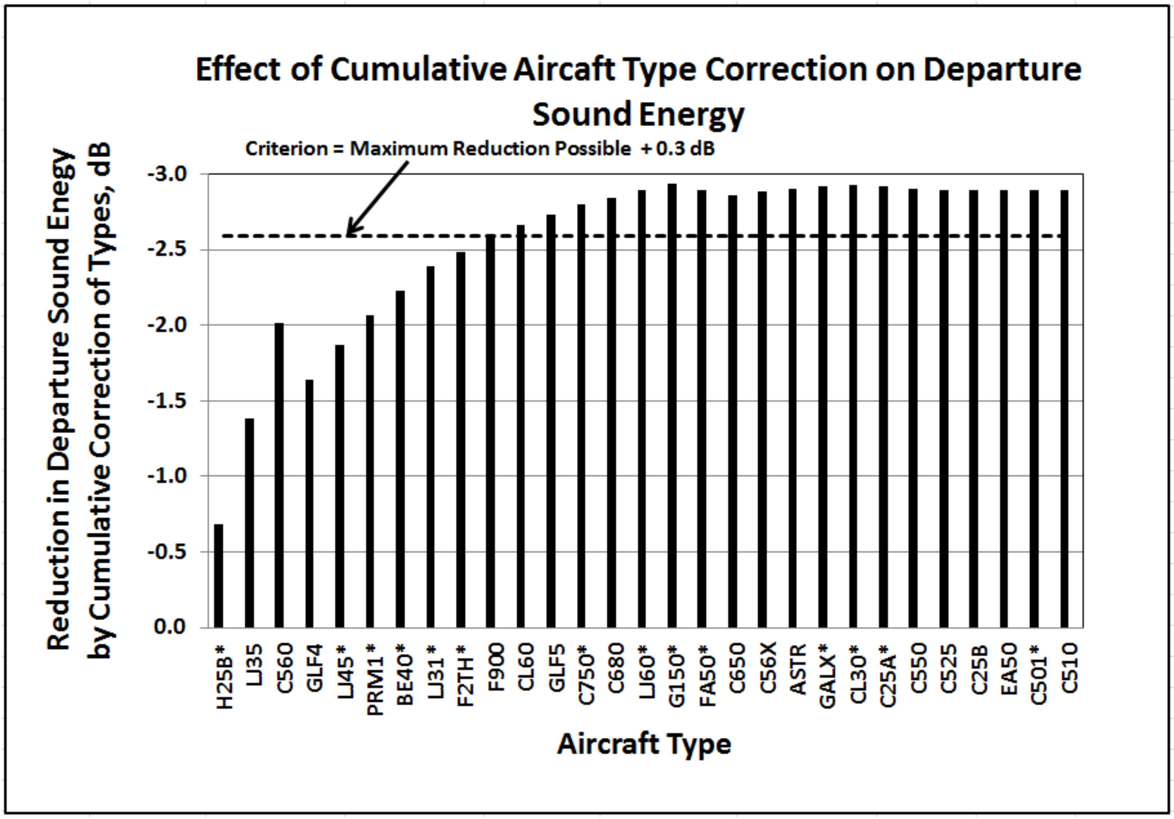

Figure 5 Effect on total departure fleet sound energy of sequentially correcting each aircraft type, from highest contributor of energy to lowest contributor; the selection criterion is shown

Table 7 Aircraft selected for detailed departure analysis, see Figure 5.

Designator of Selected Aircraft	INM Aircraft Type	Measured SEL (dB)	Modeled SEL (dB)	Measured minus Modeled (dB)	Effective Altitude Discrepancy (dB)	Discrepancy if Altitude Corrected (dB)
H25B*	LEAR35*	88.9	94.3	-5.3	-3.14	-8.48
LJ35	LEAR35	86.6	94.1	-7.5	-2.54	-10.06
C560	CNA560E/U	88.8	93.3	-4.5	-2.42	-6.89
GLF4	GIV	87.4	83.5	3.9	-3.47	0.40
LJ45*	LEAR35*	85.2	94.2	-9.0	-2.79	-11.75
PRM1*	LEAR35*	86.1	93.4	-7.4	-3.08	-10.44
BE40*	MU3001*	89.2	93.7	-4.5	-1.76	-6.25
LJ31*	LEAR35*	86.1	93.6	-7.5	-2.35	-9.86
F2TH*	CL600*	86.8	88.9	-2.1	-2.68	-4.79
F900	F10062	89.9	92.0	-2.2	-2.40	-4.58

6.3 Arrivals

Selection of the aircraft types most affecting arrival total energy was accomplished in a manner identical to the selection of departure aircraft, using arrival SEL values and operations numbers.

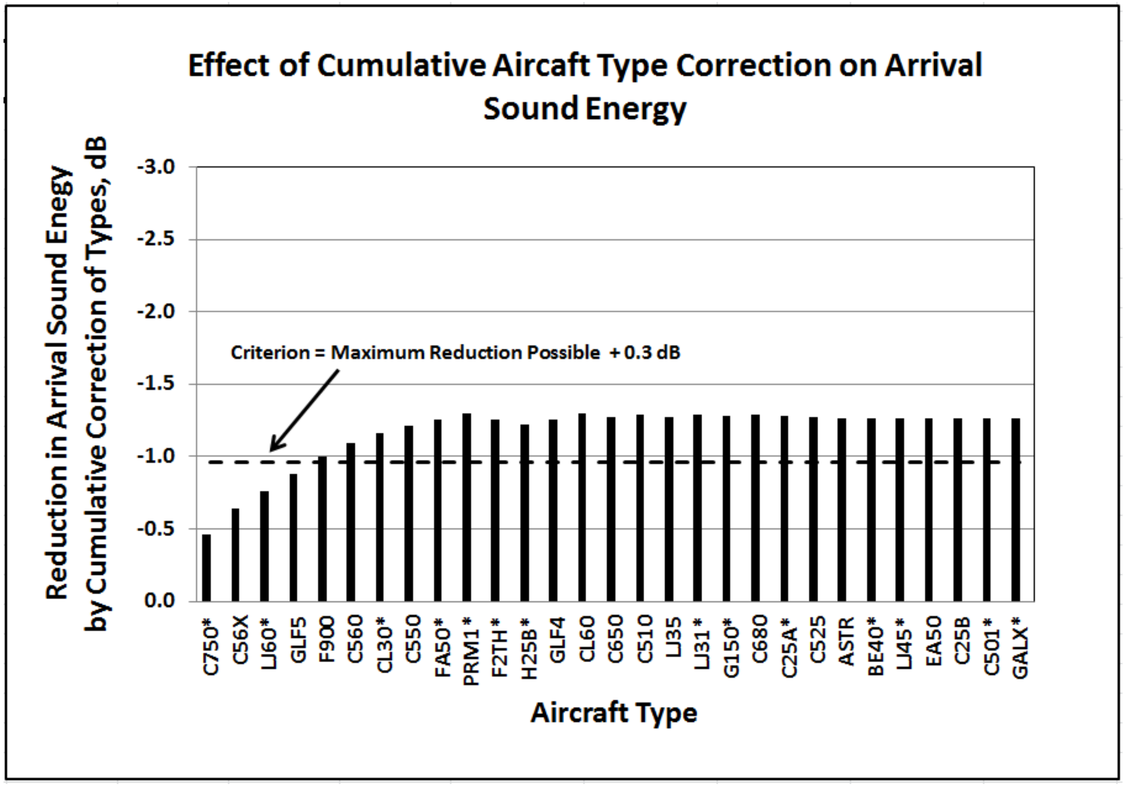

Figure 6 Effect on total arrival sound energy of sequentially correcting each aircraft type, from highest contributor of energy to lowest contributor, and associated selection criterion

Table 8 Aircraft selected for detailed arrival analysis, see Figure 6

Designator	INM Aircraft	Measured SEL (dB)	Modeled SEL (dB)	Measured minus Modeled (dB)	Effective Altitude Discrepancy (dB)	Discrepancy if Altitude Corrected (dB)
C750*	CNA750*	82.3	87.3	-5.0	1.00	-4.04
C56X	CNA560XL	85.3	87.8	-2.6	1.01	-1.54
LJ60*	CNA55B*	81.6	86.3	-4.7	1.14	-3.54
GLF5	GV	83.0	85.2	-2.2	0.90	-1.28
F900	F10062	83.9	88.1	-4.3	1.51	-2.78

7 Detailed Analysis–Causes of Error: Test Examples

As suggested by the Panel, we focused our analysis more on specific details of the aircraft flight profiles in the INM than on the internal workings of the INM. However, we did a review of INM equations and coefficients used for modeling the aircraft. We found that, despite the complexity of some of the equations, most aspects of aircraft performance were weak functions of all but basic assumptions about the fundamental variables of aircraft weight, engine static thrust, and the ratio of drag over lift. We assume that these variables are well known, and should be correct as included in the INM. Consequently, we examined only performance profiles to help identify causes of error. We chose three departure aircraft to explore possible causes of the discrepancies in sound level and altitude. We also provide detailed information about three selected arrival aircraft for future reference and consideration.

We emphasize that in what follows our efforts focused on departures for several reasons. Departures tend to have the greater influence on DNL contours, and are, or should be, more amenable to detailed examination than are arrivals. Departures tend to follow a somewhat standard sequence of application of maximum (or close to maximum) thrust for start of roll through lift off and initial climb, to decelerated climb in favor of speed increase, which may include flap retraction, then change of thrust to climb out. Arrivals, on the other hand, can be highly variable, largely for reasons of air traffic control and maintenance of separation. Additionally, as shown by Figure 6, we expect considerably less improvement in arrival sound energy computation through correction of arrivals than we expect through correction of departures. Arrivals, in fact, are relatively well modeled by the INM. The modeled arrival profiles and actual arrival profiles do not differ by much, in terms of decibels, Figure 6. We judge that reducing what arrival discrepancies exist to be of low priority.

The aircraft departures we have chosen to examine are those for the LJ35, the GLF4, and the EA50. The first two because they are two of the selected aircraft, Table 7, and are not modeled with substitution aircraft types. The EA50 is examined because we have on our team J R Engineering (JRE), the firm that developed the noise and performance profiles for the EA50.[25] Should we want to better understand specifics of how profiles are developed, we have access to their engineers.

The result of this analysis, as will be shown, is that it is likely most error in the INM modeling is caused by significant differences between the standard noise and performance profiles (management of thrust, flaps, speed, climb rates and associated noise-power-distance curves) and actual average practice. Additionally, the noise-power-distance curves (the built in relationships between power and noise as a function of distance from the aircraft) may be incorrect for some aircraft.

In the following presentations, we first provide for each selected aircraft the counts of data points used (valid matches of measured event SEL with flight track) and then reiterate the measured and modeled SEL values and the discrepancies. Three graphics then present the measured and modeled SEL, the measured minus modeled SEL differences, and the measured and modeled altitudes.

7.1 Departures

For each of the three aircraft departures, a final graphic presents all radar returns of the departure altitudes, overlaid with the standard INM altitude profile, and a “best fit” altitude profile based on a new performance profile we developed. For comparison, a polynomial fit to the radar returns is also graphed. For all three cases, the best fit is a result of iterations in the use of thrust, climb rate, speed and flaps to yield the measured altitude at the 12,000 foot track distance and to have the aircraft using the most

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[25] JRE has been involved in over 30 flight test programs ranging from very large jets (Lockheed C-5) to the smallest jets (Eclipse 500) to single engine GA aircraft.

reasonable thrust at that point that produces the best approximation to the desired SEL. The resultant "best fit" discrepancies of SEL and altitude are given.

7.1.1 LJ35

This aircraft is important not only because it is a substitute aircraft for four of the selected nine aircraft, Table 7, but because it is responsible for the largest discrepancies of all the selected departure aircraft. Table 9 and Table 10 provide basic information about the data used and the measured / modeled comparisons. Figure 7 shows the complete database of measured and modeled SEL as a function of track distance from runway takeoff end. To demonstrate the trends of the data, we plot a linear least-squares fit line.[26] Figure 7 and Figure 8 suggest that the discrepancy decreases with increasing track distance. Figure 9 shows clearly that the modeled altitude profile is higher, at least initially, than most actual altitudes.

Table 9 LJ35 sample size of database by airport

Number of Tracks w/ SEL		
Airport	A	D
BED	7	60
BWI	10	59
DEN	3	0
FXE	879	518
HPN	283	35
VNY	1191	1059
TOTAL	2373	1731

Table 10 LJ35 measured and modeled departure results summarized

Designator	INM Aircraft Type	Measured SEL (dB)	Modeled SEL (dB)	Measured minus Modeled (dB)	Effective Altitude Discrepancy (dB)	Discrepancy if Altitude Corrected (dB)
LJ35	LEAR35	86.6	94.1	-7.5	-2.5	-10.1

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[26] The actual change of SEL with track distance would unlikely be linear, but the linear relationship was used to provide a simple comparison of the trend with distance.

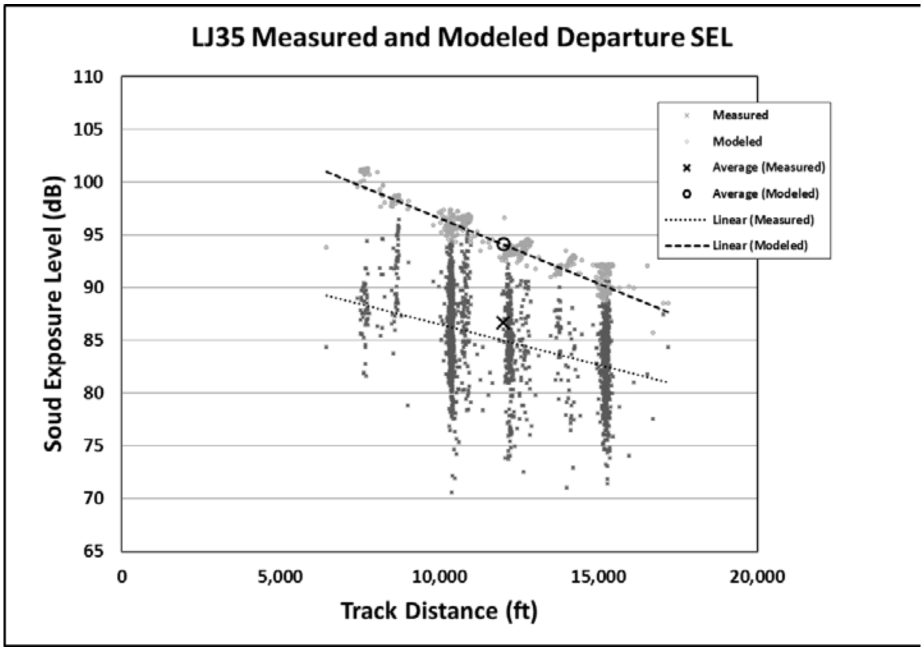

Figure 7 LJ35 measured and modeled departure SEL

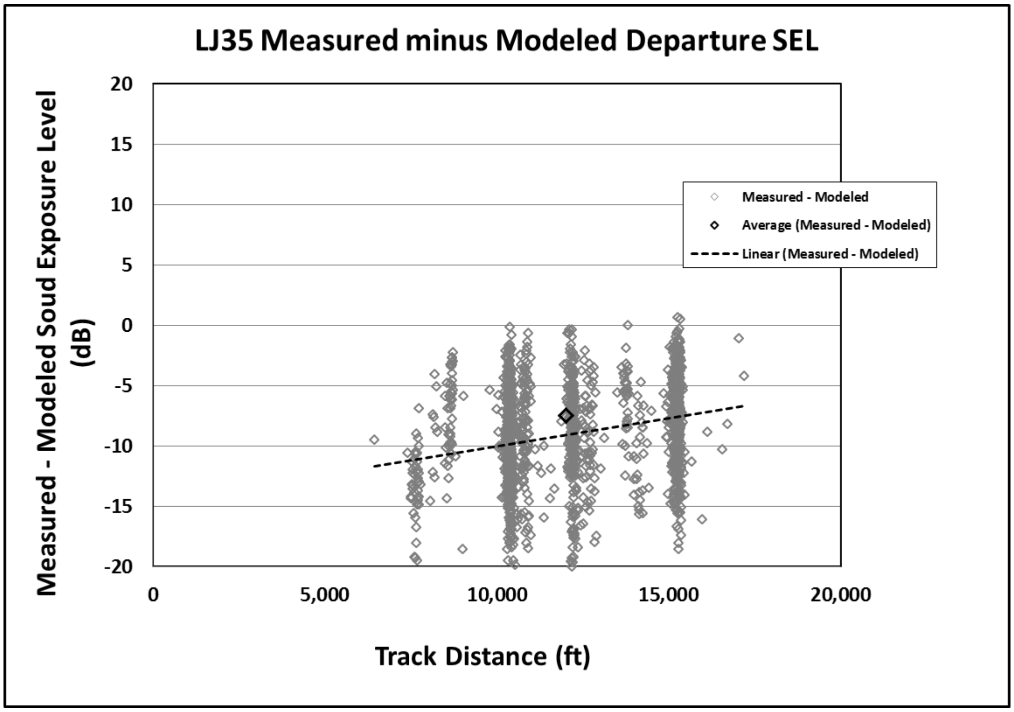

Figure 8 LJ35 measured minus modeled departure SEL

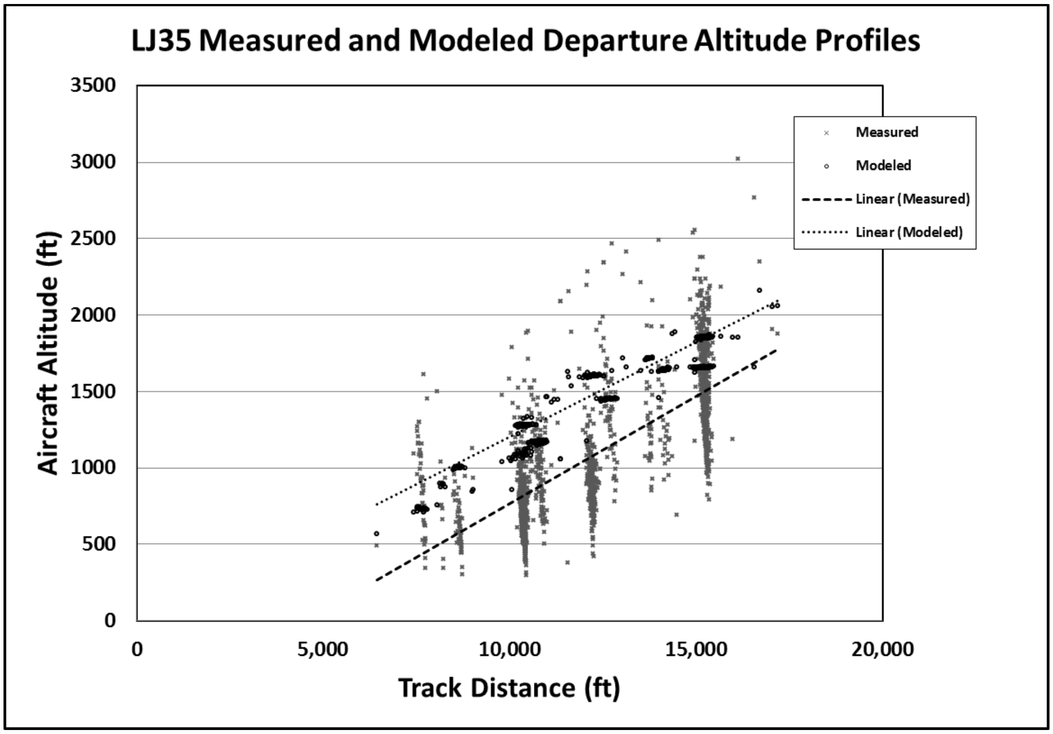

Figure 9 LJ35 measured and modeled departure altitude profiles

Figure 10 compares the standard INM LJ35 departure profile, all the radar returns, the best fit profile and a polynomial fit. The red lines identify the 12,000 foot track distance used for all departure discrepancy calculations and the average radar altitude at that track distance.[27] The measured minus modeled SEL discrepancy with the best fit profile is now -5.2 rather than -7.5. The modeled altitude is 5 feet higher than the measured altitude. It is noteworthy that the SEL discrepancy could not be made smaller while keeping the weight, thrust and speed within reasonable performance bounds. Consequently, we conclude that the NPDs (noise-power-distance curves) associated with this aircraft are incorrect and too loud as a function of thrust. This error, assuming our analysis is correct, can go a long way to explaining why the modeled GA jets are so generally louder than the measured levels since the LJ35 is a substitution for four other aircraft and with similar SEL discrepancies, see Table 7.

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[27] Details of the parameters of the best-fit profile are presented in Appendix E page 73.

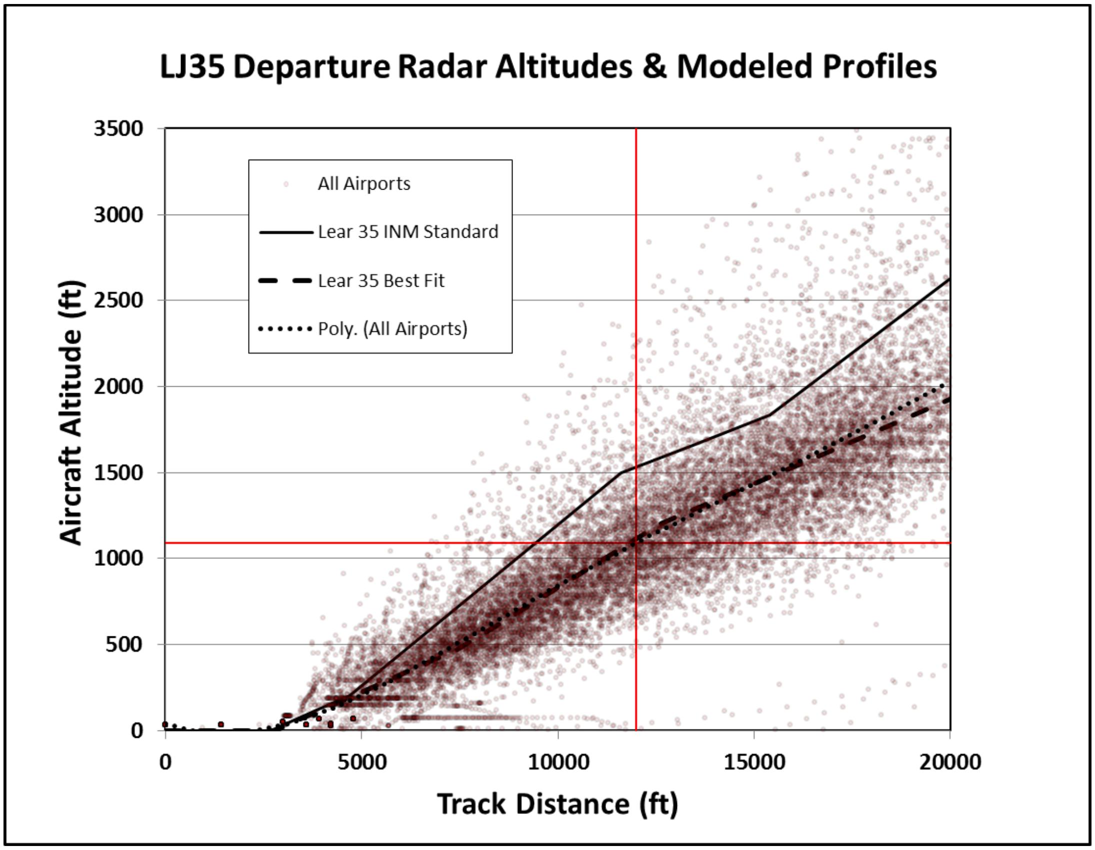

Figure 10 LJ35 departure altitudes: all radar data, INM, best fit, and polynomial fit

7.1.2 GLF4

The GLF4 was chosen for detailed analysis because its discrepancy is positive – the INM modeled SEL is *lower* than the measured SEL, while its altitude is higher than the measured altitudes. Hence, correcting the altitude may reduce the discrepancy. Table 11 and Table 12 provide basic information about the data used and the measured / modeled comparisons. Figure 11 shows the complete database of measured and modeled SEL as a function of track distance from runway takeoff end. Figure 11 and Figure 12 show that the discrepancy decreases with track distance. Figure 13 shows clearly that the modeled altitude profile is higher, and increasingly so at greater track distances.

Table 11 GLF4 sample size of database by airport

Number of Tracks w/ SEL		
Airport	A	D
BED	98	319
BWI	95	23
DEN	5	0
FXE	87	75
HPN	2355	228
VNY	2978	3159
TOTAL	5618	3804

Table 12 GLF4 measured and modeled departure results summarized

Designator	INM Aircraft Type	Measured SEL (dB)	Modeled SEL (dB)	Measured minus Modeled (dB)	Effective Altitude Discrepancy (dB)	Discrepancy if Altitude Corrected (dB)
GLF4	GIV	87.4	83.5	3.9	-3.5	0.4

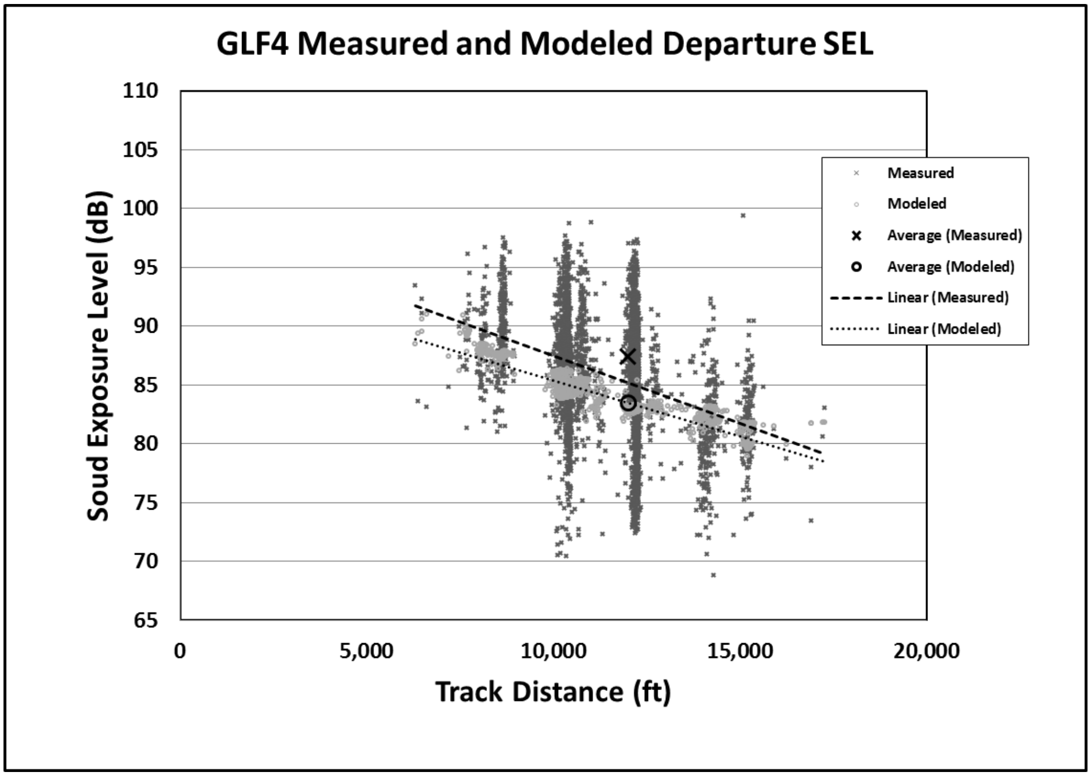

Figure 11 GLF4 measured and modeled departure SEL

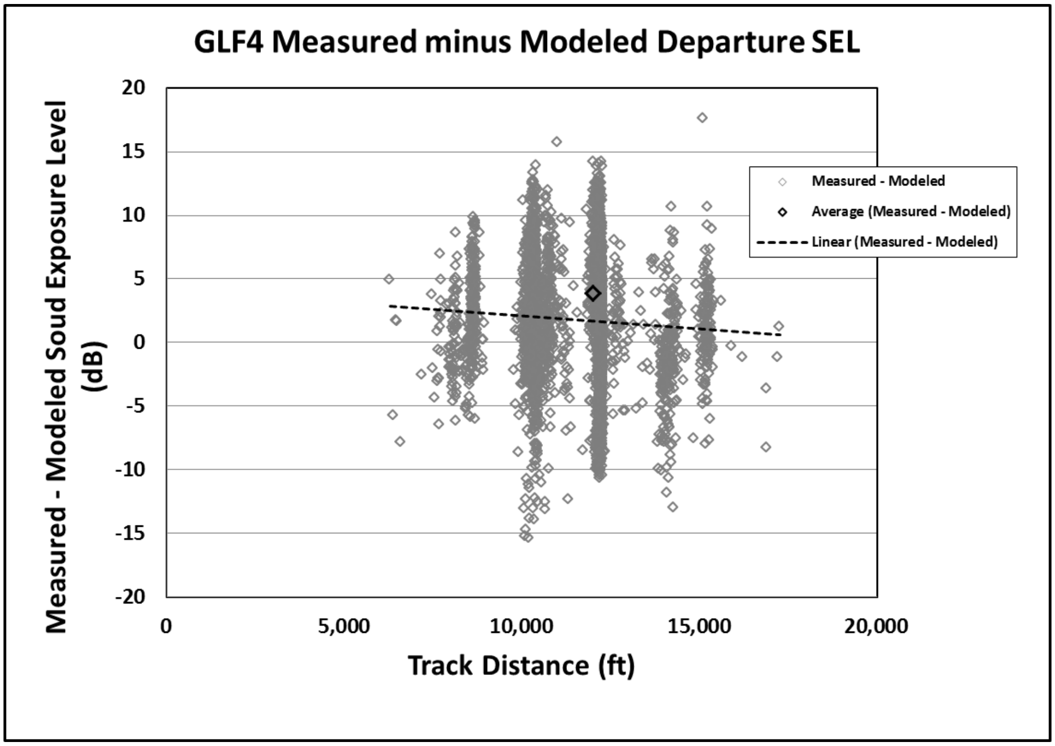

Figure 12 GLF4 measured minus modeled departure SEL

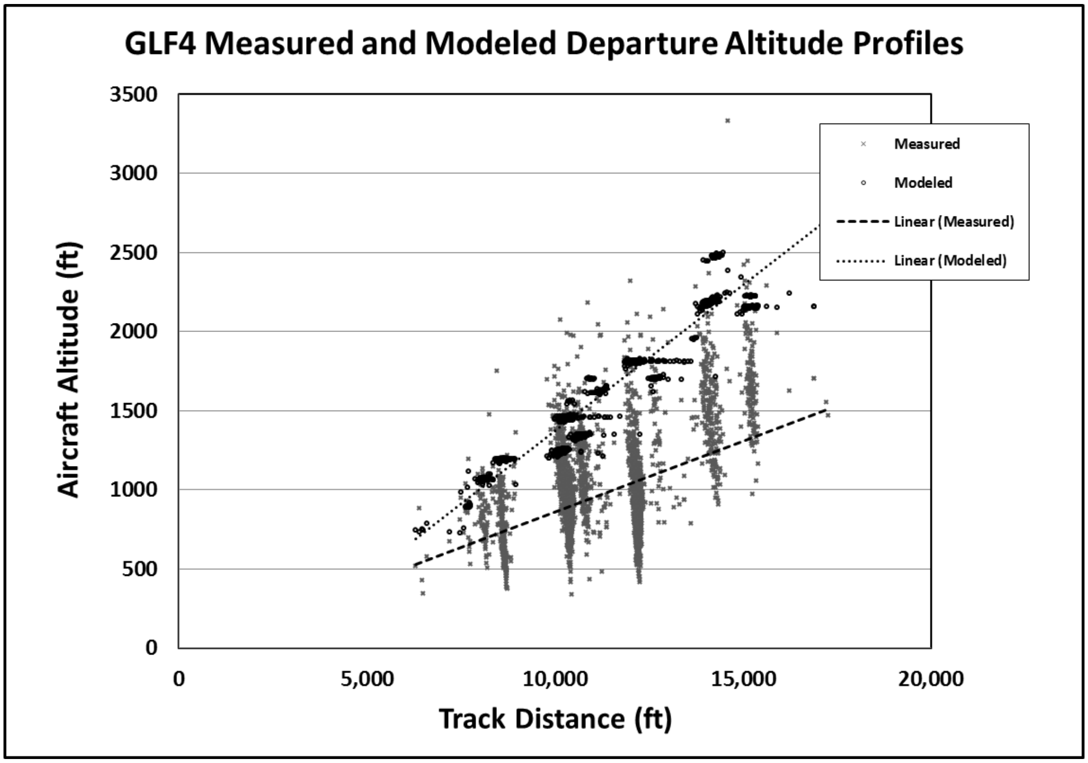

Figure 13 GLF4 measured and modeled departure altitude profiles

Figure 14 compares the standard INM GLF4 departure profile, all the radar returns, the best fit profile and a polynomial fit.[28] The measured minus modeled SEL value with the best fit profile is now -0.2 rather than +3.9. The modeled altitude is 16 feet lower than the measured altitude.

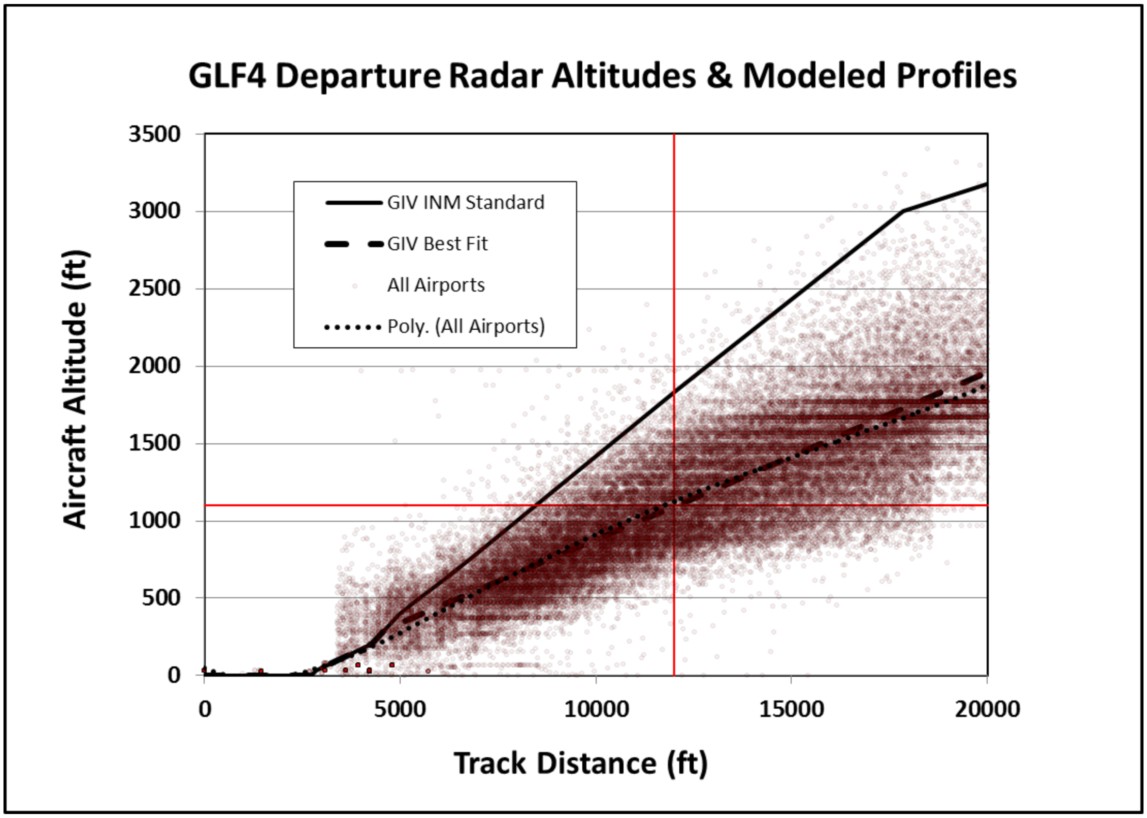

Figure 14 GLF4 departure altitudes: all radar data, INM, best fit, and polynomial fit

7.1.3 EA50

The EA50 was chosen because it is a recently added type and, as mentioned, the firm that conducted the certification tests and developed the performance information, JRE, is on our team. After Panel review of this report, we will discuss with JRE their understanding of the standard profiles that are in the INM, and their role in developing the Eclipse profiles and NPD curves. Table 13 and Table 14 provide basic information about the data used and the measured / modeled comparisons. Figure 15 shows the complete database of measured and modeled SEL as a function of track distance from runway takeoff end. Figure 15 and Figure 16 show that the discrepancy decreases slightly with track distance. Figure 17 shows clearly that the modeled altitude profile is higher, and increasingly so at greater track distances.

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[28] Details of the parameters of the best-fit profile are presented in Appendix F, page 74.

Table 13 EA50 sample size of database by airport

Number of Tracks w/ SEL		
Airport	A	D
BED	3	28
BWI	0	0
DEN	1	0
FXE	4	0
HPN	80	11
VNY	116	160
TOTAL	204	199

Table 14 EA50 measured and modeled departure results summarized

Designator	INM Aircraft Type	Measured SEL (dB)	Modeled SEL (dB)	Measured minus Modeled (dB)	Effective Altitude Discrepancy (dB)	Discrepancy if Altitude Corrected (dB)
EA50	ECLIPSE500	80.0	76.3	3.7	-3.9	-0.2

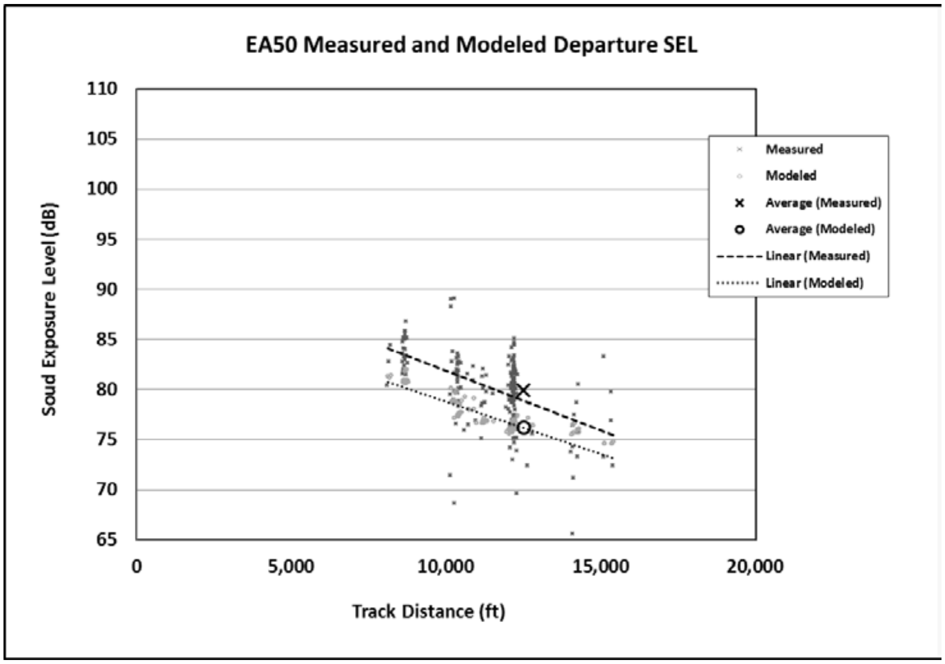

Figure 15 EA50 measured and modeled SEL

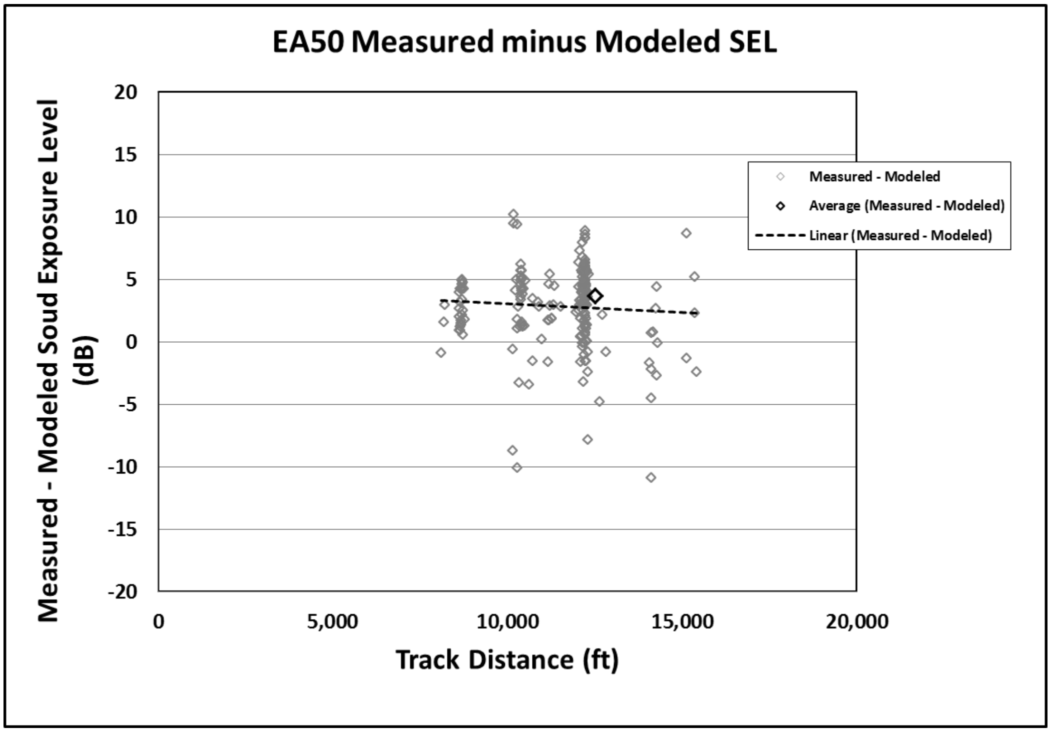

Figure 16 EA50 measured minus modeled departure SEL

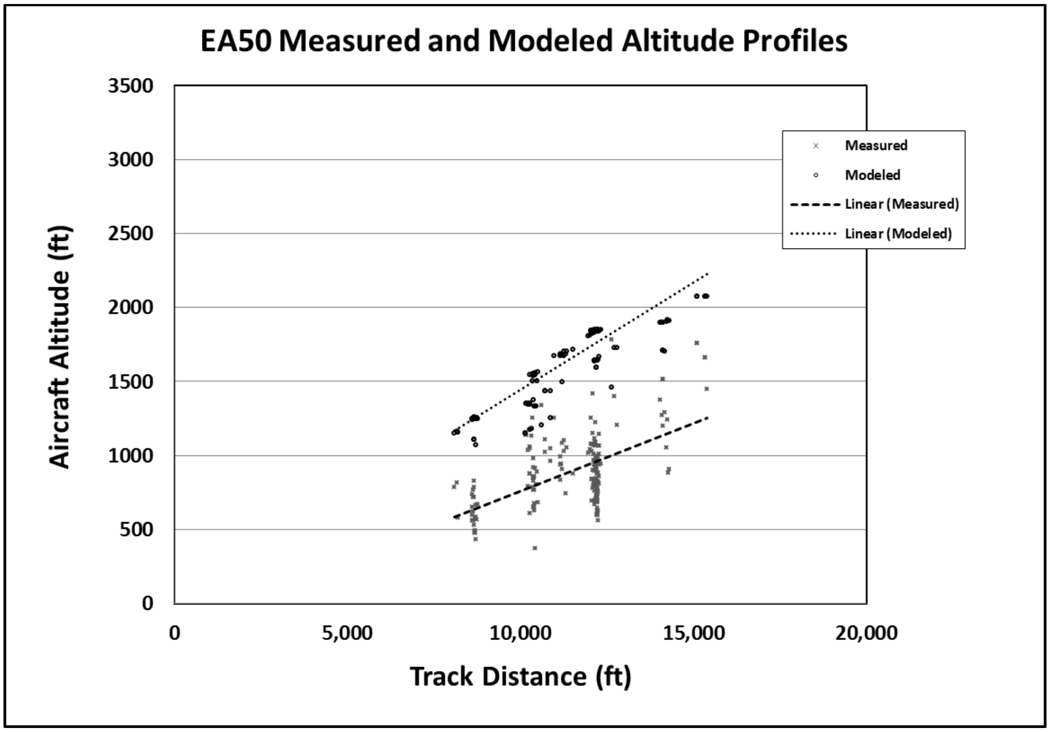

Figure 17 EA50 measured and modeled departure altitude profiles

Figure 18 provides the comparison of the standard INM EA50 departure profile with all the radar returns, the best fit profile and a polynomial fit.[29] The measured minus modeled SEL value with the best fit profile is now +0.4 rather than +3.7. The modeled altitude is 7 feet higher than the measured altitude.

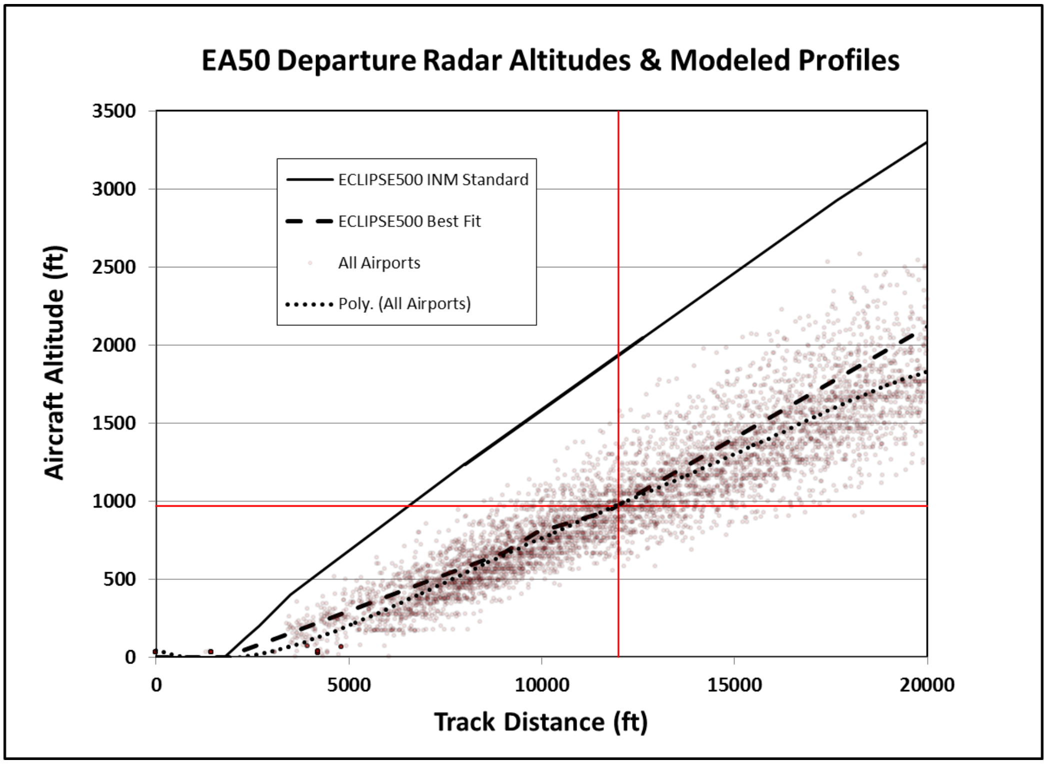

Figure 18 EA50 departure altitudes: all radar data, INM, best fit, and polynomial fit

7.2 Arrivals

The same basic information and graphs provided above for departures in Section 7.1 are provided below for the selected arrival aircraft of C56X, FLG5 and F900. These are chosen because of the five arrival aircraft, they are the three that do not use substitution aircraft. As discussed above, alternative arrival profiles have not been developed.

Examination of the data on the following three aircraft suggests several generalizations. First, SEL discrepancies tend to decrease with increasing track distance. Second, measured SEL values and hence, discrepancies are widely scattered – somewhat more so than is the case with the departure SELs. Finally, measured arrival altitudes tend to be close to the modeled altitudes at the shorter track distances, higher than the modeled altitudes at the middle distances, and lower than modeled at the furthest track distances. All this points to the complexity of arrivals and the likelihood that best fit arrival profiles will need to be a complex sequence of changes in thrust, descent rate and speed changes.

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[29] Details of the parameters of the best-fit profile are presented in Appendix G, page 75.

7.2.1 C56X

Table 15 C56X sample size of database by airport

Number of Tracks w/ SEL		
Airport	A	D
BED	69	290
BWI	49	69
DEN	14	0
FXE	87	39
HPN	2388	64
VNY	853	910
TOTAL	3460	1372

Table 16 C56X measured and modeled arrival results summarized

Designator	INM Aircraft	Measured SEL (dB)	Modeled SEL (dB)	Measured minus Modeled (dB)	Effective Altitude Discrepancy (dB)	Discrepancy if Altitude Corrected (dB)
C56X	CNA560XL	85.3	87.8	-2.6	1.01	-1.54

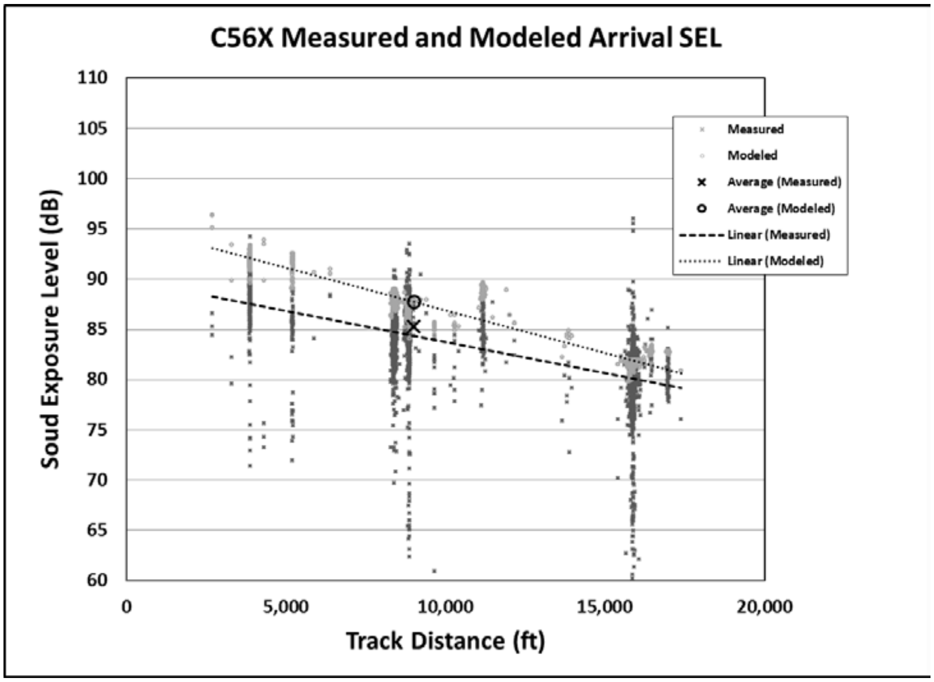

Figure 19 C56X measured and modeled arrival SEL

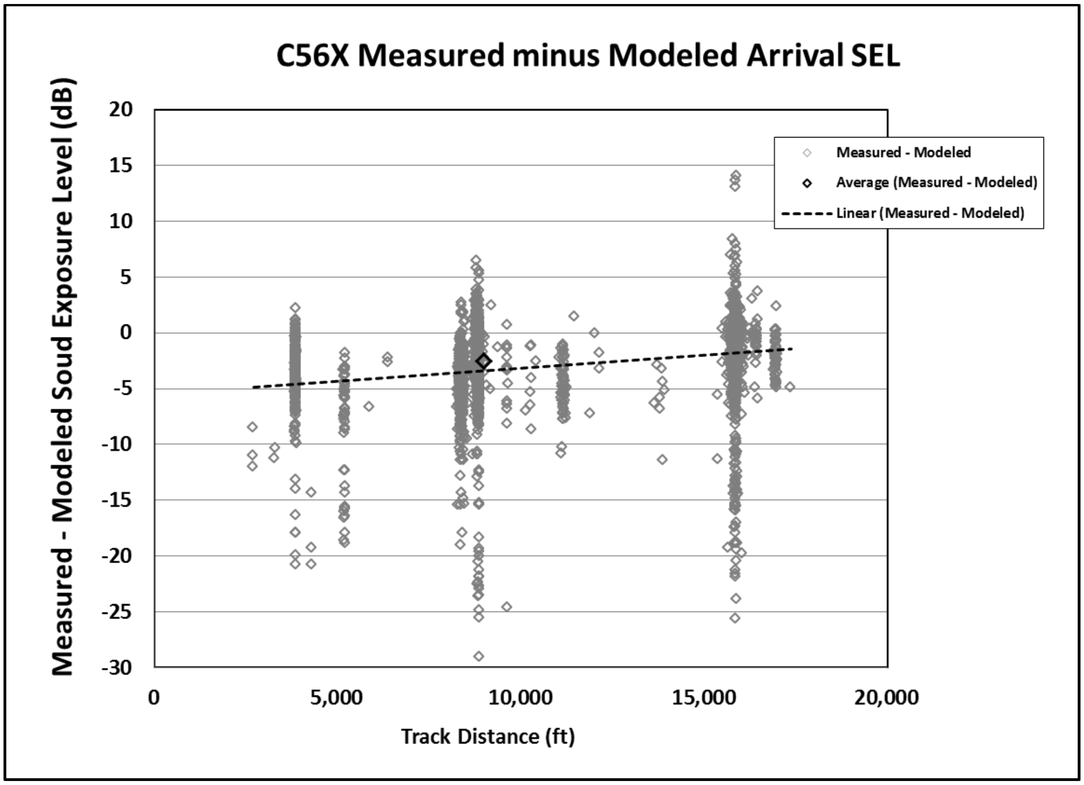

Figure 20 D56X measured minus modeled arrival SEL

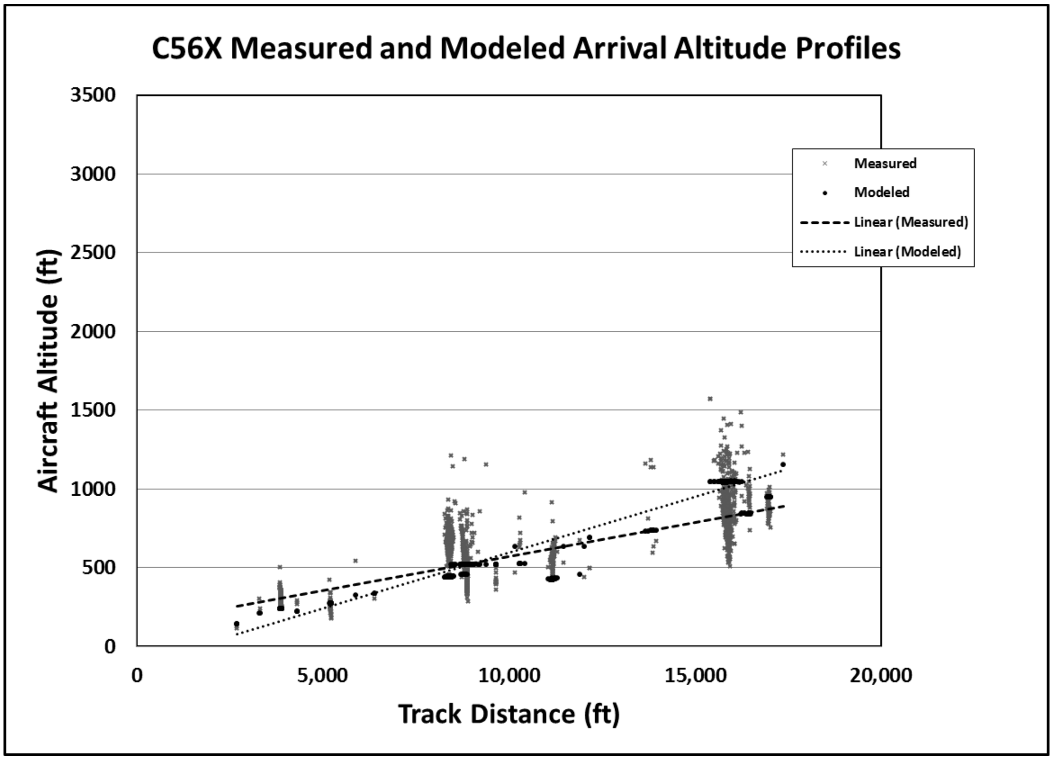

Figure 21 C56X measured and modeled arrival altitude profiles

7.2.2 GLF5

Table 17 GLF5 sample size of database by airport

Number of Tracks w/ SEL		
Airport	A	D
BED	23	85
BWI	25	9
DEN	3	0
FXE	35	29
HPN	1054	86
VNY	1107	1138
TOTAL	2247	1347

Table 18 GLF5 measured and modeled arrival results summarized

Designator	INM Aircraft	Measured SEL (dB)	Modeled SEL (dB)	Measured minus Modeled (dB)	Effective Altitude Discrepancy (dB)	Discrepancy if Altitude Corrected (dB)
GLF5	GV	83.0	85.2	-2.2	0.90	-1.28

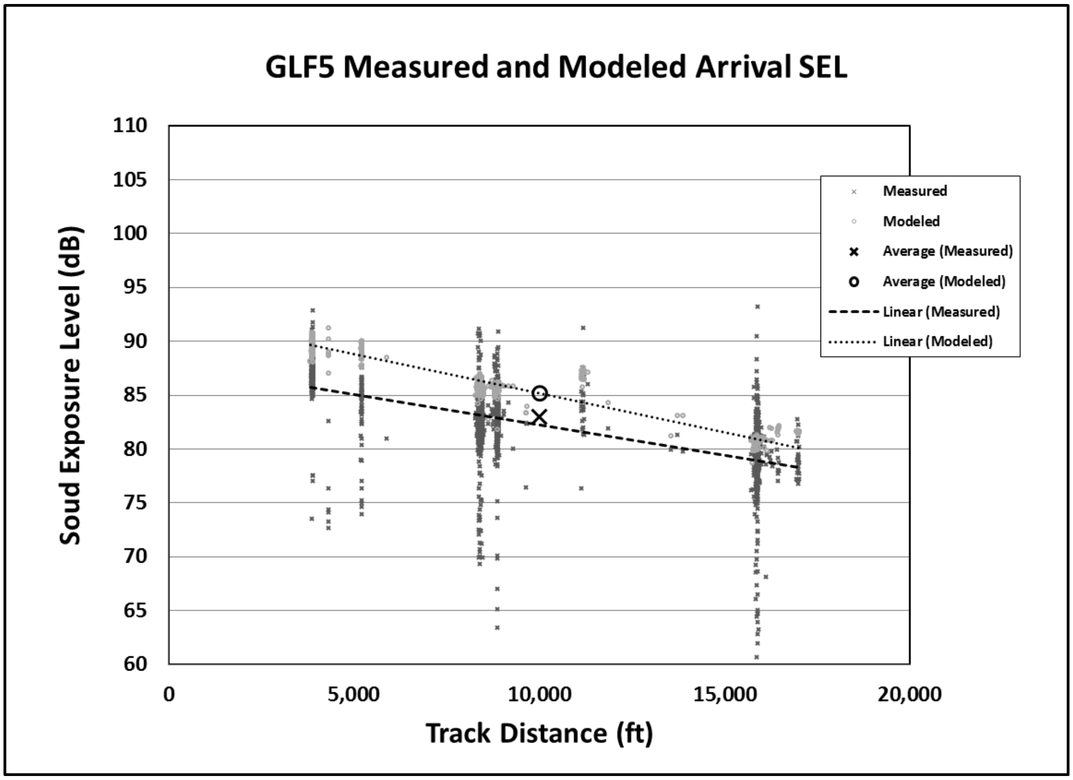

Figure 22 GLF5 measured and modeled arrival SEL

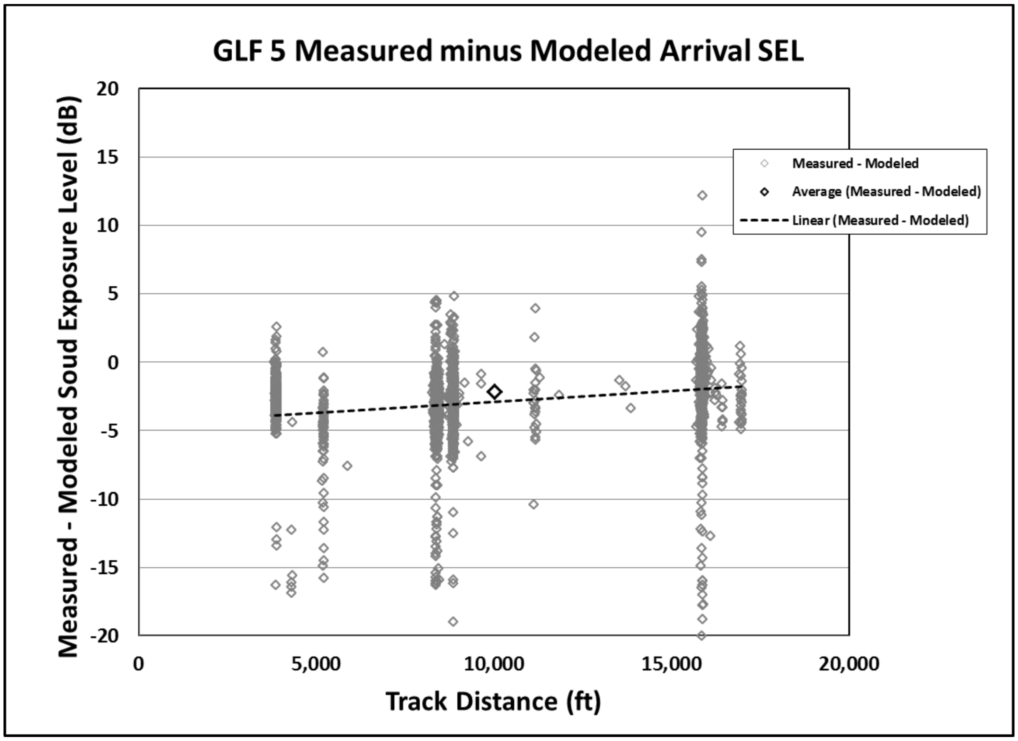

Figure 23 GLF5 measured minus modeled arrival SEL

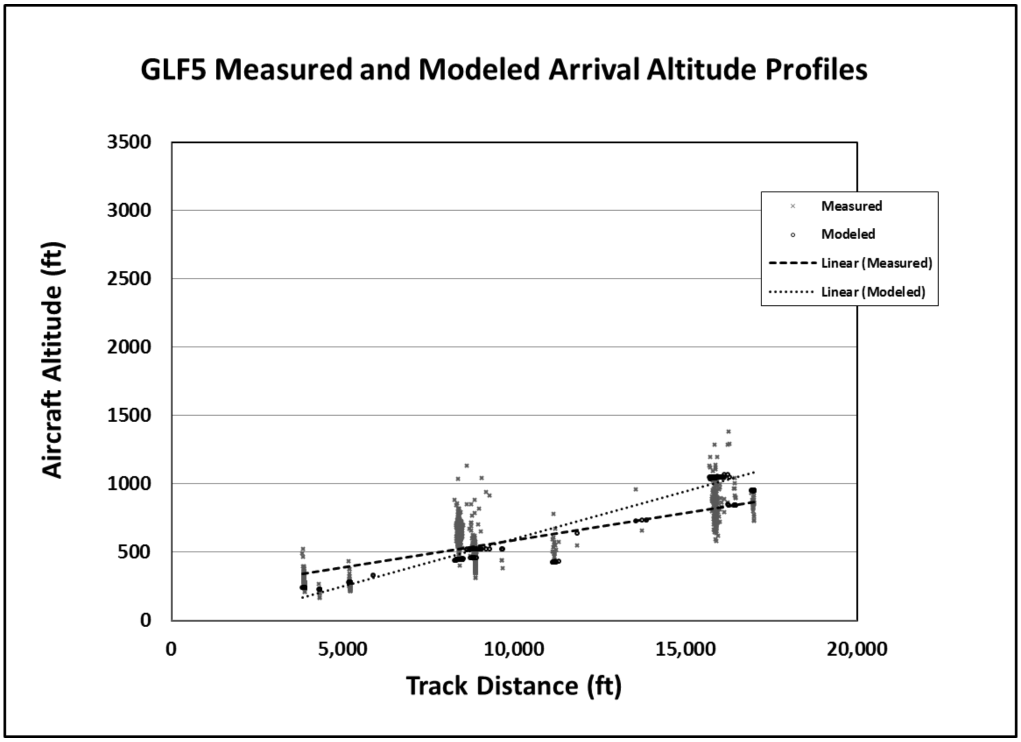

Figure 24 GLF5 measured and modeled arrival altitude profiles

7.2.3 F900

Table 19 F900 sample size of database by airport

Number of Tracks w/ SEL		
Airport	A	D
BED	0	0
BWI	24	10
DEN	0	0
FXE	0	0
HPN	0	0
VNY	325	340
TOTAL	349	350

Table 20 F900 measured and modeled arrival results summarized

Designator	INM Aircraft	Measured SEL (dB)	Modeled SEL (dB)	Measured minus Modeled (dB)	Effective Altitude Discrepancy (dB)	Discrepancy if Altitude Corrected (dB)
F900	F10062	83.9	88.1	-4.3	1.51	-2.78

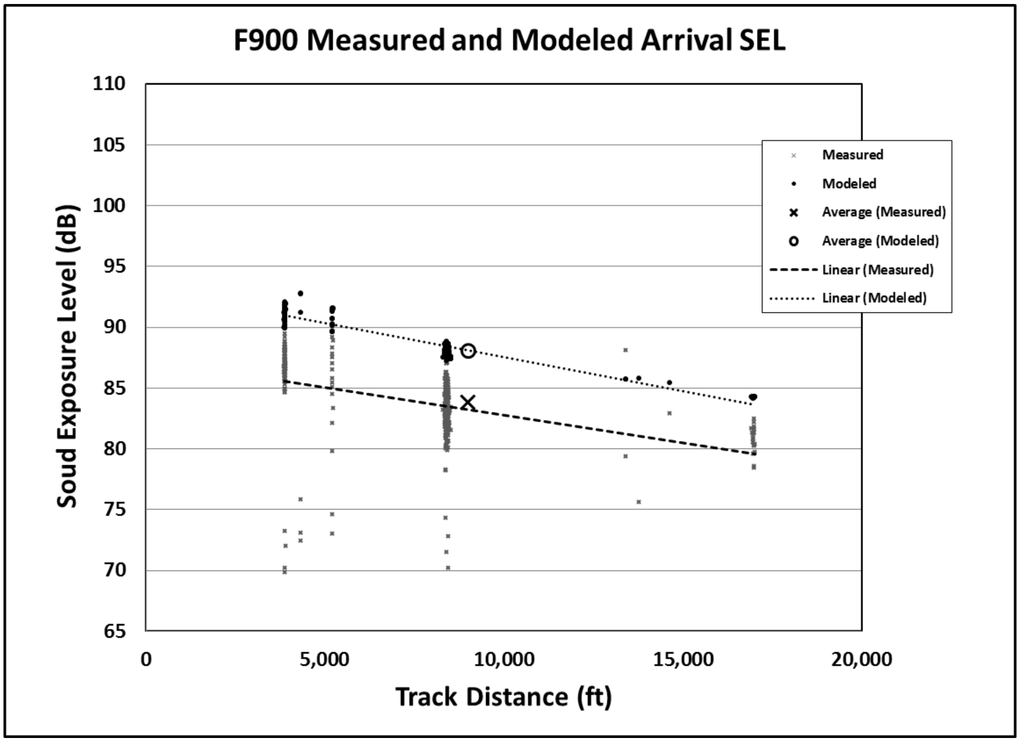

Figure 25 F900 measured and modeled arrival SEL

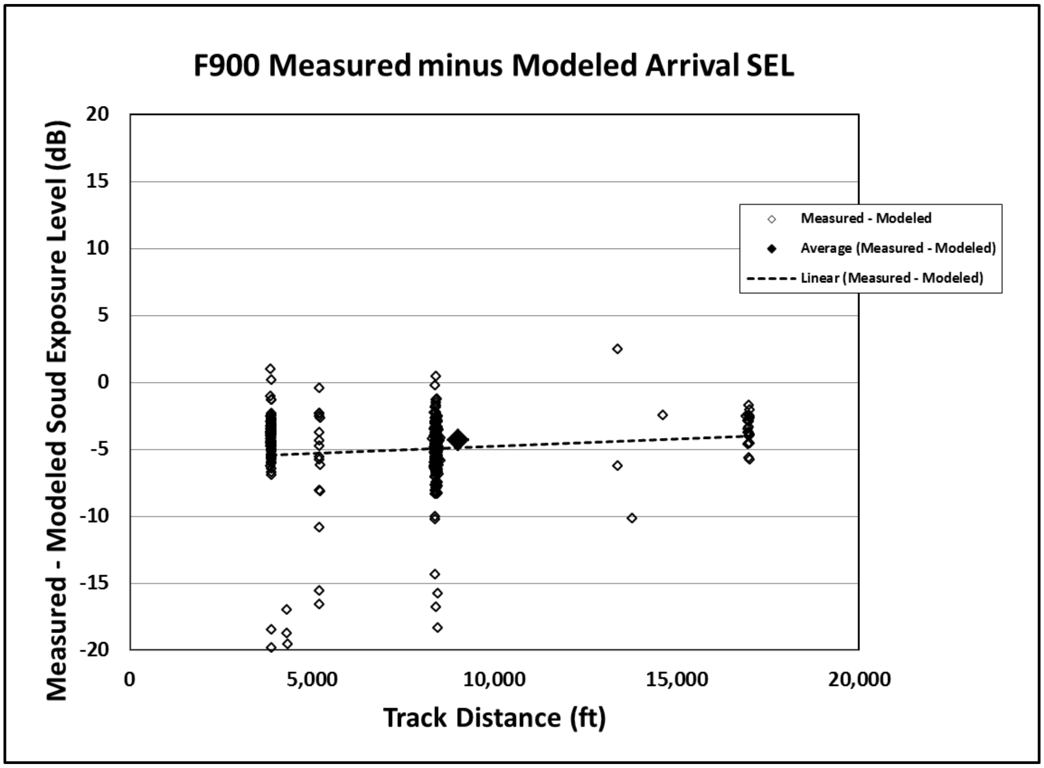

Figure 26 F900 measured minus modeled arrival SEL

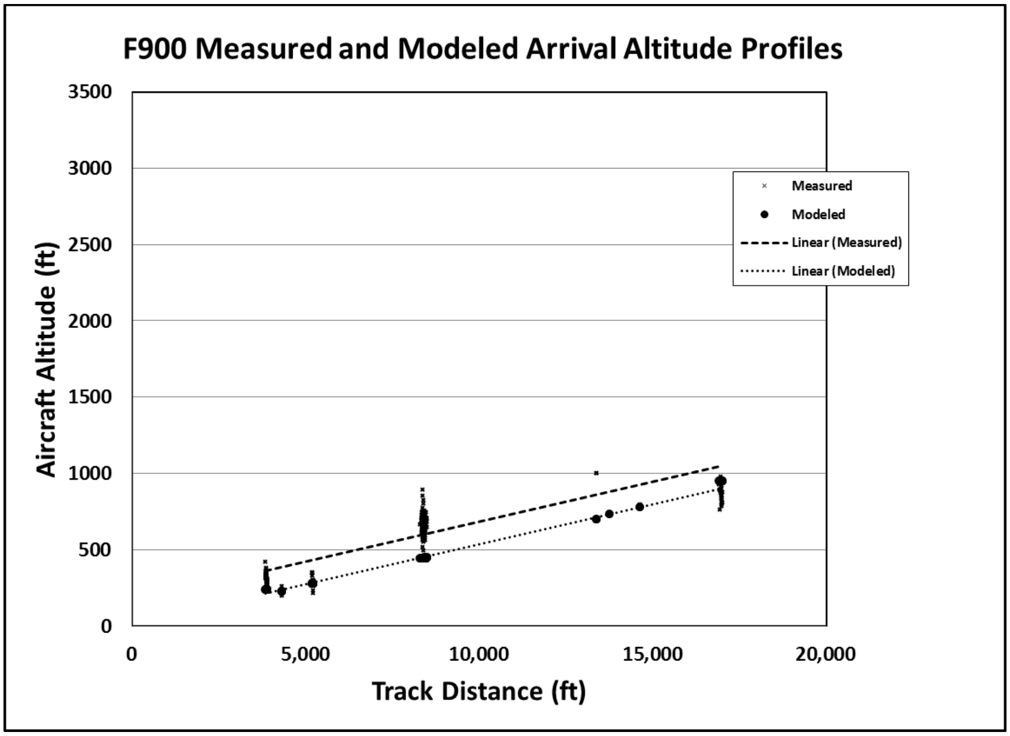

Figure 27 F900 measured and modeled arrival altitude profiles

8 Potential Solutions

As shown in Sections 4 through 7, the INM standard departure profiles for GA jet aircraft produce discrepancies in noise levels and have steeper ascents than those observed for actual operations. The general cause for these discrepancies is the use of maximum thrust departures as standard INM input. As shown earlier; by creating user defined INM profiles which empirically lower thrust levels, both altitude and noise levels can be made to match observations. With this empirical observation in place we then sought out a more operationally motivated reason to explain why aircraft would use reduced thrust during departure. A limited survey of manufacturers, operators and pilots was conducted and it was determined that operating the aircraft with reduced thrust has both economical and operational benefits and is often the preferred method for departure.

Section8.1 describes how derated takeoff thrust is commonly implemented in the aircraft by using the Assumed Temperature Method (ATM) departure. Section 8.2 describes the two methods used to test incorporating these derated thrust procedures into the INM. The goal of analyzing the two methods presented in this section is to test the procedures, judge the results *vis à vis* the measured data and the relative difficulty of each, and draw conclusions about whether to recommend one method for implementation.

8.1 Derated Thrust; Assumed Temperature Method

The Assumed Temperature Method (ATM) for applying de-related thrust for departure operations is a process where an aircraft Flight Management System (FMS) is asked to compute the thrust required to safely depart the aircraft from a given runway while demanding a decreased level of engine performance. When using the ATM, the FMS computes the required ground roll and engine performance required for operating at an increased airfield temperature. The aircraft is then operated at the lower, actual airfield temperature. The net result is a departure operation requiring a longer takeoff roll and using less engine thrust. ATM departures will overall result in less wear to an engine and airframe and can therefore be economically advantageous to operators.

When compared to an INM standard departure profile an ATM departure also has a significant effect on aircraft noise levels. Aircraft using the ATM produce less thrust and noise but also depart at lower altitudes. In some cases these two factors result in lower sound levels on the ground, but they can also “cancel out” with the decreased thrust producing lower noise and the lower altitude producing higher noise. However, the specific trade-offs and on-the-ground results are highly dependent on individual aircraft type.

8.2 Methods for Applying Derated Thrust in INM to Provide Realistic Results

Applying the ATM derated thrust to aircraft in the INM can be accomplished through two general methods. These are labelled here for convenience, “ATM1” and “ATM2.”

1) ATM1 – This method requires determining the specific thrust levels for ATM operations from manufacturer or operator surveys then creating custom profiles to match these inputs.

2) ATM2 – This is a more efficient method that first uses the INM’s internal computation processes to determine the aircraft departure profile, including thrust levels and other profile parameters at an assumed elevated temperature. The resulting departure data are then converted into a static “profile points” style profile which is then input into the INM and run at the normal or average airfield temperature.

Both of these processes were evaluated using the GIV and Lear35 INM types and used as a check on the validity of each method when compared to the measured results and radar profile data described in the earlier part of this report, Sections 4 through 7. The ATM2 method was also used to evaluate the CNA560E INM type and compared to radar data. Figure 28, Figure 29, and Figure 30 show the resulting altitude / distance plots for the observed radar data as well as the resulting ATM1 and ATM2 profiles. The computation methods are described next in Sections 8.2.1 and 8.2.2.

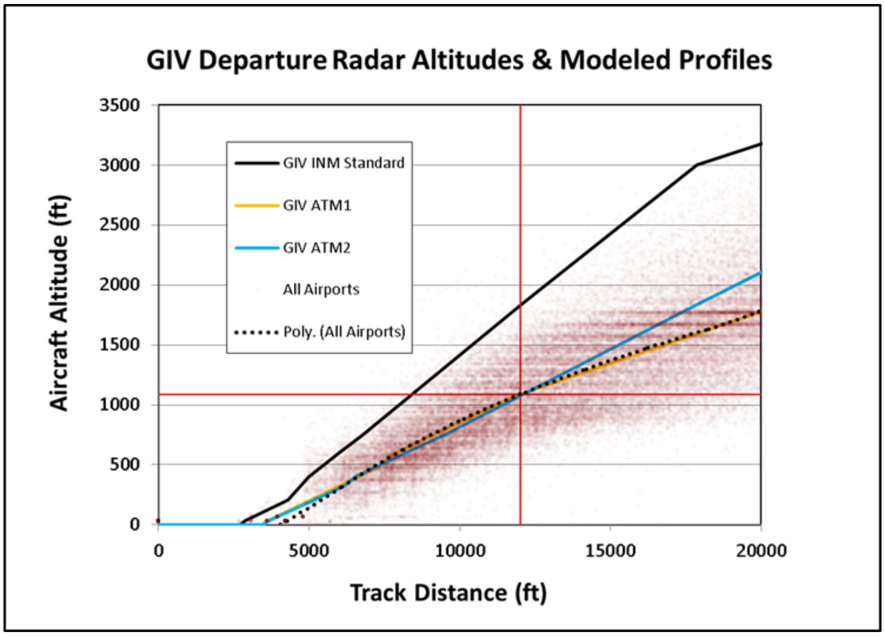

Figure 28 GIV departure altitudes: all radar data, ATM profiles and polynomial fit

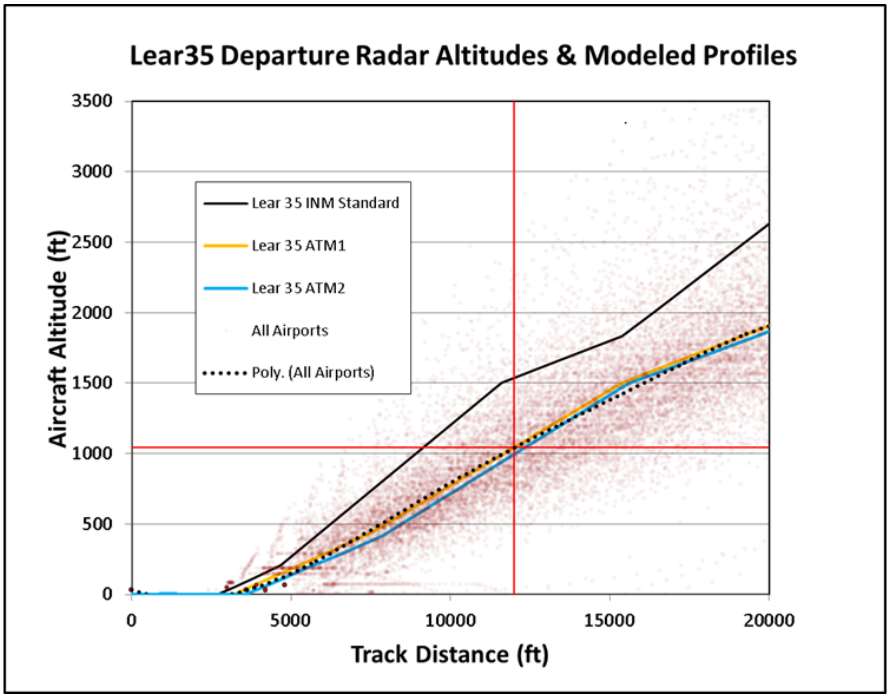

Figure 29 Lear35 departure altitudes: all radar data, ATM profiles and polynomial fit

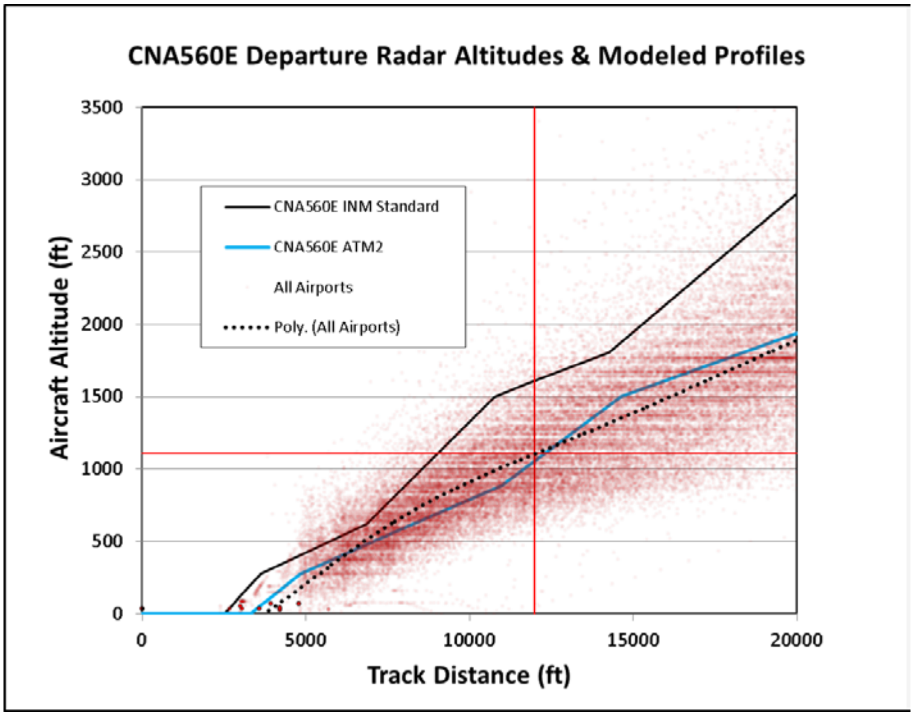

Figure 30 CNA560E departure altitudes: all radar data, ATM2 profile and polynomial fit

8.2.1 Using Specific Profile Definitions from Operator and Manufacturer Surveys (ATM1 profiles)

This method for introducing reduced thrust for an INM aircraft departure involves changing the thrust coefficient given in INM "Thrust Jet"[30] database where, as described in INM 7.0 User's Guide Section 9.11, the thrust for a given jet engine is described as:

Equation 1 INM Thrust Jet

$$\frac{F_n}{\delta} = E + FV_c + G_a A + G_b A^2 + HT$$

Where:

- F_n is the Net thrust per engine in pounds;
- δ is the ratio of the atmospheric pressure to sea-level standard pressure;
- E is the coefficient equal to the static net corrected engine thrust at sea level pressure;
- F is the airspeed correction coefficient;
- G_a and G_b are altitude correction coefficients; and
- H is temperature correction coefficient.

To change the computed thrust due to the ATM, the E coefficient is altered to match thrust levels either provided by the manufacture or derived (using the Thrust General coefficients) for reduced thrust.

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[30] Thrust Jet (thr_jet.dbf): This is the fundamental database (or table) that contains for each jet, for each operational mode of departure (takeoff, climb, etc.) a set of data (lines) giving the coefficients for computing the net correct lbs. thrust per engine for each mode. For some aircraft, the INM also has a Thrust General (thr_gnr.dbf) database that permits computation of lbs. thrust per engine using alternative thrust related metrics of N1 (percent maximum engine RPM) or EPR (engine pressure ration), see discussion below of Lear35 thrust modifications.

Adjustments to the speed coefficients (G_a , G_b) in theory are also required; however a new regression analysis using complete performance data for aircraft flying ATM profiles would be required to derive these speed coefficients and is outside of scope of this project. As an approximation, the existing speed coefficients were used; recall that in Section 2.1.6, the *E* coefficient is the dominant factor in the thrust equation and small discrepancies in the *G* coefficients will not result in significant discrepancies to calculated thrust. As a validation for this assumption a sensitivity analysis using manufacturer provided thrust data was done for the GIV aircraft and is described in the next Section.

GIV Aircraft ATM Thrust jet and profile modifications:

Validity of Leaving Speed Coefficient Unchanged for Thrust Determination

Gulfstream Aerospace provided four thrust values for the GIV aircraft: ATM thrusts at 0 Kts and at 160 Kts; max thrust at 0 Kts and at 160 Kts. The max thrust at 0 Kts was equal to the max thrust used by the INM and simply validated the INM Standard profile thrust parameter. The other thrusts were used first to examine the effects of not modifying the speed coefficient contained in the INM and second, to develop ATM.

First, to examine the effect of the speed coefficient, the standard INM departure profile was run to determine the thrust it calculates at 160 Kts. The result (10,813) is given in Table 21 and compared with the Gulfstream provided max thrust at 160 Kts (10,892). Next, the Gulfstream provided ATM thrust at 0 Kts was used in the INM to compute a resultant thrust at 160 Kts (8,533) and compared with the Gulfstream ATM thrust at 160 Kts (8,791). Table 21 also shows this comparison. The discrepancy between the INM computed thrust and the ATM 160 Kts thrust is larger, however this discrepancy is relatively small compared with the relative thrust change between the max thrust levels and the ATM thrust levels. The result was therefore considered accurate enough to use unchanged speed coefficients for developing ATM1. Final implementation of this method into the INM would require new speed coefficients for fully accurate INM computation of ATM thrust levels and profile.

Table 21 Relative discrepancy due to speed coefficients

INM calculated	Gulfstream Provided	%Difference
GIV Max Thrust Departure (lbs. 160 Kts at Sea Level)		
10,813	10,892	0.7%
GIV ATM Thrust Departure (lbs. 160 Kts Sea Level)		
8,533	8,791	2.9%

Table 22 compares the Thrust General coefficients of the INM standard takeoff parameters with the ATM1 coefficients where the *E* coefficient is set to the static ATM departure thrust level provided by Gulfstream. The ATM1 value for the *E* coefficient is what was used for the start of takeoff segment in modeling the ATM1 GIV departure.

Table 22 Standard vs. ATM1 thrust general coefficients

Mode	E	F	G_a	G_b	H
Max Thrust (STANDARD)	13725.0	-18.20000	0.318900	-0.00002	0.000
ATM1 (Gulfstream)	11445.0	-18.20000	0.318900	-0.00002	0.000

Completion of ATM1 for GIV

To complete development of ATM1, the appropriate cutback thrust and associated altitude for the change to climb thrust was required. Standard INM GIV procedure profiles have a significant thrust cutback around 400 ft. as the aircraft transitions from a takeoff to climb segment. When the ATM profile is used, the amount of thrust cutback applied during this Standard transition is no longer as appropriate. From an interview with a Gulfstream jet pilot (telephone interview with Charles Saul) as well as information from the VNY Clay Lacy survey, typical ATM departures do appear to have thrust cutback during this transition however they are not as significant a cutback or as soon as that used during the Standard takeoff. To compensate for this longer acceleration period, the ATM thrust was used up to 2000 ft. before beginning an INM climb segment. For aircraft without significant changes between takeoff and climb thrust segments this adjustment should not be needed. The INM Standard and ATM1 profiles are shown in INM format in Appendix H as tables Table 36 and Table 37 respectively as well as plotted above on Figure 28.

LEAR35 Aircraft ATM Thrust jet modifications:

In addition to applying this approach to the GIV it was also applied to the Lear35 INM type; however detailed ATM thrust levels were not obtainable so an interpolated approach using data within the INM was used in conjunction with information obtained from an operator survey conducted previously.

In addition to the Thrust Jet database, which INM uses to calculate the thrust in lbs. for given operational configurations, speeds and temperatures, as mentioned in Footnote 30 there is also a Thrust General database available for reference use in calculating thrust levels at more discrete settings using other thrust metrics. This database contains thrust coefficients similar to those described in Equation 1, however additional *K* coefficients are now included which allow for thrust to be calculated as a function of aircraft engine operating parameters EPR and N1.

In general terms, N1 and EPR are non-dimensional parameters used by the aircraft flight management systems (FMSs) to monitor the thrust and operational state of an engine.

- N1 is proportional to the engine's rotational fan speed and is measured in values of 0%-100%
- EPR is proportional to the engine's internal to external pressure ratio and generally falls in a range between 1 and 2, however this range is unique to each engine model.

Equations for thrust as a function of *N1* and *EPR* are given below:.

Equation 2 INM Thrust General for EPR

$$\frac{F_n}{\delta} = E + FV_c + G_a A + G_b A^2 + HT + K_{1a}(EPR) + K_{1b}(EPR)^2$$

Equation 3 INM Thrust General for N1

$$\frac{F_n}{\delta} = E + FV_c + G_a A + G_b A^2 + HT + K_2(N1_c) + K_3(N1_c)^2$$

$$N1_c = \frac{N1}{\sqrt{\theta}};$$

$$\theta = \text{ratio of the temperature at the airplate to the sea} - \text{level standard temperature}$$

For the Lear35, an operator survey from Clay Lacy Aviation at VNY provided a typical engine N1 setting of approximately 95% for Lear 35 departures. The N1 value can then be used with Equation 3 to determine the corresponding thrust level. We accepted this reduced thrust level as equivalent to an ATM thrust and can be used to create an updated ATM Thrust Jet entry where the *E* coefficient from Equation 1 is equal to the ATM thrust determined from Equation 3.

One additional complication to this approach is that the INM does not include Thrust General coefficients for the LEAR35. To approximate this lack of Thrust General coefficients, an average ratio between the maximum thrust level at N1=100% and the desired N1=95% can be calculated using aircraft in a class similar to the Lear35, but for which Thrust General coefficients are available.

Based on general size and engine thrust the CNA55B, CNA560E and CNA525C aircraft were selected to define this surrogate average. These aircraft have Thrust General coefficients in the INM. Table 23 lists these three comparable aircraft and the LEAR35, giving maximum takeoff weight and maximum thrust. Using an N1 of 95% in Equation 3 for the three comparables, the overall average yields 86.3% of the maximum N1=100% thrust.

Table 23 Lear35 surrogate aircraft N1 comparisons

Aircraft	MTOW Lbs.	Max Takeoff Thrust, lbs. (=100%)	N1=95% in Equation 3 gives, lbs	Resulting %Thrust
LEAR35	18,300	3,412.2		
CNA55B	16,950	2,658.7	2302.4	86.6%
CNA560E	14,800	3,316.5	2875.4	86.7%
CNA525C	16,300	3,464.1	2968.7	85.7%
Average % Thrust				**86.3%**

Using the 86.3% thrust average calculated in Table 23, a new ATM user defined Thrust General *E* coefficient of 2945.8 is then calculated for the Lear35 ATM departure. As with the GIV, the speed coefficients are left unchanged which may introduce a small percent thrust error, but not of significant level to impact the overall description. Table 24 gives the final Thrust General ATM coefficients.

Table 24 Lear35 thrust jet coefficients

Mode	E	F	G_a	G_b	H
Max Thrust (STANDARD)	3412.2	-3.88800	-0.00441	0.00000154350	0.000
ATM (interpolated)	2945.8	-3.88800	-0.00441	0.00000154350	0.000

The resulting profiles are as shown plotted on Figure 29, above.

8.2.2 Using INM to Produce Assumed Temperature Method (ATM2) Profiles

In addition to the method described in Section 8.2.1 a separate approach to applying ATM profiles provides a less direct, but more approachable process. Analogous to how the aircraft FMS is given an elevated temperature with which to compute departure profile information, the INM flight profile output using an elevated temperature and standard procedure profile can be used to create an ATM fixed point profile to be run at the actual airfield temperature.

The temperature adjustment selected by the FMS for actual aircraft operations is dependent on multiple factors including runway length, obstacle clearance and other safety considerations. As it is not possible to account for all of these considerations in this test case, a temperature adjustment was selected allowing for the best fit altitude distance profile compared to actual operations as presented in the radar data.

The base INM case for this study used a Temperature of 59.9°F based on an average of the six study airports where the elevated temperatures evaluated will start with this as their base.

GIV Aircraft ATM Case Temperature Adjustment

The best fit GIV ATM profile as shown in Figure 28 was achieved with an assumed temperature of 107°F. The fixed point profile used is shone below in Table 38, Appendix I. One failing with this approach is that thrust changes are applied along the entire profile and not just during takeoff. From an interview with a Gulfstream pilot (Charles Saul) as well as information from the VNY Clay Lacy survey, typical ATM operations do appear to have thrust cutback in the initial climb segments after takeoff; however they are not as significant a cutback as used during takeoff.

The standard GIV procedure profiles have a significant thrust cutback around 400ft as the aircraft transitions from a takeoff to climb segment. When this ATM approach is applied to the thrust settings above 400 feet, the thrust is therefore reduced more than is appropriate. To compensate for this thrust settings above 400ft, they were scaled up by one third to bring them in line with thrust values calculated in Section 8.2.1 from the data provided by Gulfstream. The resulting profile in INM profile points format in shown in Appendix I, Table 38 and plotted in Figure 28.

For aircraft without significant changes between Takeoff and climb thrust segments this adjustment should not be needed.

Lear35 Aircraft ATM Case Temperature Adjustment

The best fit Lear35 ATM profile as shown in Figure 29 occurred for an assumed temperature of 120°F. . The resulting profile in INM profile points format is shown in Appendix I, Table 39.

CNA560E Aircraft ATM Case Temperature Adjustment

One significant advantage to this method for generating ATM profiles is that there is not an explicit reliance on data external to the INM to generate inputs. As an example of this process, the ATM2 method was used to generate a reduced thrust CNA560E profile. In discussions with Cessna Aviation as well as a Cessna 560 pilot, no separately defined ATM procedure is in place for any Cessna business Jet aircraft. As show in Figure 30 however, applying this ATM methodology and comparing it to radar provides excellent agreement to the flown profiles. The best fit CNA560E ATM profile as shown in Figure 30 occurred for an assumed temperature of 110°F. The resulting profile in INM profile points format is shown in Appendix I, Table 40.

8.3 Noise Results for Assumed Temperature Method Profiles

The ATM profile modifications described in Section8.2 were conducted initially without consideration to noise levels. This was done in an effort to establish that the correct physics was occurring with the derated thrust departures in use. Once the ATM profile was created, the measured vs. modeled noise value at a point 12,000 feet from the runway end was evaluated to determine if the use of derated thrust could obtain a good match for both the altitude profile and noise levels. Where agreement between measured and modeled values was not obtained, the profile was further evaluated to be sure no additional modifications were necessary.

GIV noise level comparisons and considerations:

As described in Section 8.2 the initial ATM profiles generated were modified to better match the takeoff to climb transition the aircraft are observed to be flying. The parameters by which these modifications were made were evaluated against their noise results to come up with the best match.

Table 25 describes the final Thrust, Altitude and noise values for the GIV for the Standard and ATM profiles. With the ATM profiles in place there is now agreement within 20ft of altitude and less than a half dB in Noise compared to greater than 600 ft discrepancy in altitude and a 3dB discrepancy in noise.

Table 25 GIV noise measured vs. modeled noise levels

Profile	INM NPD	Thrust lbs.	Altitude ft.	SEL dB Noise Levels		
				Modeled	Measured	Difference
Observed Radar Data			1,088		87.4	
STANDARD	TAYGIV	9,097	1,758	84.2	87.4	-3.2
ATM1	TAYGIV	8,722	1,078	87.0	87.4	-0.4
ATM2	TAYGIV	8,721	1,060	87.5	87.4	0.1

Lear35 noise level comparisons and considerations:

As described in Section 8.2 no additional profile modifications beyond the thrust reductions were needed for the Lear35. Despite this level of agreement with the altitude profile, using the default Lear35 INM Noise Power Distance (NPD) curve resulted in modeled noise levels approximately 8dB above the measured values.

The INM defines the Lear35 as using the Garrett/Honeywell TFE731-2 engines which are assigned to the TF731 NPD curves. With the noise discrepancy of about 8dB of what is observed in the measurements, it appears that these NPD curves are incorrect for the current Lear35 fleet and do not accurately represent the observed noise levels.

A possible explanation for the discrepancy could be that the original prototype of the Lear35 used the early stage TFE731-2 engine (the INM TFE7312 NPD) which was later updated to the TFE731-2b engine before the initial production run[31]. There is no additional information within the INM for the TFE731-2b engine; however the difference in modeled minus measured noise level is possible if the active Lear35 fleet uses a variant of the TFE731 engine different from what was used for the original INM certification of NPD levels.

To test this assumption, the TF7313 NPD curves (for the TFE731-3 engine, the successor to the TFE731-2 engine), were used with the Lear35 and ATM profiles. Table 26 describes the final Thrust, Altitude and noise values for the Lear35 for the Standard and ATM profile. With the ATM profiles in place and using the TF7313 NPD curves there is now a good agreement in altitude and less than a one dB difference in noise compared to a greater than 8dB difference for the INM standard inputs.

Table 26 Lear35 noise measured vs. modeled noise levels

Profile	INM NPD	Thrust lbs.	Altitude ft.	SEL dB Noise Levels		
				Modeled	Measured	Difference
Observed Radar Data			1,041			
STANDARD	TF7312	2,788	1,524	94.7	86.6	8.1
ATM1	**TF7313**	2,329	1,024	86.8	86.6	0.2
ATM2	**TF7313**	2,377	976	87.4	86.6	0.8

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[31] Janes' All the World's Aircraft 1980-81 Page 342

CNA560E noise level comparisons and considerations:

As described in Section 8.2 no additional profile modifications beyond the thrust reductions were needed for the CNA560E.

Table 27 describes the final Thrust, Altitude and noise values for the CNA560E for the Standard and ATM2 profile where with the ATM profile in place there is now a high agreement in altitude and less than a one dB difference in noise. Noise levels for the Standard profiles also agree with the measurement levels however the altitude of the Standard is approximately 500ft above what is observed. Introducing the ATM profiles allow for both the altitude and noise levels to agree.

Table 27 CNA560E noise measured vs. modeled noise levels

Profile	INM NPD	Thrust lbs.	Altitude ft.	SEL dB Noise Levels		
				Modeled	Measured	Difference
Observed Radar Data			1,106			
STANDARD	2PW535	2,840	1,596	88.8	88.8	0.0
ATM2	2PW535	2,473	1,030	89.2	88.8	0.4

8.4 Similarity to Commercial Jet Operation

Commercial jet departure operations also use reduced or derated thrust. Another ACRP study, 02-55, Enhanced AEDT Modeling of Aircraft Arrival and Departure Profiles, is exploring developing standard profiles that include reduced thrust procedures. Eventually, some standardization across all jet aircraft reduced thrust departures could be thought desirable, though from the findings of this study, the possibility of consistency is judged remote because of how different the methods of implementation are likely to be. Commercial jet aircraft continuously record all engine and flight parameters, providing the types of data pursued in this study. GA jets rarely have on-board equipment to record such data, and hence the techniques for developing appropriate departure profiles are likely to remain quite different for the two classes of aircraft.

9 Suggested Implementation Plan

9.1 ATM Implementation Options

As shown in Section 8, underlying changes to GA jet thrust settings must be applied to match observations in both aircraft profile altitudes and noise levels. Using the Assumed Temperature Method as a guide to adjust the thrust is the most direct and consistent method for altering thrust levels. It is this study's conclusion that incorporated the ATM as a procedure, based on ATM2, to be followed by INM modelers at airports where GA jets are an important contributor to community noise exposure would be useful. The following two subsections elaborate on why this is the conclusion. Section 9.2 describes implementation plans for both ATM1 and ATM2. ATM1 is included as further background that supports the conclusion. Section 9.3 provides cost estimates.

9.1.1 Not a Preferred Option – Implementation of ATM1

Using the ATM1 method described in Section 8.2.1 would require updated Thrust Jet data in order to make reduced thrust departure profiles available as standard INM input. Generating these inputs would require coordination with aircraft manufacturers (as with the GIV evaluated in Section 8.2.1). Where updated information from manufactures is not available, an expanded operator survey and interpolated analysis (as with the Lear35 evaluated in Section 8.2.1) will be necessary to assemble the needed Thrust Jet inputs.

Evaluation of not just the *E* thrust coefficient but the *G* speed coefficients with additional data not available for this project will be needed in order to complete any new Thrust Jet entries in the standard INM database. (See Equation 1, page 53, Equation 2, page 55 and Equation 3, page 55.) Additionally, standard profile procedures will need to be evaluated and potentially modified to be consistent with reduced thrust profiles, especially for profiles with segments incurring large thrust changes.

Though Gulfstream was extremely helpful, for them to provide the information required some time from an engineer and not all manufacturers can be expected to have the resources to devote to this effort. Additionally, some of the aircraft are no longer manufactured and it is unlikely a manufacturer or engineer will be able to access the data needed to provide the information. Finally, locating an available pilot or operator able to discuss their procedures will be difficult, and even if there are pilots available, their information is likely to be in terms of EPR or N1, and there may be insufficient information in the INM database to translate these variables into the pounds thrust required for modeling.

9.1.2 Preferred Option – Development of guidelines for applying ATM2

Using the ATM2 method described in Section 8.2.2, no radar data, measured sound levels, pilot or manufacturer information is needed, however detailed guidance is necessary to ensure consistency of application. Conversion of profiles from the standard procedure database to the static profile points format that results from the ATM2 method creates profiles tailored to airport and runway layout and to the modeled temperature. These profiles are created as user defined input.

The major variable in the ATM2 method will be choosing the assumed temperature for creating the profile. Profiles built in Section 8.2.2 relied on a target altitude and noise level at a defined evaluation location, derived from empirical radar and noise monitoring data, which in practice will not be readily available for most noise modeling.

Where radar data are not available for a direct altitude validation, a relatively straight forward process will be described in the guidelines. All that needs to be known by the modeler is a modeling temperature, which is required in any case for INM modeling, and the approximate length of takeoff roll used by the

GA jets to be modeled. The guidelines will describe the use of an assumed temperature that will provide the profile, which is then run at the modeling temperature. The takeoff roll is checked to verify that it is within some identified tolerance of the observed roll, and if not, iterations of the assumed temperature are run until the modeled takeoff roll is within the tolerance. This approach provides an airport specific departure profile for any GA jet departure. In cases where GA jets are known to use maximum thrust takeoffs, no adjustment is needed.

The advantage of providing these guidelines is the simplicity and proven accuracy of the method. In addition, developing the guidelines will be relatively uncomplicated, see Section 9.2.2. The only additional information required is the approximate length of takeoff roll, which could be acquired by observation, if necessary. Before implementation of these guidelines however, development will require testing of the method, as described in Section 7.1, for the other seven aircraft identified (Table 7). This testing will show whether or not the standard INM NPD curves are reasonable, or as shown in Section 8.3 for aircraft like the Lear 35, need to be revised before the guidelines can be finalized.[32] Implementation should also include final testing at two or more specific airports that have detailed data on aircraft ground movements – ASDE-X.

9.2 Implementation Process

9.2.1 Implementation of an ATM1 Process

Implementation of the ATM1 method would require input and contribution from FAA as well as aircraft manufacturers. To include ATM profiles as standard input in the INM, two key database features would need to be updated to include new information:

Update the INM thrust jet (thr_jet.dbf) database:

This database includes the regression coefficients required to compute corrected thrust at a given speed, altitude and temperature. With the exception of the Gulfstream II aircraft, no reduced thrust departure profiles are currently included as standard INM data for GA jets. Updated coefficients for aircraft using reduced thrust departures would need to be produced.

- For aircraft currently in production, operators could be requested to provide these data, where new coefficients would then be calculated directly.
- For aircraft currently out of production an interpolative approach would be used to approximate the coefficients. Possible methods for this approach may include:
    - Determining the static thrust coefficient for ATM departures through expanded operator surveys; then look for functional dependencies across the entire standard database of GA jets for the higher order speed, altitude and temperature coefficients as a function of thrust.
    - Determine an approximate physical relationship on an aircraft by aircraft basis between thrust and the higher order coefficients. Highly accurate radar or on-board flight data, capable of capturing acceleration as a function of time and distance for known aircraft weights would have to be available.

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[32] Because four of the remaining ten aircraft use the LEAR35 INM types as the substitution aircraft, testing will show if the changed NPD curves for the LEAR35, as suggested in Section 8.3, are appropriate for these four aircraft as well.

Update procedure profile database:

Once the reduced thrust levels for the ATM departure profiles have been determined with the updated thrust jet database, the standard procedural departure steps would need to be reviewed for compatibility with reduced thrust. Due to the more gradual climb out rates, the thrust cutback points specified for the standard profiles are no longer likely to be applicable.

After obtaining or interpolating new reduced thrust coefficients from manufacturers or other FAA programs, a validation program comparing radar data altitude flight profiles as well as noise measurement correlations is recommended to ensure the provided data results in accurate modeled results compared to in practice flight procedures.

9.2.2 Implementation of an ATM2 Process

Implementation of an ATM2 process would be through FAA development of a procedure to be followed by modelers. ATM2 Profiles can be built within the INM by using features within the model to generate all of the necessary inputs. The steps outlined here describe a procedure that could be followed by those modelers familiar with the INM, its databases and terminology.

Building an ATM2 Profile Using INM Profile Graphs Data

Step 1: Setup two INM cases for each aircraft requiring an Assumed Temperature Method (ATM2) profile. The cases should be identical except that the first (here termed "C_STD") should have the temperature defined as actual local temperature to be modeled and the second ("C_ATM2") should have the temperature initially defined at an estimated elevated level. This estimated level is arbitrary, but doubling the local temperature can often be a reasonable first estimate. Table 28 gives an example of the values stored in the INM **case.dbf** file for both these cases.

Table 28 INM case.dbf example for standard vs. Initial ATM2 profile

CASE_ID	CASE_DESC	DATE	TEMPERATUR	PRESSURE	DO_HUMID	HUMIDITY	HEADWIND
C_STD	Actual Local Temperature		59.9	29.98	Y	62.0	8.0
C_ATM2	Assumed Temperature		120.0	29.98	Y	62.0	8.0

Step 2: Within INM open the **CIVIL // Profile Graphs** menu and select the desired aircraft and runway combination. Export the profile graphs then export the profile graph data from **File // Export As**. Do this for both the C_STD and C_ATM2 INM cases. This will result in two INM **calc_prof_pts.dbf** files. Table 29 and Table 30 show these outputs for the standard profile and ATM2 profile respectively.

Table 29 INM calc_prof_pts.dbf for standard profile

CASE_ID	ACFT_ID	OP_TYPE	RWY_ID	PROF_ID1	PROF_ID2	PT_NUM	DISTANCE	ALTITUD	SPEED	THR_SET	OP_MODE
C_STD	LEAR35	D	09	STANDARD	1	1	0.0	0.0	0.0	3410.35	D
C_STD	LEAR35	D	09	STANDARD	1	2	2672.5	0.0	144.8	2852.91	D
C_STD	LEAR35	D	09	STANDARD	1	3	4691.2	205.6	160.1	2795.53	D
C_STD	LEAR35	D	09	STANDARD	1	4	11595.4	1500.0	163.2	2795.27	D
C_STD	LEAR35	D	09	STANDARD	1	5	15391.0	1833.6	189.9	2698.84	D
C_STD	LEAR35	D	09	STANDARD	1	6	16391.0	2006.6	190.4	2428.98	D
C_STD	LEAR35	D	09	STANDARD	1	7	22134.8	3000.0	193.3	2433.84	D
C_STD	LEAR35	D	09	STANDARD	1	8	42356.8	4547.0	270.3	2211.66	D
C_STD	LEAR35	D	09	STANDARD	1	9	50161.8	5500.0	274.2	2222.54	D
C_STD	LEAR35	D	09	STANDARD	1	10	67809.1	7500.0	282.8	2253.56	D
C_STD	LEAR35	D	09	STANDARD	1	11	92456.8	10000.0	294.1	2307.96	D

Table 30 INM calc_prof_pts.dbf for ATM2 profile

CASE_ID	ACFT_ID	OP_TYPE	RWY_ID	PROF_ID1	PROF_ID2	PT_NUM	DISTANCE	ALTITUDI	SPEED	THR_SET	OP_MODE
C_ATM2	LEAR35	D	09	STANDARD	1	1	0.0	0.0	0.0	2943.14	D
C_ATM2	LEAR35	D	09	STANDARD	1	2	3565.6	0.0	153.0	2385.70	D
C_ATM2	LEAR35	D	09	STANDARD	1	3	7875.1	414.5	169.6	2349.23	D
C_ATM2	LEAR35	D	09	STANDARD	1	4	15589.7	1500.0	172.5	2402.63	D
C_ATM2	LEAR35	D	09	STANDARD	1	5	22079.4	2038.7	201.4	2331.93	D
C_ATM2	LEAR35	D	09	STANDARD	1	6	23079.4	2178.9	201.8	2098.76	D
C_ATM2	LEAR35	D	09	STANDARD	1	7	28938.4	3000.0	204.4	2141.32	D
C_ATM2	LEAR35	D	09	STANDARD	1	8	62640.6	5418.2	289.9	2013.94	D
C_ATM2	LEAR35	D	09	STANDARD	1	9	63442.8	5500.0	290.3	2017.56	D
C_ATM2	LEAR35	D	09	STANDARD	1	10	83625.5	7500.0	299.6	2106.12	D
C_ATM2	LEAR35	D	09	STANDARD	1	11	110593.6	10000.0	311.8	2216.81	D

Step 3: Repeat Steps 1 and 2 for different Assumed Temperatures defined for C_ATM2 until a suitable target initial departure roll distance (as specified in the DISTANCE column for PT_NUM=2) is achieved or a target altitude at a given track distance is reached. The target departure roll and / or target altitude would be based either on radar data or on operator/stakeholder input. Comparisons to measured noise levels can also be done to determine the validity of the selected assumed temperature.

Step 4: Once appropriate targets have been reached, the **calc_prof_pts.dbf** file can be converted to a **prof_pts.dbf** file by removing the CASE_ID and RWY_ID fields and renaming the PROF_ID1 field to reflect the ATM2 method and runway. Table 31 gives the final inputs for the ATM2 **prof_pts.dbf** profile with an accompanying **profile.dbf** entry shown in Table 32.

Table 31 INM prof_pts.dbf data for final ATM2 profile using profile graphs export

ACFT_ID	OP_TYPE	PROF_ID1	PROF_ID2	PT_NUM	DISTANCE	ALTITUDI	SPEED	THR_SET	OP_MODE
LEAR35	D	ATM2_09	1	1	0.0	0.0	0.0	2943.14	D
LEAR35	D	ATM2_09	1	2	3565.6	0.0	153.0	2385.70	D
LEAR35	D	ATM2_09	1	3	7875.1	414.5	169.6	2349.23	D
LEAR35	D	ATM2_09	1	4	15589.7	1500.0	172.5	2402.63	D
LEAR35	D	ATM2_09	1	5	22079.4	2038.7	201.4	2331.93	D
LEAR35	D	ATM2_09	1	6	23079.4	2178.9	201.8	2098.76	D
LEAR35	D	ATM2_09	1	7	28938.4	3000.0	204.4	2141.32	D
LEAR35	D	ATM2_09	1	8	62640.6	5418.2	289.9	2013.94	D
LEAR35	D	ATM2_09	1	9	63442.8	5500.0	290.3	2017.56	D
LEAR35	D	ATM2_09	1	10	83625.5	7500.0	299.6	2106.12	D
LEAR35	D	ATM3_09	1	11	110593.6	10000.0	311.8	2216.81	D

Table 32 INM profile.dbf data for final ATM2 profile

ACFT_ID	OP_TYPE	PROF_ID1	PROF_ID2	WEIGHT
LEAR35	D	ATM2_09	1	18300

Building an ATM2 Profile Using INM flight.txt Data

A variation to the Profile Graphs data method described above is to use the output from the INM flight path report. This approach has the potential to be more accurate, however may be less accessible to those not sufficiently familiar with the model. The Profile Graphs output, while based on the same data as in **flight.txt,** and easily accessed through the INM graphical interface, are summary outputs. The flight profile information given in the flight path report, **flight.txt,** is more complete and better reflects the internal data INM uses during modeling.

The main advantage of utilizing the flight path report data occurs for profiles where rapid changes in thrust or speed occur such as in early thrust cutbacks. Where these transitional profile configurations occur, INM profiles using the smaller more discrete intervals between profile steps available from the flight path report better capture the flown profile.

Step 1: The same processes outlined in Steps 1 through 3 for the Profile Graphs method can be repeated, even using the same Profile Graphs output to determine the target level to match in order to define the assumed temperature. One exception to this may be if radar data is going to be used to compare directly to the model profile. Exporting the full flight path report for each iteration may be warranted in this case to better compare subtleties in the flown flight profile.

Step 2: Determine the final profile once an assumed temperature has been determined. The flight path report can be run after an INM case has been run. To generate this flight path data assign one operation per aircraft of interest to each runway of interest on a simple straight out INM vector track. Choose a noise output, either a contour, standard or detailed grid in order for the INM to run, but only the flight path report and not the noise results will be evaluated.

Step 3: Once the INM run has completed, select **Output // Flight Path Report** in the INM menu. This will output the flight path report to **flight.txt** in the **Scenario/Case folder**.

Step 4: For each aircraft and runway combination entered in Step 2, there will be an entry in **flight.txt** containing the modeled operations data as shown in Table 33. These data contain a header with the aircraft type, runway, profile name and other parameters followed by a table of data containing the distance, altitude, speed, and thrust data.

Step 5: Once the flight path report data have been generated for the final assumed temperature, the **flight.txt** file must be manually reformatted into a **prof_pts.dbf** file using the data column mapping shown in

Table 34. The final formatted **prof_pts.dbf** file as shown in Table 35 can then be included in the INM pared with the **profile.dbf** file shown in Table 32. Note that comparing the data in Table 35 to Table 31 more profile steps are generated with more discrete steps in each parameter.

Table 33 INM flight.txt data for example ATM2 profile

AIRPLA OPERATIONS
0
acft_id = LEAR35
eng_type = J (Jet,Turboprop,Piston)
stat_thrust = 3500 (Pounds)
thrust_type = L (P=Perc L=Poun X=Other)
owner_cat = G (Commercial,GenAviation,Military)
op_type = D (A=appr,D=dep,T=touch&go,F=circuit,V=overflight,R=runup)
numb_ops = 1.0000, 0.0000, 0 (day,eve,ngt)
frst_a_nois = 0
numb_a_nc = 4
frst_p_nois = 4
numb_p_nc = 4
model_type = I (Inm,Noisemap)
spect_num = 216, 113, 0 (approach,depart,afterburner)
flt_path = D-09-09_D-0-STANDARD-1
numb_segs = 24

seg	start-x	start-y	start-z	unit-x	unit-y	unit-z	length	speed	d.spd	thrust	d.thr	op	flaps	bank	duratior
0	0	0	0	1	0	0	55.7	0	18.1	2943.1	-69.7	D	-NONE-	0	3.6
1	55.7	0	0	1	0	0	167.1	18.1	18.1	2873.5	-69.7	D	-NONE-	0	3.6
2	222.9	0	0	1	0	0	278.6	36.2	18.1	2803.8	-69.7	D	-NONE-	0	3.6
3	501.4	0	0	1	0	0	390	54.4	18.1	2734.1	-69.7	D	-NONE-	0	3.6
4	891.4	0	0	1	0	0	501.4	72.5	18.1	2664.4	-69.7	D	-NONE-	0	3.6
5	1392.8	0	0	1	0	0	612.8	90.6	18.1	2594.7	-69.7	D	-NONE-	0	3.6
6	2005.7	0	0	1	0	0	724.3	108.7	18.1	2525.1	-69.7	D	-NONE-	0	3.6
7	2729.9	0	0	1	0	0	835.7	126.9	18.1	2455.4	-69.7	D	-NONE-	0	3.6
8	3565.6	0	0	0.9954	0	0.0957	554.6	145	2.2	2385.7	-4.9	D	-NONE-	0	2.2
9	4117.7	0	53.1	0.9954	0	0.0957	661.9	147.2	2.6	2380.8	-5.8	D	-NONE-	0	2.6
10	4776.6	0	116.5	0.9954	0	0.0957	787.2	149.8	3.1	2375	-6.7	D	-NONE-	0	3.1
11	5560.1	0	191.9	0.9954	0	0.0957	992.9	152.9	3.8	2368.3	-8.3	D	-NONE-	0	3.8
12	6548.5	0	286.9	0.9954	0	0.0957	1332.8	156.7	4.9	2360	-10.8	D	-NONE-	0	5
13	7875.1	0	414.5	0.9902	0	0.1393	7790.6	161.6	2.8	2349.2	53.4	D	-NONE-	0	28.3
14	15589.7	0	1500	0.9966	0	0.0827	3124.4	164.5	14.5	2402.6	-35.3	D	-NONE-	0	10.8
15	18703.4	0	1758.5	0.9966	0	0.0827	3387.6	178.9	14.5	2367.3	-35.3	D	-NONE-	0	10.8
16	22079.4	0	2038.7	0.9903	0	0.1388	1009.8	193.4	0.4	2331.9	-233.2	D	-NONE-	0	3.1
17	23079.4	0	2178.9	0.9903	0	0.1388	5916.2	193.8	2.6	2098.8	42.6	D	-NONE-	0	18
18	28938.4	0	3000	0.9974	0	0.0716	5791.2	196.4	17.1	2141.3	-25.5	D	-NONE-	0	16.7
19	34714.8	0	3414.5	0.9974	0	0.0716	6274.5	213.5	17.1	2115.8	-25.5	D	-NONE-	0	16.7
20	40973.2	0	3863.5	0.9974	0	0.0716	6757.8	230.6	17.1	2090.4	-25.5	D	-NONE-	0	16.7
21	47713.6	0	4347.2	0.9974	0	0.0716	7241	247.7	17.1	2064.9	-25.5	D	-NONE-	0	16.7
22	54936.1	0	4865.4	0.9974	0	0.0716	7724.3	264.8	17.1	2039.4	-25.5	D	-NONE-	0	16.7
23	62640.6	0	5418.2	0.9948	0	0.1014	806.4	281.9	0.4	2013.9	3.6	D	-NONE-	0	1.7
24	63442.8	0	5500	0.9951	0	0.0986	20282	282.3	9.3	2017.6	88.6	D	-NONE-	0	41.9
25	83625.5	0	7500	0.9957	0	0.0923	7548.5	291.6	3.5	2106.1	31.4	D	-NONE-	0	15.2
26	91141.7	0	8196.8	0.9957	0	0.0923	19535	295	8.8	2137.5	79.3	D	-NONE-	0	38.7
27	110593.6	0	10000	0.9957	0	0.0923	1	303.8	0	2216.8	0	D	-NONE-	0	0

Table 34 INM flight.txt to prof_pts.dbf data mapping

prof_pts	flight.txt
ACFT_ID	header: acft_id
OP_TYPE	header: flt_path
PROF_ID1	header: flt_path
PROF_ID2	header: flt_path
PT_NUM	seg incremented by one
DISTANCE	calculated from start-x and start-y
ALTITUDE	start-z
SPEED	speed
THR_SET	thrust
OP_MODE	op

Table 35 prof_pts.dbf data for final ATM2 profile using flight path report

ACFT_ID	OP_TYPE	PROF_ID1	PROF_ID2	PT_NUM	DISTANCE	ALTITUDE	SPEED	THR_SET	OP_MODE
LEAR35	D	ATM2_09	1	1	0	0	0	2943.1	D
LEAR35	D	ATM2_09	1	2	55.7	0	18.1	2873.5	D
LEAR35	D	ATM2_09	1	3	222.9	0	36.2	2803.8	D
LEAR35	D	ATM2_09	1	4	501.4	0	54.4	2734.1	D
LEAR35	D	ATM2_09	1	5	891.4	0	72.5	2664.4	D
LEAR35	D	ATM2_09	1	6	1392.8	0	90.6	2594.7	D
LEAR35	D	ATM2_09	1	7	2005.7	0	108.7	2525.1	D
LEAR35	D	ATM2_09	1	8	2729.9	0	126.9	2455.4	D
LEAR35	D	ATM2_09	1	9	3565.6	0	145	2385.7	D
LEAR35	D	ATM2_09	1	10	4117.7	53.1	147.2	2380.8	D
LEAR35	D	ATM2_09	1	11	4776.6	116.5	149.8	2375	D
LEAR35	D	ATM2_09	1	12	5560.1	191.9	152.9	2368.3	D
LEAR35	D	ATM2_09	1	13	6548.5	286.9	156.7	2360	D
LEAR35	D	ATM2_09	1	14	7875.1	414.5	161.6	2349.2	D
LEAR35	D	ATM2_09	1	15	15589.7	1500	164.5	2402.6	D
LEAR35	D	ATM2_09	1	16	18703.4	1758.5	178.9	2367.3	D
LEAR35	D	ATM2_09	1	17	22079.4	2038.7	193.4	2331.9	D
LEAR35	D	ATM2_09	1	18	23079.4	2178.9	193.8	2098.8	D
LEAR35	D	ATM2_09	1	19	28938.4	3000	196.4	2141.3	D
LEAR35	D	ATM2_09	1	20	34714.8	3414.5	213.5	2115.8	D
LEAR35	D	ATM2_09	1	21	40973.2	3863.5	230.6	2090.4	D
LEAR35	D	ATM2_09	1	22	47713.6	4347.2	247.7	2064.9	D
LEAR35	D	ATM2_09	1	23	54936.1	4865.4	264.8	2039.4	D
LEAR35	D	ATM2_09	1	24	62640.6	5418.2	281.9	2013.9	D
LEAR35	D	ATM2_09	1	25	63442.8	5500	282.3	2017.6	D
LEAR35	D	ATM2_09	1	26	83625.5	7500	291.6	2106.1	D
LEAR35	D	ATM2_09	1	27	91141.7	8196.8	295	2137.5	D
LEAR35	D	ATM2_09	1	28	110593.6	10000	303.8	2216.8	D

9.3 Implementation Costs

9.3.1 ATM1

For aircraft still in production, the first step in the development of ATM1 profiles would be the creation of a revised requirement document analogous to what is currently requested of manufacturers to provide INM input data, including the thrust coefficients, at time of aircraft certification. This document will include a description of the reduced thrust profile to be flown. New reduced thrust coefficients derived from data generated through this process will then be used for inclusion in the INM. Cost to update the requirement document to include the reduced thrust departures would fall on FAA internally and would also cost manufacturers for generating the data needed to derive new INM thrust coefficients is unknown. For FAA, the authors are not in a position to estimate internal costs, but an estimate would likely be on the order of one or two or more person months. For manufacturers, the costs may be considerable if new flight or simulator operations are required to produce the needed data.

For existing aircraft types, there are two different costs: one for aircraft currently being manufactured, and one for aircraft no longer manufactured. For both types, flying or use of simulators may be required – at considerable expense one can assume. For aircraft being manufactured, the costs should be lower than for those no longer manufactured. Costs will include time spent by manufacturer engineers, FAA (or contractor) for collection of radar data and validation of resulting profiles. If surveys of pilots / operators are required, costs will be for collection and harmonization of reported thrust use and climb rates (pilots will not all necessarily use identical procedures for a given aircraft type), regression of results to determine speed coefficients, and validation of resulting profiles. A very rough estimate, including manufacturer costs or for us of pilot data and regressions to produce the coefficients is from $100,000 per aircraft to $500,000 per aircraft.

9.3.2 ATM2

Steps include verifying the process with the seven aircraft types not analyzed in this study. The draft procedures would then be written and reviewed. The draft procedures should be tested at several airports with available radar and measured sound level data. Ideally, the procedures will also be applied at two or three airports that have Airport Surface Detection Equipment, Model X (ASDE-X). This equipment provides accurate aircraft ground locations, including during takeoff roll, and would provide the takeoff roll length for verification of the ATM2 method. Costs for developing and test of ATM2 procedures are estimated to be about $250,000 to $500,000, depending on how much additional validation is deemed necessary.

Appendix A. Literature Review References

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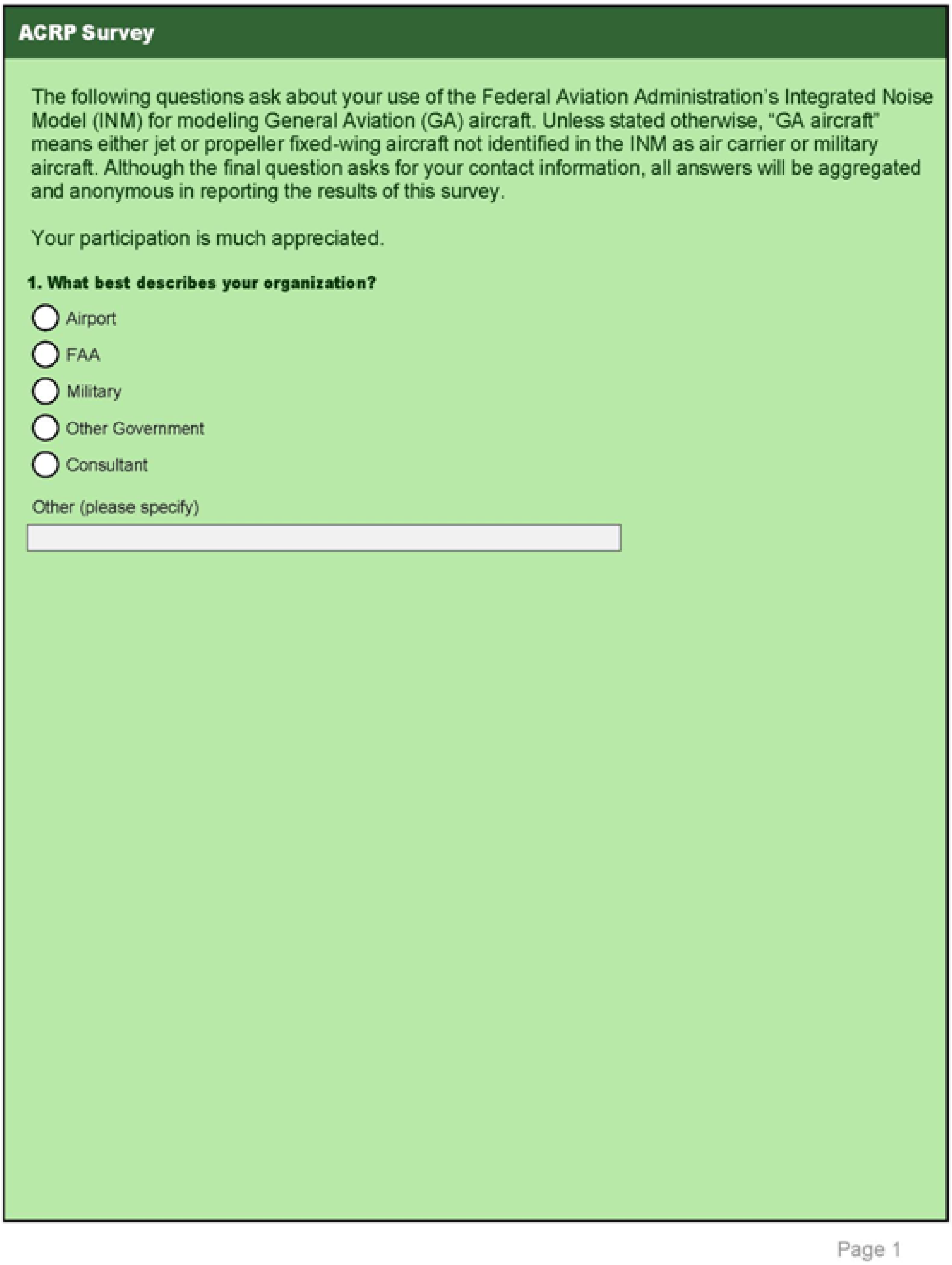
Appendix B. INM Survey Questionnaire–U.S.

(Note - International questionnaire does not refer to FAA as possible organization.)



ACRP Survey

The following questions ask about your use of the Federal Aviation Administration's Integrated Noise Model (INM) for modeling General Aviation (GA) aircraft. Unless stated otherwise, "GA aircraft" means either jet or propeller fixed-wing aircraft not identified in the INM as air carrier or military aircraft. Although the final question asks for your contact information, all answers will be aggregated and anonymous in reporting the results of this survey.

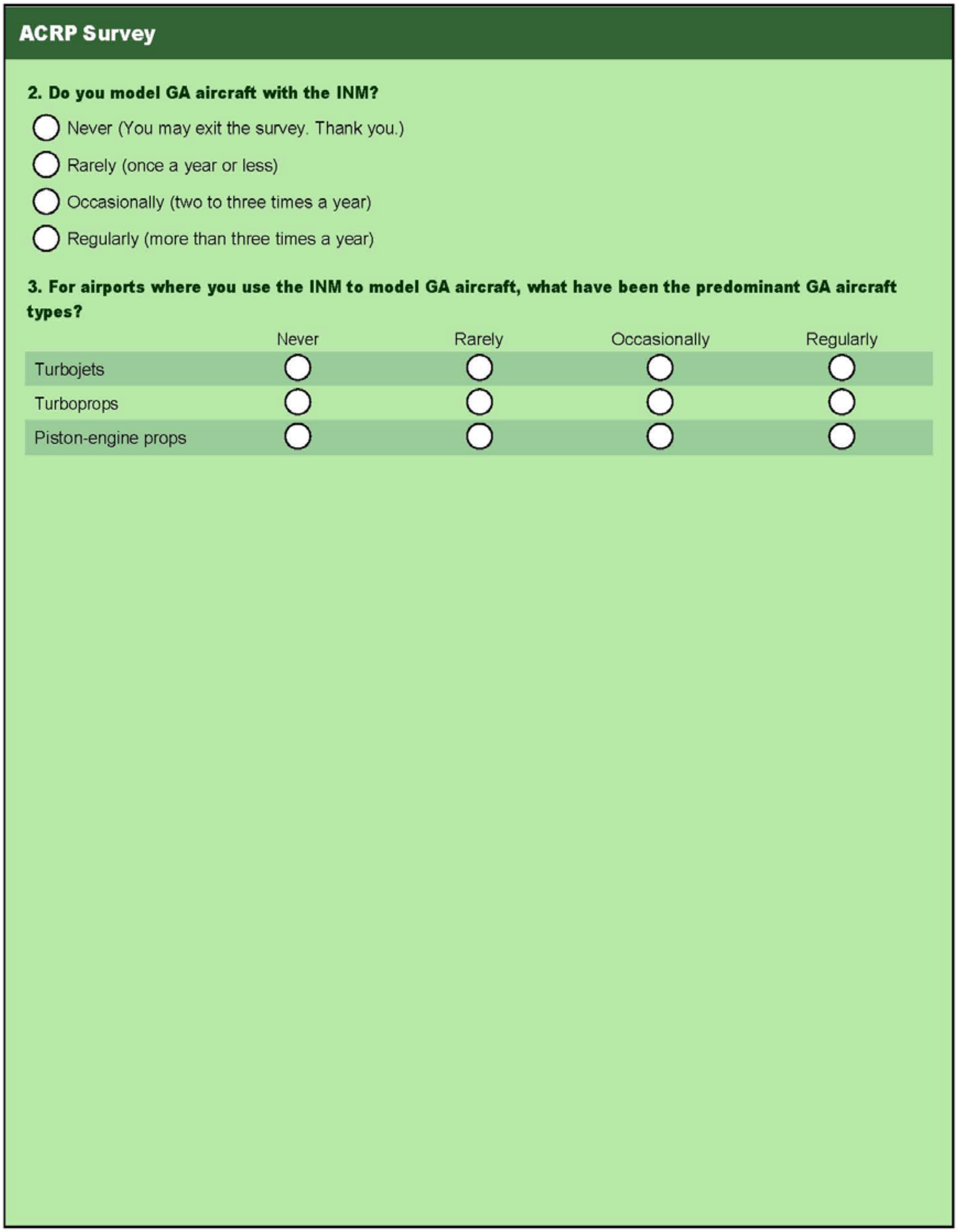
Your participation is much appreciated.

1. What best describes your organization?

○ Airport
○ FAA
○ Military
○ Other Government
○ Consultant

Other (please specify)

Page 1



ACRP Survey

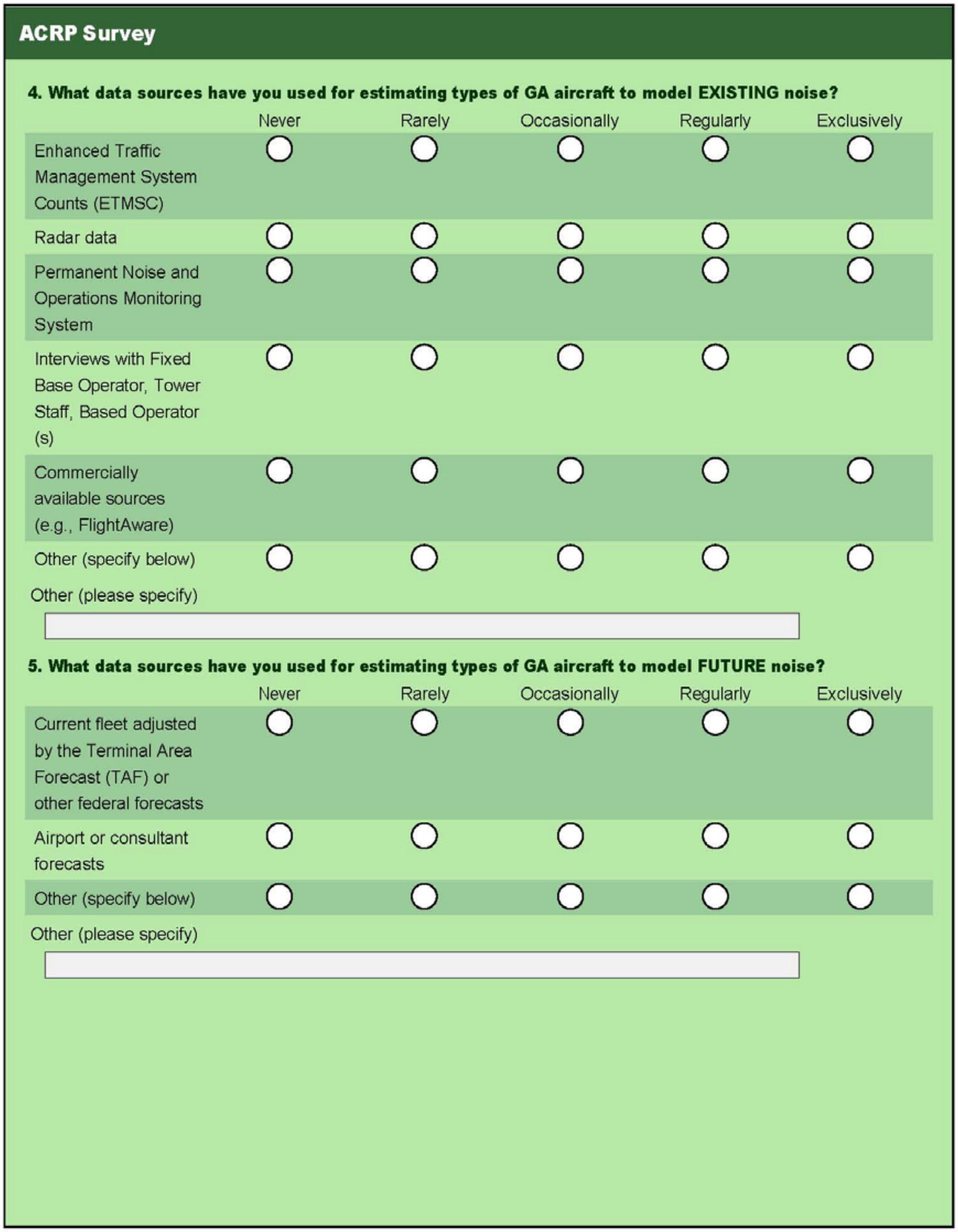
2. Do you model GA aircraft with the INM?

○ Never (You may exit the survey. Thank you.)
○ Rarely (once a year or less)
○ Occasionally (two to three times a year)
○ Regularly (more than three times a year)

3. For airports where you use the INM to model GA aircraft, what have been the predominant GA aircraft types?

	Never	Rarely	Occasionally	Regularly
Turbojets	○	○	○	○
Turboprops	○	○	○	○
Piston-engine props	○	○	○	○

Page 2



ACRP Survey

4. What data sources have you used for estimating types of GA aircraft to model EXISTING noise?

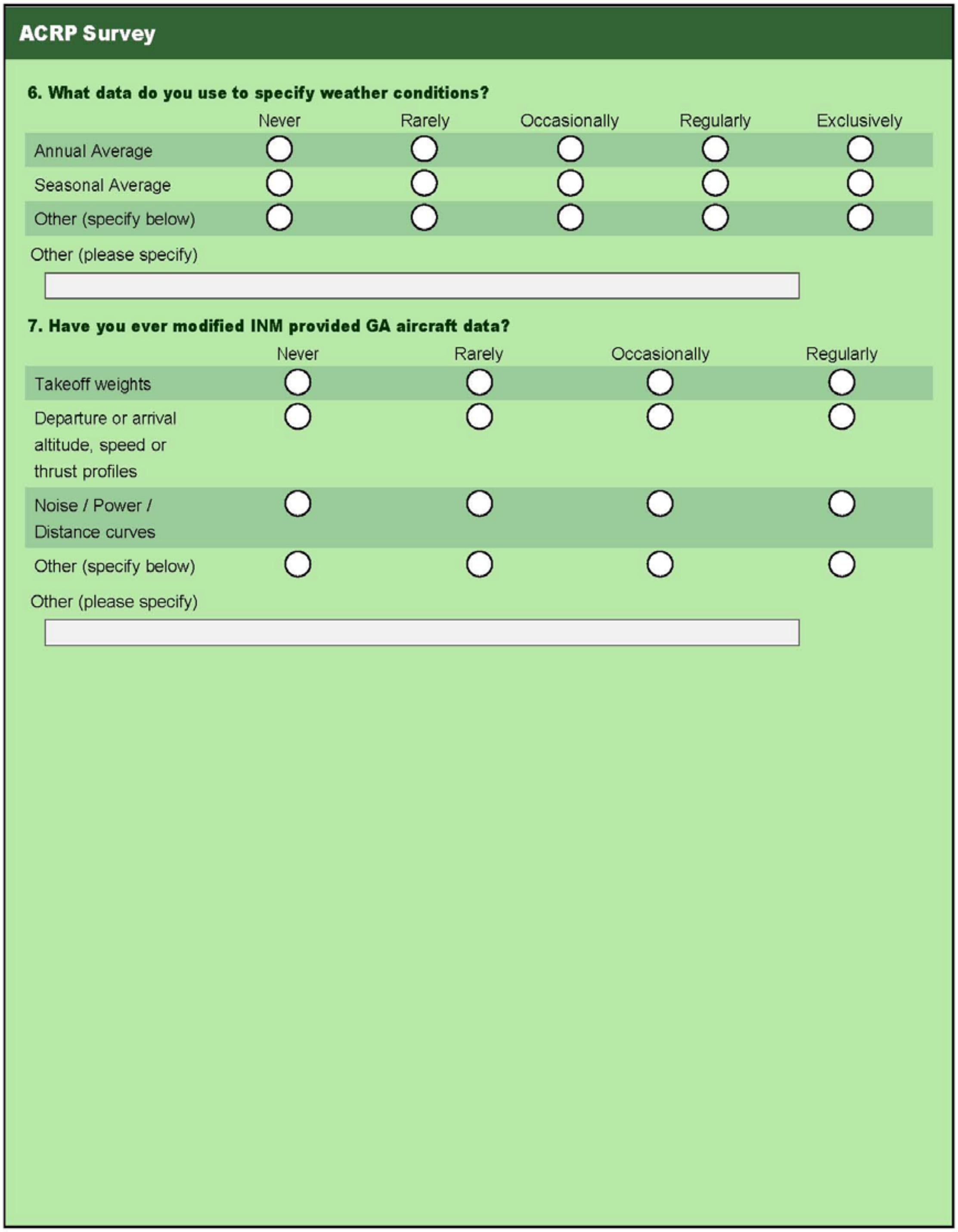
	Never	Rarely	Occasionally	Regularly	Exclusively
Enhanced Traffic Management System Counts (ETMSC)	○	○	○	○	○
Radar data	○	○	○	○	○
Permanent Noise and Operations Monitoring System	○	○	○	○	○
Interviews with Fixed Base Operator, Tower Staff, Based Operator (s)	○	○	○	○	○
Commercially available sources (e.g., FlightAware)	○	○	○	○	○
Other (specify below)	○	○	○	○	○

Other (please specify)

5. What data sources have you used for estimating types of GA aircraft to model FUTURE noise?

	Never	Rarely	Occasionally	Regularly	Exclusively
Current fleet adjusted by the Terminal Area Forecast (TAF) or other federal forecasts	○	○	○	○	○
Airport or consultant forecasts	○	○	○	○	○
Other (specify below)	○	○	○	○	○

Other (please specify)



ACRP Survey

6. What data do you use to specify weather conditions?

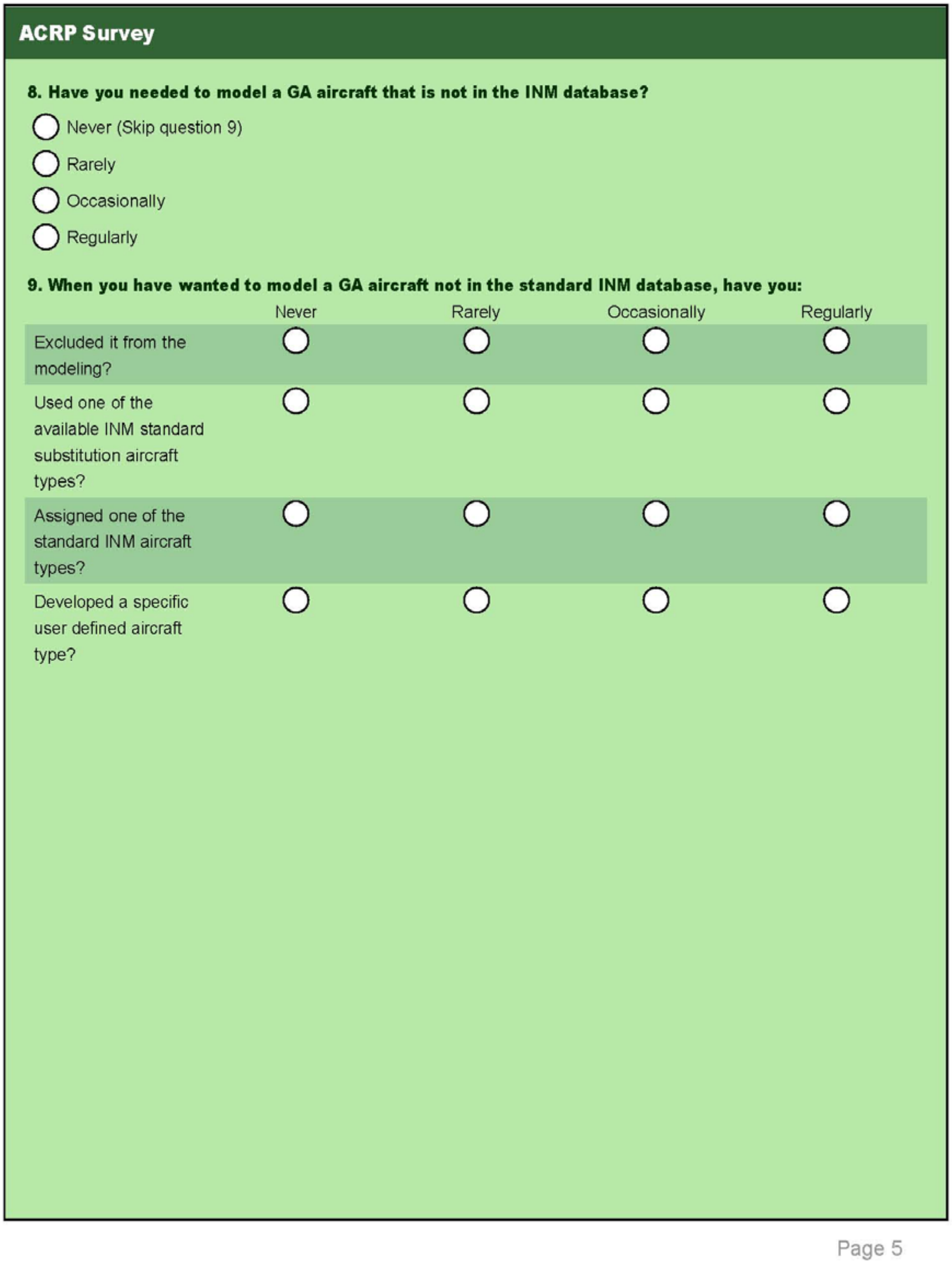
	Never	Rarely	Occasionally	Regularly	Exclusively
Annual Average	○	○	○	○	○
Seasonal Average	○	○	○	○	○
Other (specify below)	○	○	○	○	○

Other (please specify)

7. Have you ever modified INM provided GA aircraft data?

	Never	Rarely	Occasionally	Regularly
Takeoff weights	○	○	○	○
Departure or arrival altitude, speed or thrust profiles	○	○	○	○
Noise / Power / Distance curves	○	○	○	○
Other (specify below)	○	○	○	○

Other (please specify)



ACRP Survey

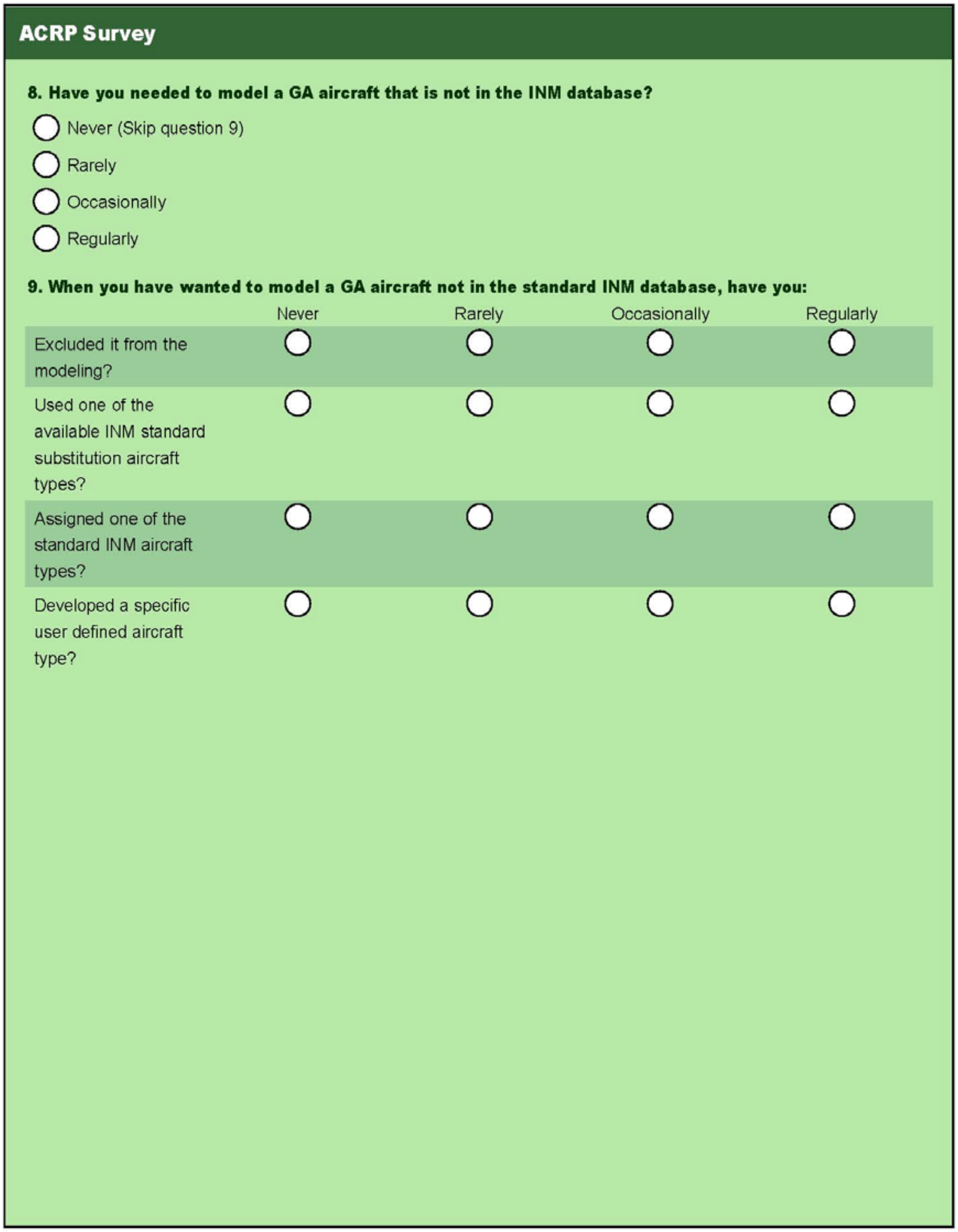
8. Have you needed to model a GA aircraft that is not in the INM database?

- ○ Never (Skip question 9)
- ○ Rarely
- ○ Occasionally
- ○ Regularly

9. When you have wanted to model a GA aircraft not in the standard INM database, have you:

	Never	Rarely	Occasionally	Regularly
Excluded it from the modeling?	○	○	○	○
Used one of the available INM standard substitution aircraft types?	○	○	○	○
Assigned one of the standard INM aircraft types?	○	○	○	○
Developed a specific user defined aircraft type?	○	○	○	○

Page 5



ACRP Survey

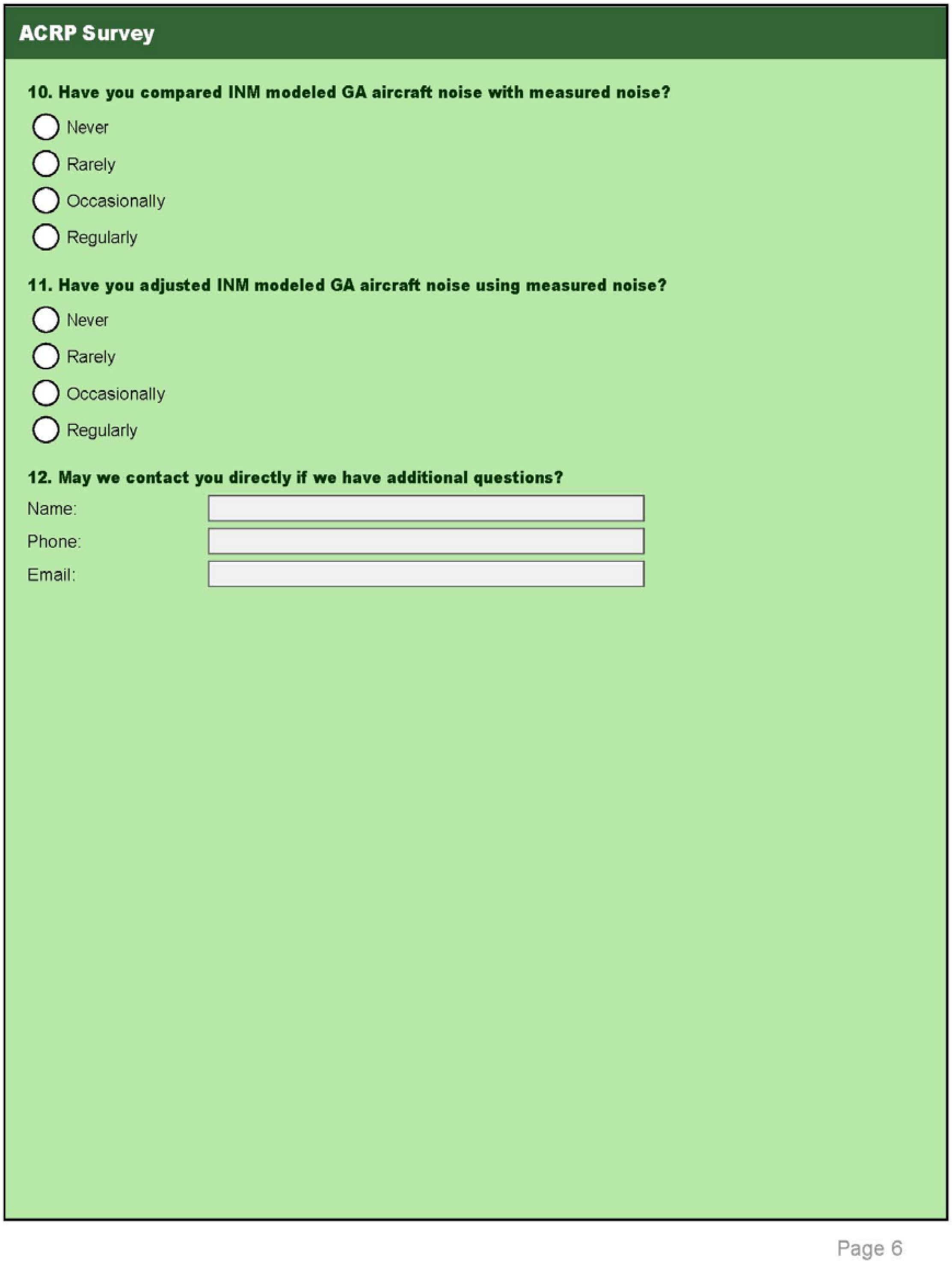
8. Have you needed to model a GA aircraft that is not in the INM database?

○ Never (Skip question 9)
○ Rarely
○ Occasionally
○ Regularly

9. When you have wanted to model a GA aircraft not in the standard INM database, have you:

	Never	Rarely	Occasionally	Regularly
Excluded it from the modeling?	○	○	○	○
Used one of the available INM standard substitution aircraft types?	○	○	○	○
Assigned one of the standard INM aircraft types?	○	○	○	○
Developed a specific user defined aircraft type?	○	○	○	○

Page 5



ACRP Survey

10. Have you compared INM modeled GA aircraft noise with measured noise?

○ Never
○ Rarely
○ Occasionally
○ Regularly

11. Have you adjusted INM modeled GA aircraft noise using measured noise?

○ Never
○ Rarely
○ Occasionally
○ Regularly

12. May we contact you directly if we have additional questions?

Name:
Phone:
Email:

Page 6

Appendix C. Summary of INM Users Surveyed

ACRP INM Survey Summary	**Note**	**International Targets**	**Int. %**	**U.S. Targets**	**U.S. %**	**Total Targets**	**Total %**
Total INM Professionals E-Mailed Survey Invitation		138		345		483	
Bounced/Old/Bad E-Mail Addresses Never Resolved		39		84		123	
Sub-Total - Survey Requests Received By Survey Targets		**99**	**100.0%**	**261**	**100.0%**	**360**	**100.0%**
Total Invitees That E-Mailed "Not Going To Complete"	1	7	7.1%	26	10.0%	33	9.2%
Total Surveys Commenced But Not Completed	2	8	8.1%	33	12.6%	41	11.4%
Total Surveys Completed		20	20.2%	62	23.8%	82	22.8%
Sub-Total - Targets Responding To Survey Request		**35**	**35.4%**	**121**	**46.4%**	156	**43.3%**
Completed Surveys with Completed Contact Info		17	85.0%	40	64.5%	57	69.5%
Completed Surveys without Completed Contact Info		3	15.0%	22	35.5%	25	30.5%

Note 1: These invitees responded by e-mail that they do not model GA, use INM, are not qualified to respond, someone better in their organization, or combinations thereof.

Note 2: These Invitees began but did not complete the survey. The primary reason for these incompletions would be Question 2, "Do you model GA aircraft with the INM?" with answer #1 being "Never (You may exit the survey. Thank You)."

Appendix D. Propeller Aircraft Discrepancies

We have conducted identical analyses of propeller and jet aircraft. However, in selecting jet aircraft most in need of correction, Section 6, we found that once these significant jet aircraft were corrected, also correcting the significant propeller aircraft would improve total fleet sound energy (equivalent to effects on DNL) less than an additional 0.1 dB. However, there are some significant sound level discrepancies (measured minus modeled levels) for propeller aircraft which may be worth pursuing later, and for reference have listed the departure and arrival discrepancies in this Appendix. In general, we found that measured propeller departure altitudes were higher than modeled (Effective Altitude Discrepancy less than zero), and measured arrival altitudes were lower than modeled (Effective Altitude Discrepancy greater than zero).

DEPARTURES

Designator	Description	INM Aircraft Type Used	Measured SEL (dB)	Modeled SEL (dB)	Measured minus Modeled (dB)	Effective Altitude Discrepancy (dB)	Discrepancy if Altitude Corrected (dB)
BE20	Hawker Beechcraft Corp 200, 1300 Super King Air, Commuter	CNA441	82.0	76.6	5.4	-3.1	2.3
BE9L	Hawker Beechcraft Corp 90, A90 to E90 King Air	CNA441	82.5	76.6	5.9	-3.4	2.4
SR22	Cirrus SR-22	GASEPV	85.7	83.4	2.4	-2.5	-0.1
BE58	Hawker Beechcraft Corp 58 Baron	BEC58P	87.6	86.4	1.2	-2.2	-1.0
PA31	Piper PA-31/31P Navajo, Navajo Chieftain, Chieftain, Pressurized Navajo, Mojave, T-1020	PA31	85.6	85.3	0.3	-1.2	-0.9
BE30	Hawker Beechcraft Corp 300 Super King Air	DO228	80.8	78.6	2.2	-2.3	-0.1
C421	Cessna 421, Golden Eagle, Executive Commuter	BEC58P	86.0	86.3	-0.4	-3.3	-3.7
C182	Cessna 182, Skylane	CNA182	82.0	87.6	-5.7	-1.1	-6.7
BE55	Hawker Beechcraft Corp 55 Baron	BEC58P	87.6	86.4	1.2	-2.5	-1.3
C310	Cessna 310, T310	BEC58P	84.9	86.4	-1.5	-3.5	-5.0
C414	Cessna 414, Chancellor	BEC58P	86.8	86.4	0.3	-3.0	-2.7
C208	Cessna 208 Caravan 1, (Super) Cargomaster, Grand Caravan	CNA208	82.4	80.9	1.5	-2.3	-0.8
C441	Cessna 441 Conquest, Conquest 2	CNA441	80.7	76.6	4.1	-2.9	1.2
C210	Cessna 210, T210, (Turbo)Centurion	CNA206	85.8	88.6	-2.9	-2.2	-5.1
PA32	Piper PA-32 Cherokee Six, Six, Saratoga, Turbo Saratoga	GASEPV	84.6	83.1	1.5	-3.7	-2.2
C172	Cessna 172, P172, R172, Skyhawk, Hawk XP, Cutlass	CNA172	80.8	78.9	1.9	-1.2	0.8
BE35	Hawker Beechcraft Corp 35 Bonanza	GASEPV	85.7	83.1	2.6	-3.0	-0.4
C340	Cessna 340	BEC58P	84.4	86.3	-1.9	-2.9	-4.8
PA34	Piper PA-34 Seneca	BEC58P	84.0	86.3	-2.4	-3.2	-5.5
PA46	Piper PA-46-310P/350P Malibu, Malibu Mirage	GASEPV	84.3	83.1	1.2	-3.4	-2.2
PA44	Piper PA-44 Seminole, Turbo Seminole	BEC58P	83.0	86.3	-3.2	-2.3	-5.5
BE33	Hawker Beechcraft Corp 33 Debonair, Bonanza	GASEPV	84.7	82.9	1.8	-2.3	-0.5
C206	Cessna 206, P206, T206, TP206, U206, TU206, (Turbo)Super Skywagon, (Turbo) Super Skylane, (Turbo) Skywagon 206, (Turbo) Stationair, (Turbo) Stationair 6	CNA206, CNA20T	83.8	84.3	-0.6	-2.8	-3.4

Designator	Description	INM Aircraft Type Used	Measured SEL (dB)	Modeled SEL (dB)	Measured minus Modeled (dB)	Effective Altitude Discrepancy (dB)	Discrepancy if Altitude Corrected (dB)
P28B	Piper PA-28-201T/235/236 Cherokee, Cherokee Charger/Pathfinder, Dakota, Turbo Dakota	BEC58P	78.9	86.8	-7.9	-3.1	-10.9
M20P	Mooney M-20, M-20A/B/C/D/E/F/G/J/L/R/S, Mark 21, Allegro, Eagle, Ranger, Master, Super 21, Chaparral, Executive, Statesman, Ovation, 201, 205, ATS, MSE, PFM (non-turbocharged engine)	GASEPV	81.6	82.9	-1.3	-3.9	-5.2
P28R	Piper PA-28R-1802/3, Turbo Arrow 3/200/201 Cherokee Arrow, Arrow	GASEPV	83.2	83.7	-0.5	-2.8	-3.3
P28A	Piper PA-28-140/150/151/160/161/180/181 Archer, Cadet, Cherokee, Cherokee Archer/Challenger/Chief/Cruiser/Flite Liner/Warrior, Warrior	PA28	83.1	82.7	0.3	-1.1	-0.8
PC12	Pilatus PC-12, Eagle	CNA208	79.7	80.9	-1.2	-1.3	-2.5

ARRIVALS

Designator	Description	INM Aircraft Type Used	Measured SEL (dB)	Modeled SEL (dB)	Measured minus Modeled (dB)	Effective Altitude Discrepancy (dB)	Discrepancy if Altitude Corrected (dB)
BE20	Hawker Beechcraft Corp 200, 1300 Super King Air, Commuter	CNA441	83.4	81.0	2.5	1.4	3.9
BE9L	Hawker Beechcraft Corp 90, A90 to E90 King Air	CNA441	83.2	80.9	2.3	1.8	4.1
SR22	Cirrus SR-22	GASEPV	81.9	83.2	-1.3	1.1	-0.1
BE58	Hawker Beechcraft Corp 58 Baron	BEC58P	82.7	83.1	-0.5	1.4	0.9
PA31	Piper PA-31/31P Navajo, Navajo Chieftain, Chieftain, Pressurized Navajo, Mojave, T-1020	PA31	81.3	78.3	3.0	1.5	4.5
BE30	Hawker Beechcraft Corp 300 Super King Air	DO228	83.1	83.0	0.2	1.0	1.1
C421	Cessna 421, Golden Eagle, Executive Commuter	BEC58P	82.1	82.8	-0.7	1.7	0.9
C182	Cessna 182, Skylane	CNA182	78.7	74.8	3.9	1.1	5.1
BE55	Hawker Beechcraft Corp 55 Baron	BEC58P	82.8	83.0	-0.2	1.8	1.6
C310	Cessna 310, T310	BEC58P	80.9	82.9	-2.1	1.5	-0.6
C414	Cessna 414, Chancellor	BEC58P	81.3	82.9	-1.6	0.7	-0.9
C208	Cessna 208 Caravan 1, (Super) Cargomaster, Grand Caravan	CNA208	83.7	87.0	-3.3	1.6	-1.7
C441	Cessna 441 Conquest, Conquest 2	CNA441	81.2	80.8	0.4	2.0	2.4
C210	Cessna 210, T210, (Turbo) Centurion	CNA206	86.4	80.3	6.1	1.4	7.5
PA32	Piper PA-32 Cherokee Six, Six, Saratoga, Turbo Saratoga	GASEPV	80.4	83.1	-2.6	1.8	-0.8
C172	Cessna 172, P172, R172, Skyhawk, Hawk XP, Cutlass	CNA172	81.4	71.2	10.2	1.8	12.0
BE35	Hawker Beechcraft Corp 35 Bonanza	GASEPV	80.7	83.1	-2.4	2.1	-0.3
C340	Cessna 340	BEC58P	80.2	82.9	-2.7	1.4	-1.3
PA34	Piper PA-34 Seneca	BEC58P	79.5	83.1	-3.6	1.4	-2.2
PA46	Piper PA-46-310P/350P Malibu, Malibu Mirage	GASEPV	81.4	83.1	-1.7	1.8	0.0
PA44	Piper PA-44 Seminole, Turbo Seminole	BEC58P	80.1	82.9	-2.8	1.8	-1.0

Designator	Description	INM Aircraft Type Used	Measured SEL (dB)	Modeled SEL (dB)	Measured minus Modeled (dB)	Effective Altitude Discrepancy (dB)	Discrepancy if Altitude Corrected (dB)
BE33	Hawker Beechcraft Corp 33 Debonair, Bonanza	GASEPV	81.7	83.2	-1.5	1.9	0.4
C206	Cessna 206, P206, T206, TP206, U206, TU206, (Turbo) Super Skywagon, (Turbo) Super Skylane, (Turbo) Skywagon 206, (Turbo) Stationair, (Turbo) Stationair 6	CNA206, CNA20T	79.4	77.9	1.5	1.7	3.2
P28B	Piper PA-28-201T/235/236 Cherokee, Cherokee Charger/Pathfinder, Dakota, Turbo Dakota	BEC58P	76.7	83.2	-6.5	0.2	-6.2
M20P	Mooney M-20, M-20A/B/C/D/E/F/G/J/L/R/S, Mark 21, Allegro, Eagle, Ranger, Master, Super 21, Chaparral, Executive, Statesman, Ovation, 201, 205, ATS, MSE, PFM (non-turbocharged engine)	GASEPV	79.0	83.4	-4.4	0.8	-3.5
P28R	Piper PA-28R-1802/3, Turbo Arrow 3/200/201 Cherokee Arrow, Arrow	GASEPV	78.7	83.3	-4.6	1.4	-3.2
P28A	Piper PA-28-140/150/151/160/161/180/181 Archer, Cadet, Cherokee, Cherokee Archer/Challenger/Chief/Cruiser/Flite Liner/Warrior, Warrior	PA28	79.7	68.7	11.0	1.5	12.5
PC12	Pilatus PC-12, Eagle	CNA208	85.8	86.9	-1.1	1.0	-0.1

Appendix E. LJ35 Standard and Best Fit Departure Profiles

The following two graphs show the thrust use in pounds (left axis), altitude in feet above field level (left axis as well), and speed in knots (right axis). In addition to having the thrust applied differently from the standard for the best fit, the takeoff and cruise thrust were lowered to 85% of the standard maximum thrust, and the weight was lowered to 75% of the standard maximum takeoff weight.

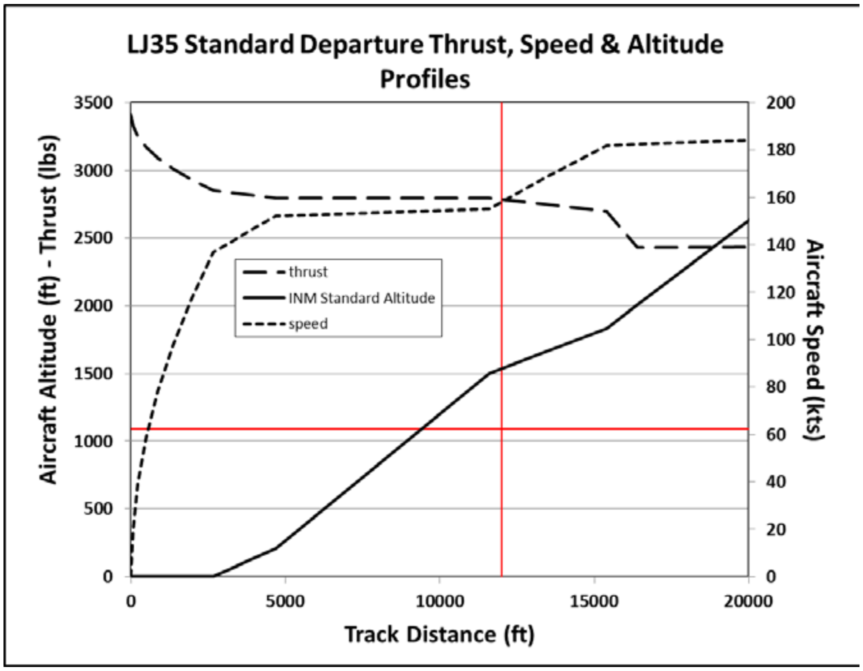


Figure 31 LJ35 INM standard profile variables

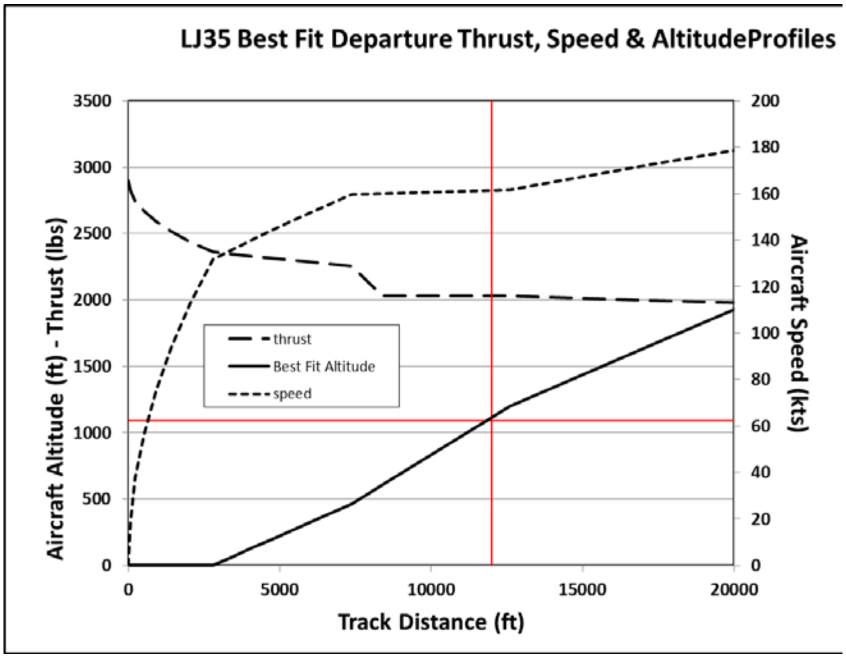


Figure 32 LJ35 best fit profile variables

Appendix F. GLF4 Standard and Best Fit Departure Profiles

The following two graphs show the thrust use in pounds (left axis), altitude in feet above field level (left axis as well), and speed in knots (right axis). As shown, the use of thrust is essentially unchanged from standard to best fit profile. Rather, the best fit departure exchanges increased altitude for increased speed, thus keeping the aircraft lower and close to the measured altitudes.

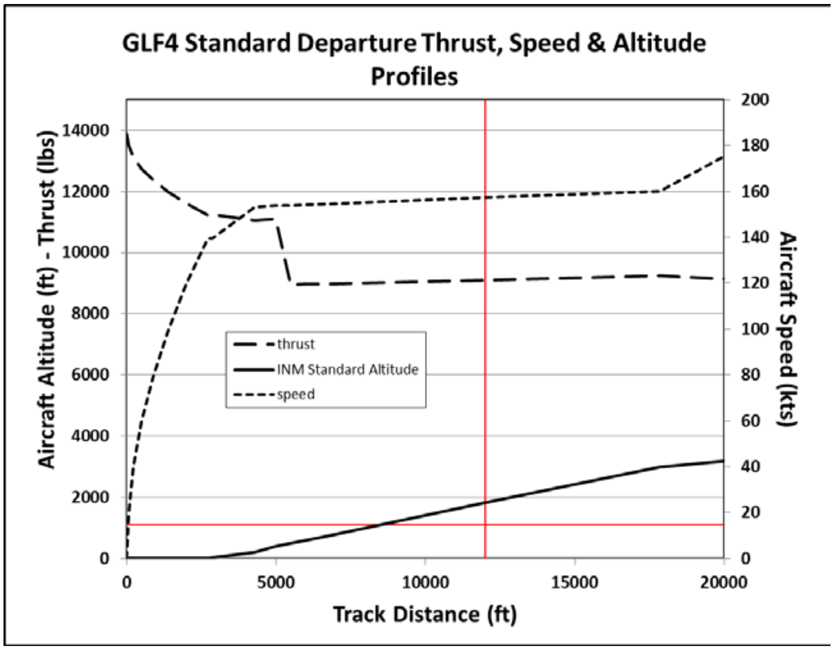


Figure 33 GLF4 INM standard profile variables

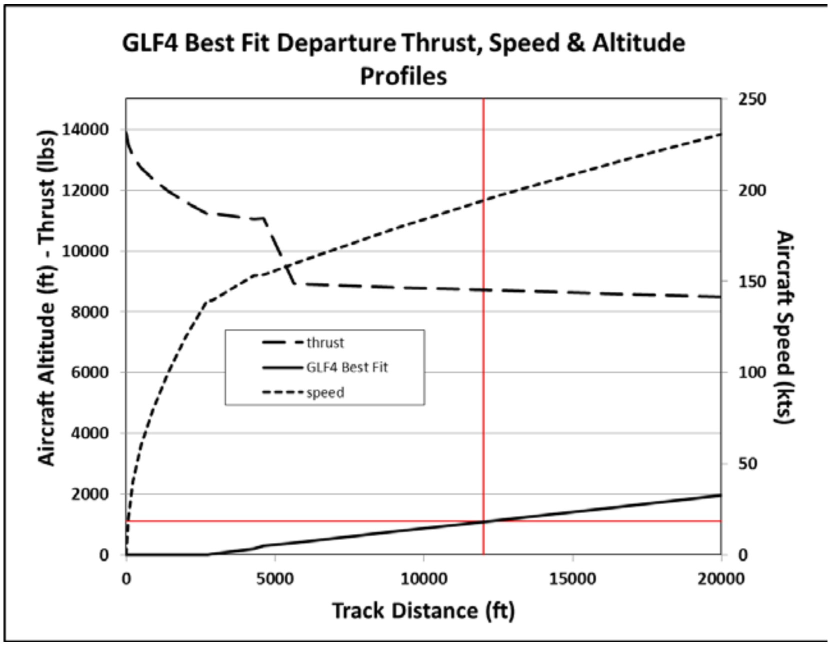


Figure 34 GLF4 best fit profile variables

Appendix G. EA50 Standard and Best Fit Departure Profiles

The following two graphs show the thrust use in pounds (left axis), altitude in feet above field level (left axis as well), and speed in knots (right axis). As shown, the use of thrust is only slightly modified from standard to best fit profile. Rather, the best fit departure follows the general concept of the standard departures with a takeoff segment, then adjustments in succeeding segments of the target altitudes and climb rates to reach the measured altitude and SEL value. For the EA50, this approach results in a somewhat unusual set of speed and altitude profiles, but see Section 0.

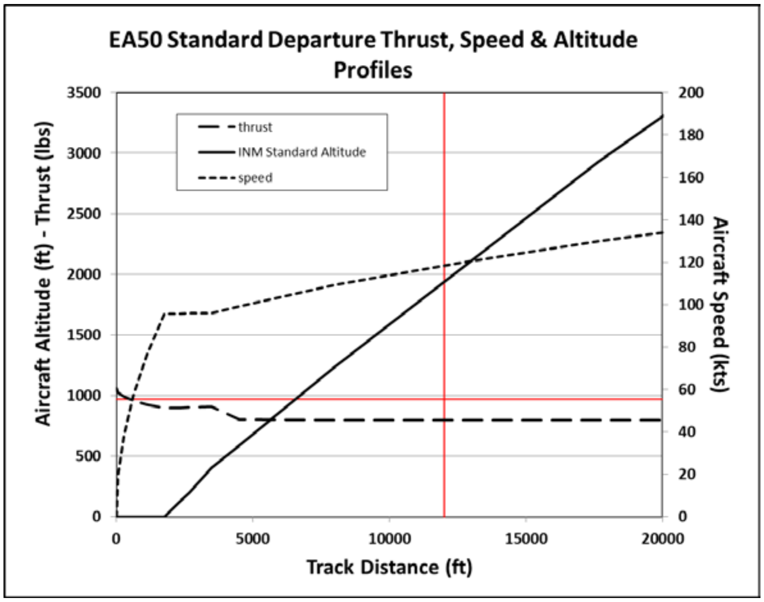


Figure 35 EA50 INM standard profile variables

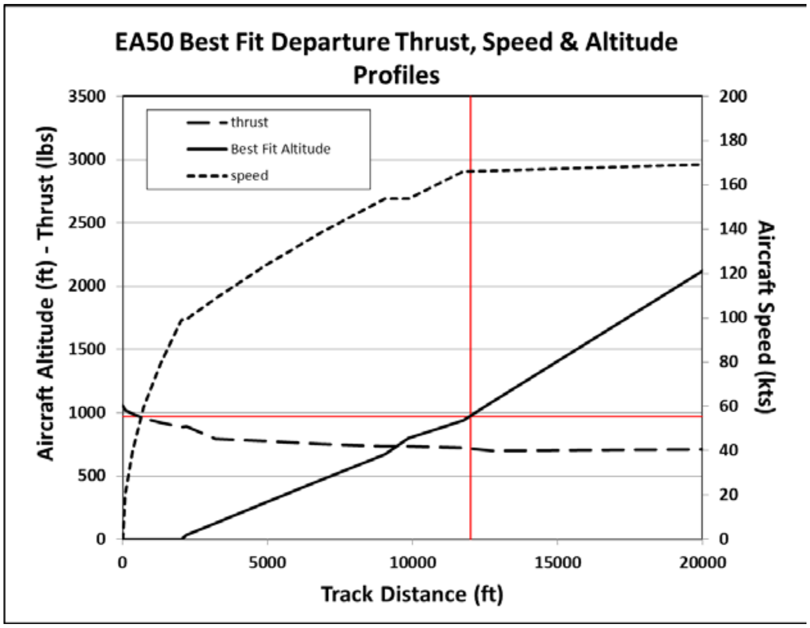


Figure 36 EA50 best fit profile variables

Appendix H. GIV STANDARD and ATM1 Procedure Profiles

Table 36 GIV Standard Profile

ACFT_ID	OP_TYPE	PROF_ID1	PROF_ID2	STEP_NUM	STEP_TYPE	FLAP_ID	THR_TYPE	PARAM1	PARAM2	PARAM3
GIV	D	STANDARD	1	1	T	T-20-D	T	0.0	0.0	0.0
GIV	D	STANDARD	1	2	C	T-20-D	T	35.0	0.0	0.0
GIV	D	STANDARD	1	3	A	T-20-D	T	1800.0	159.2	0.0
GIV	D	STANDARD	1	4	C	T-20-U	T	400.0	0.0	0.0
GIV	D	STANDARD	1	5	C	T-20-U	C	600.0	0.0	0.0
GIV	D	STANDARD	1	6	C	T-20-U	C	750.0	0.0	0.0
GIV	D	STANDARD	1	7	C	T-10-U	C	1850.0	0.0	0.0
GIV	D	STANDARD	1	8	C	T-10-U	C	3000.0	0.0	0.0
GIV	D	STANDARD	1	9	A	T-0-U	C	1750.0	250.0	0.0
GIV	D	STANDARD	1	10	C	T-0-U	C	5000.0	0.0	0.0
GIV	D	STANDARD	1	11	C	T-0-U	C	6000.0	0.0	0.0
GIV	D	STANDARD	1	12	C	T-0-U	C	7000.0	0.0	0.0
GIV	D	STANDARD	1	13	C	T-0-U	C	8000.0	0.0	0.0
GIV	D	STANDARD	1	14	C	T-0-U	C	9000.0	0.0	0.0
GIV	D	STANDARD	1	15	C	T-0-U	C	10000.0	0.0	0.0

Table 37 GIV ATM1 Profile

ACFT_ID	OP_TYPE	PROF_ID1	PROF_ID2	STEP_NUM	STEP_TYPE	FLAP_ID	THR_TYPE	PARAM1	PARAM2	PARAM3
GIV	D	ATM1	1	1	T	T-20-D	T	0.0	0.0	0.0
GIV	D	ATM1	1	2	C	T-20-D	T	35.0	0.0	0.0
GIV	D	ATM1	1	3	A	T-20-D	T	1800.0	160.0	0.0
GIV	D	ATM1	1	4	C	T-10-U	T	400.0	0.0	0.0
GIV	D	ATM1	1	5	C	T-10-U	T	600.0	0.0	0.0
GIV	D	ATM1	1	6	A	T-10-U	T	2000.0	180.0	0.0
GIV	D	ATM1	1	7	A	T-0-U	C	1850.0	250.0	0.0
GIV	D	ATM1	1	8	C	T-0-U	C	5000.0	0.0	0.0
GIV	D	ATM1	1	9	C	T-0-U	C	6000.0	0.0	0.0
GIV	D	ATM1	1	10	C	T-0-U	C	7000.0	0.0	0.0
GIV	D	ATM1	1	11	C	T-0-U	C	8000.0	0.0	0.0
GIV	D	ATM1	1	12	C	T-0-U	C	9000.0	0.0	0.0
GIV	D	ATM1	1	13	C	T-0-U	C	10000.0	0.0	0.0

Appendix I. ATM2 Profile Points Profiles

Table 38 GIV ATM Profile Points Profile

ACFT_ID	OP_TYPE	PROF_ID1	PROF_ID2	PT_NUM	DISTANCE	ALTITUDE	SPEED	THR_SET	OP_MODE
GIV	D	ATM2	1	1	0.0	0.0	0.0	12164.90	D
GIV	D	ATM2	1	2	2669.4	0.0	128.1	9916.50	D
GIV	D	ATM2	1	3	3486.6	0.0	146.4	9595.30	D
GIV	D	ATM2	1	4	3662.2	35.0	146.5	9601.60	D
GIV	D	ATM2	1	5	6189.2	327.1	161.2	9421.60	D
GIV	D	ATM2	1	6	6527.9	400.0	161.4	9434.60	D
GIV	D	ATM2	1	7	7366.5	500.0	161.7	**8620.70**	D
GIV	D	ATM2	1	8	8205.2	600.0	161.9	**8651.10**	D
GIV	D	ATM2	1	9	9470.3	750.0	162.3	**8673.90**	D
GIV	D	ATM2	1	10	17951.1	1850.0	165.2	**8840.90**	D
GIV	D	ATM2	1	11	27126.3	3000.0	168.2	**9015.60**	D
GIV	D	ATM2	1	12	35519.3	3639.9	187.5	**8966.50**	D
GIV	D	ATM2	1	13	44822.7	4349.2	206.8	**8917.50**	D
GIV	D	ATM2	1	14	55036.7	5128.0	226.1	**8868.40**	D
GIV	D	ATM2	1	15	66161.2	5976.1	245.4	**8819.30**	D
GIV	D	ATM2	1	16	78196.2	6893.7	264.7	**8770.10**	D
GIV	D	ATM2	1	17	91141.7	7880.7	284.0	**8721.10**	D
GIV	D	ATM2	1	18	97425.7	8359.8	292.9	**8691.70**	D
GIV	D	ATM2	1	19	98014.8	8409.8	293.2	**8699.30**	D
GIV	D	ATM2	1	20	98604.9	8459.8	293.4	**8706.80**	D
GIV	D	ATM2	1	21	99196.0	8509.8	293.6	**8714.40**	D
GIV	D	ATM2	1	22	99788.3	8559.8	293.9	**8722.00**	D
GIV	D	ATM2	1	23	105047.3	9000.0	296.0	**8788.90**	D
GIV	D	ATM2	1	24	117310.8	10000.0	300.9	**8940.80**	D

Table 39 Lear35 ATM Profile Points Profile

ACFT_ID	OP_TYPE	PROF_ID1	PROF_ID2	PT_NUM	DISTANCE	ALTITUDE	SPEED	THR_SET	OP_MODE
LEAR35	D	ATM2	1	1	0.0	0.0	0.0	2943.10	D
LEAR35	D	ATM2	1	2	3565.6	0.0	145.0	2385.70	D
LEAR35	D	ATM2	1	3	4117.7	53.1	147.2	2380.80	D
LEAR35	D	ATM2	1	4	4776.6	116.5	149.8	2375.00	D
LEAR35	D	ATM2	1	5	5560.1	191.9	152.9	2368.30	D
LEAR35	D	ATM2	1	6	6548.5	286.9	156.7	2360.00	D
LEAR35	D	ATM2	1	7	7875.1	414.5	161.6	2349.20	D
LEAR35	D	ATM2	1	8	15589.7	1500.0	164.5	2402.60	D
LEAR35	D	ATM2	1	9	18703.4	1758.5	178.9	2367.30	D
LEAR35	D	ATM2	1	10	22079.4	2038.7	193.4	2331.90	D
LEAR35	D	ATM2	1	11	23079.4	2178.9	193.8	2098.80	D
LEAR35	D	ATM2	1	12	28938.4	3000.0	196.4	2141.30	D
LEAR35	D	ATM2	1	13	34714.8	3414.5	213.5	2115.80	D
LEAR35	D	ATM2	1	14	40973.2	3863.5	230.6	2090.40	D
LEAR35	D	ATM2	1	15	47713.6	4347.2	247.7	2064.90	D
LEAR35	D	ATM2	1	16	54936.1	4865.4	264.8	2039.40	D
LEAR35	D	ATM2	1	17	62640.6	5418.2	281.9	2013.90	D
LEAR35	D	ATM2	1	18	63442.8	5500.0	282.3	2017.60	D
LEAR35	D	ATM2	1	19	83625.5	7500.0	291.6	2106.10	D
LEAR35	D	ATM2	1	20	91141.7	8196.8	295.0	2137.50	D
LEAR35	D	ATM2	1	21	110593.6	10000.0	303.8	2216.80	D

Table 40 CNA560E ATM Profile Points Profile

ACFT_ID	OP_TYPE	PROF_ID1	PROF_ID2	PT_NUM	DISTANCE	ALTITUDE	SPEED	THR_SET	OP_MODE
CNA560E	D	ATM2	1	1	0.0	0.0	0.0	2860.60	D
CNA560E	D	ATM2	1	2	2449.5	0.0	111.6	2560.80	D
CNA560E	D	ATM2	1	3	3334.1	0.0	130.2	2510.90	D
CNA560E	D	ATM2	1	4	3612.2	51.3	130.3	2513.30	D
CNA560E	D	ATM2	1	5	3944.1	112.5	130.4	2516.30	D
CNA560E	D	ATM2	1	6	4338.8	185.2	130.6	2519.80	D
CNA560E	D	ATM2	1	7	4836.6	277.0	130.8	2524.10	D
CNA560E	D	ATM2	1	8	7720.0	563.7	148.8	2495.20	D
CNA560E	D	ATM2	1	9	10975.9	887.4	166.9	2466.40	D
CNA560E	D	ATM2	1	10	14625.2	1500.0	168.5	2495.60	D
CNA560E	D	ATM2	1	11	15625.2	1581.6	173.2	2414.60	D
CNA560E	D	ATM2	1	12	18323.9	1801.9	185.3	2395.30	D
CNA560E	D	ATM2	1	13	21205.2	2037.1	197.5	2376.00	D
CNA560E	D	ATM2	1	14	27907.7	3000.0	200.5	2420.30	D
CNA560E	D	ATM2	1	15	31733.7	3162.0	219.0	2388.70	D
CNA560E	D	ATM2	1	16	35896.5	3338.3	237.5	2357.00	D
CNA560E	D	ATM2	1	17	40396.2	3528.8	255.9	2325.40	D
CNA560E	D	ATM2	1	18	45232.7	3733.6	274.4	2293.70	D
CNA560E	D	ATM2	1	19	61368.5	5500.0	282.3	2375.10	D
CNA560E	D	ATM2	1	20	81035.4	7500.0	291.6	2467.20	D
CNA560E	D	ATM2	1	21	91141.7	8431.3	296.2	2510.70	D
CNA560E	D	ATM2	1	22	108166.5	10000.0	303.8	2582.30	D