Determining the Environmental Benefits of Implementing Continuous Descent Arrival Procedures

Paper #594
Eric P. Dinges

ATAC Corporation, 755 N. Mathilda Ave., Ste. 200, Sunnyvale, CA 94085

ABSTRACT

Several research and development efforts to date have been aimed at demonstrating that Continuous Descent Arrival (CDA) procedures have the potential for significant environmental benefits including reductions in noise, emissions, and fuel burn. The benefits evaluation portion of these efforts typically involves evaluating small numbers of CDA flights under idealized flight test conditions. This paper focuses on the development and application of analytical methods for quantifying potential airport-wide environmental benefits of implementing CDAs. These efforts are being performed as part of the development of a CDA modeling capability within the U.S. Federal Aviation Administration's Aviation Environmental Design Tool (AEDT). Existing internationally accepted modeling methods and data are used, where appropriate, including methods described in the Society of Automotive Engineers (SAE) Aerospace Information Report (AIR) 1845, the Third Edition of European Civil Aviation Conference (ECAC) Doc 29, and data from EUROCONTROL's Aircraft Noise and Performance (ANP) database. These are used in conjunction with real-world operational and flight procedure data to look at the noise, emissions and fuel burn benefits of CDAs. The noise benefits are quantified in terms of changes in Day Night Average Sound Level (DNL) contours, the emissions benefits are quantified in terms of change in total mass of eight different pollutants, and the fuel burn benefits are quantified in terms of the change in total mass of the fuel burned. The benefits are evaluated based on both actual implementation levels and potential future levels of CDA implementation as a function of traffic flow density. This type of analysis may help support Air Traffic Management (ATM) decisions on CDA implementation based on tradeoffs between the efforts required to implement CDAs versus the predicted environmental benefits.

INTRODUCTION

Recent studies have shown that Continuous Descent Arrival (CDA) procedures have the potential for producing significant reductions to both noise and emissions levels in the vicinity of airports, thereby reducing capacity restraints due to environmental concerns. A capability to model those environmental benefits is needed to support CDA implementation efforts. In addition, methods needed for accurate before and after CDA comparisons will improve the modeling of arrival flight profiles for environmental purposes in general and are applicable to other operations-based environmental mitigation strategies that could be considered by the ATM community.

There are currently several limitations in the standard methods used for noise and emissions modeling of arrival operations that prevent a meaningful determination of the benefits to be obtained from CDAs or other operational procedures. This paper describes those limitations and addresses methods for overcoming them. It also outlines methods for overcoming current limitations related to modeling CDA flight paths themselves. These methods are assessed in a sample analysis of the noise, emissions and fuel burn benefits of CDA implementation at a major U.S. airport, based on actual current levels of CDA implementation as well as on potential future levels of implementation as a function of traffic flow density. This sample analysis is the second of two for the same airport, expanding on the initial analysis[1] and also incorporating lessons learned.

BACKGROUND

There have been several recent efforts that involve the modeling of CDAs for a small number of flights. These efforts include the CDA testing and analysis at Louisville International Airport (KSDF) performed by the FAA/NASA/Transport Canada sponsored Partnership for Air Transportation Noise and Emissions Reduction (PARTNER)[2], and EUROCONTROL's Sourdine project[3]. The PARTNER work focused on designing and implementing CDAs, but also investigated both the measured and modeled noise and emissions benefits from a small number of actual flights following CDA profiles developed specifically for late night operations at KSDF. The Sourdine project was more focused on modeling and source noise data rather than CDA implementation, but again focused on a small number of flights under test conditions. It looked at enhancing the current method of predicting aircraft source noise levels purely as a function of thrust by also considering aircraft configuration and speed. Through the development of configuration-specific Noise-Power-Distance (NPD) curves, it is possible to consider the airframe noise generated, which is especially important when attempting to accurately model noise levels from low-thrust CDAs. Other evaluations of CDAs have also been performed recently at the Nottingham East Midlands airport in the UK, Schiphol Airport in the Netherlands and Sacramento's Mather, Los Angeles International, and Atlanta Hartsfield airports in the U.S. Like the Louisville effort, these evaluations focused on CDA design and implementation. None of these efforts were focused on the type of airport-wide environmental analysis of the type typically required for environmental regulatory compliance.

The potential airport-wide environmental impacts of CDAs have yet to be investigated in great detail. Additionally, there are limitations with current standard practices for modeling arrival flight operations that interfere with airport-wide studies of the environmental benefits of CDAs. The aircraft flight paths currently used during airport noise and emissions analysis are typically generated using guidance from standards documents such as the Society of Automotive Engineers (SAE) Aerospace Information Report (AIR)-1845[4] or the European Civil Aviation Conference (ECAC) Document 29[5]. These documents describe methods for calculating aircraft flight paths using performance data and flight profiles supplied by aircraft manufacturers. The two main sources for these data accessible by the general public are the standard database from the Federal Aviation Administration's (FAA) Integrated Noise Model (INM)[6], and EUROCONTROL's recently created Aircraft Noise and Performance (ANP) database.

The two databases are consistent with each other and conform to SAE-AIR-1845 and ECAC Document 29 guidance. Flight profiles from the INM database are used directly when performing noise analyses with the INM and they are also used when modeling airport emissions using the current version of the FAA's Emissions and Dispersion Modeling System (EDMS)[7].

The INM and ANP databases contain manufacturer-supplied arrival and departure profiles for most aircraft in the world's commercial aircraft fleet. These profiles were developed to represent how each aircraft would normally fly at typical commercial airports. There are several profiles defined for departure operations, representing a range of operating weights. For arrival operations, however, there is typically only one flight procedure defined per aircraft. Additionally, departure profiles are typically calculated from well understood departure flight procedures, whereas arrival profiles typically follow an idealistic constant 3 degree glideslope. Models like the INM allow users to modify the standard flight profiles contained in the database or even create their own profiles, however experience shows that the majority of airport noise and emissions analyses rely on the standard, manufacturer-supplied profiles. Experience also shows that there can be large differences between the manufacturer-supplied arrival profiles used for environmental modeling and the arrival profiles actually being flown at airports. In fact, the typical manufacturer-supplied arrival profiles often closely resemble CDAs and are not suitable for use when trying to generate baseline noise and emissions levels for comparison with those generated by CDAs.

Unlike other efforts that have involved modeling a very limited number of CDAs under tightly controlled conditions, this paper applies enhancements to current methods for modeling aircraft flight paths for environmental analysis to determine the potential airport-wide benefits of CDAs at a major U.S. airport. The demonstration and assessment of this capability was performed using portions of the FAA's Aviation Environmental Design Tool (AEDT), which will eventually fully incorporate the INM and EDMS, as well as FAA's System for assessing Aviation's Global Emissions (SAGE)[8],the Model for Assessing Global Exposure to the Noise of Transport Aircraft (MAGENTA)[9], and the Noise Integrated Routing System (NIRS). The study is considered one of several capability demonstrator sample problems that have been undertaken in support of continued AEDT development.

FLIGHT OPERATION DEFINITIONS

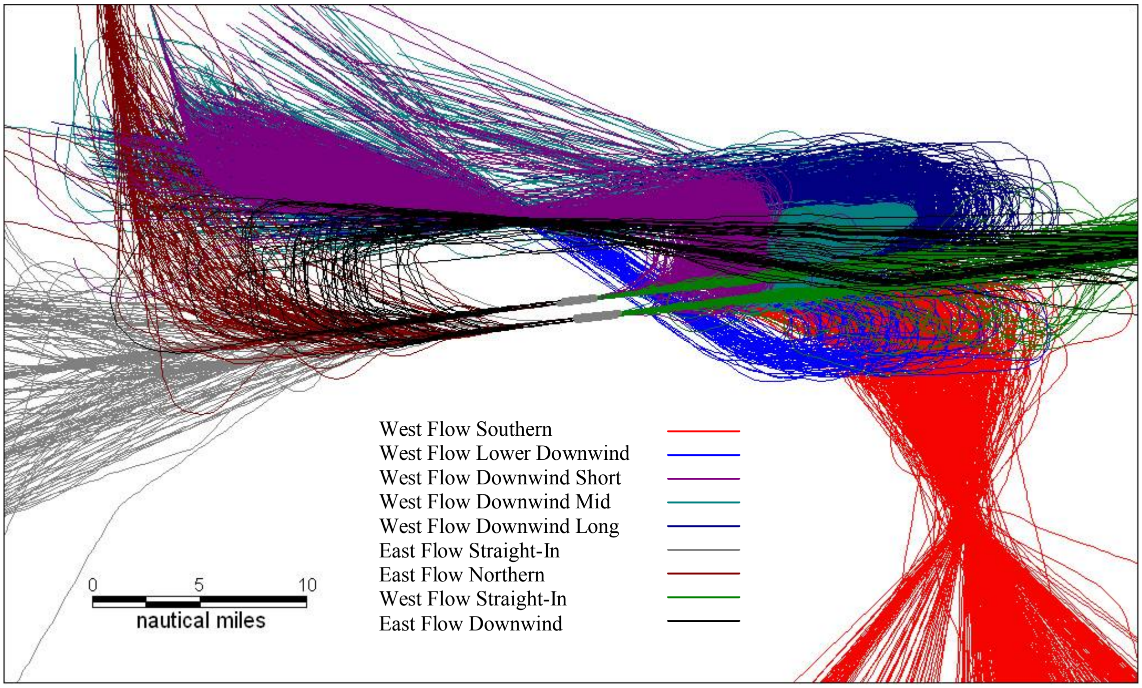
The capability demonstration undertaken under this effort models average daily arrival operations for all operating configurations at Los Angeles International Airport (LAX). This airport was chosen for the demonstration because it exhibits variation in vertical arrival profiles and therefore provides a good example of the potential for noise, emissions and fuel burn benefits due to the implementation of CDA procedures. Many airport-specific factors determine the amount of fleet mix and flight trajectory variation that will exist at a given airport. Twenty-four days of the FAA/NASA Performance Data Analysis and Reporting System (PDARS)[10] based radar data were used to define the average daily flight operations and the baseline flight profiles for this demonstration. Modeled flights were limited to flights from aircraft with FAA weight classifications of F

(757), H (Heavy), and L (Large). These weight classifications are used to determine the required separation distance between different types of aircraft, and Boeing 757's have their own weight classification (F) due to their unique wake characteristics. Operations associated with aircraft in these categories are expected to contribute significantly to the noise and emissions produced around the modeled airport. These categories also include most aircraft types for which the detailed flight performance data necessary to model noise and emissions from radar data exists within the INM/AEDT and ANP databases.

Aircraft types are identified within the radar data using the International Civil Aviation Organization (ICAO) four-letter aircraft codes (e.g. B737), which do not have the fidelity to identify the specific aircraft model versions and engine configurations needed for accurately modeling noise and emissions. AEDT contains the aircraft performance data necessary to derive thrust, and therefore noise and emission levels, from radar data for a limited set of aircraft. The aircraft noise and performance data within INM/AEDT are directly analogous to the data available within the ANP database. AEDT also contains data on the emissions produced by a limited set of aircraft engines. Consequently, not all of the flights observed in the radar data could be included in this capability demonstration. Mappings were developed between FAA Aircraft Identifiers ICAO four-letter aircraft codes and supported AEDT aircraft/engine identifiers with the goal of capturing as many of the aircraft types found in the radar data as possible.

Different arrival routes into an airport have different characteristics including both vertical and horizontal paths due to the design of the local airspace. Therefore it is important to look at the different arrival routes independently when determining the effects of arrival procedure changes like the implementation of CDAs. The arrival flight operations for this capability demonstration and assessment were separated into ten arrival types including seven different types for the dominant west-flow operating configuration and three different types for the east-flow operating configuration. Baseline ground tracks were defined directly from radar data, assigning a unique track to each flight operation. As detailed in the PARTNER CDA study at KSDF, aircraft flying CDA procedures typically fly consistent, pre-defined ground tracks to ensure that an optimal CDA flight path is achieved. Unfortunately, such ground tracks have only been defined for one of the arrival routes at the modelled airport to date. Therefore, for this demonstration a single nominal CDA track was derived from the appropriate baseline radar tracks for each arrival type and runway end combination. A graphical depiction of the baseline and CDA ground tracks for each arrival type is shown in Figure 1.

Figure 1: LAX Radar and CDA Ground Tracks per Arrival Type



The final extent to which CDAs can be realistically implemented at the modelled airport is not known at this time. The level of CDA implementation will be dictated by numerous ATM considerations that are beyond the scope of this demonstration. Given this context, the demonstration attempts to determine the noise, emissions and fuel burn impacts from a range of possible CDA implementation levels. The evaluated CDA implementation levels include a hypothetical look spanning a pre-implementation baseline (with no CDAs) to a scenario where every arrival is a CDA, with five graduated steps in between. They also include a look at actual (though limited) implementation levels defined using trajectory and operations data covering a fourteen day actual post-CDA implementation time period.

The actual CDA implementation is evaluated in the “Actual CDA” scenario. The scenario is based directly on the fourteen day post-implementation data set and therefore includes fewer individual flight trajectories than the baseline scenario (fourteen vs. twenty-four days worth of trajectories), and includes an aircraft fleet mix similar but not identical to the baseline scenario. Unlike the hypothetical implementation scenarios, the Actual CDA scenario includes the affects of all of the airspace changes made for the post-implementation situation. It is often not possible to implement CDAs without at least some changes to other aspects of the airspace, and it is important to include the effects of these other airspace changes when trying to determine the true airport-wide impacts of CDAs.

CDAs require carefully determined minimum separation distances at high altitudes to ensure that aircraft do not violate the minimum in-trail separation distances prior to landing[11]. Therefore, a very significant factor determining whether or not a CDA can be flown is likely to be the level of traffic congestion for a given stream of traffic or arrival route. Another significant factor is the affect of operations from other, nearby airports on the arrival routes. With the former factor in mind, the five graduated steps between the baseline and the full CDA implementation scenarios used for the hypothetical CDA implementation scenarios are defined using traffic flow thresholds independently applied to flights on each of the ten modelled arrival routes. These traffic flow thresholds specify the number of flights within a given 15-minute time period that can be accommodated while flying CDAs. The five traffic thresholds are equal to 0.75, 1.75, 3.0, 4.25, and 5 flights per 15-minute time period per arrival route, respectively. These threshold values were chosen because they represent somewhat even steps between the all-baseline and all-CDA scenarios in terms of the percentage of total arrivals utilizing CDAs. For each scenario using traffic thresholds, if the number of flights within a given 15-minute time period is below the given traffic flow threshold, all flights during that period are modelled using CDA profiles along CDA ground tracks, rather than following the radar-defined trajectories. Figure 2 displays the number of arrivals per 15-minute interval for the Straight-In arrival route. Table 1 contains the total percentage of CDA operations per scenario, with each scenario including flight operations on all ten arrival routes.

Figure 2: Average Daily Straight-In Arrivals

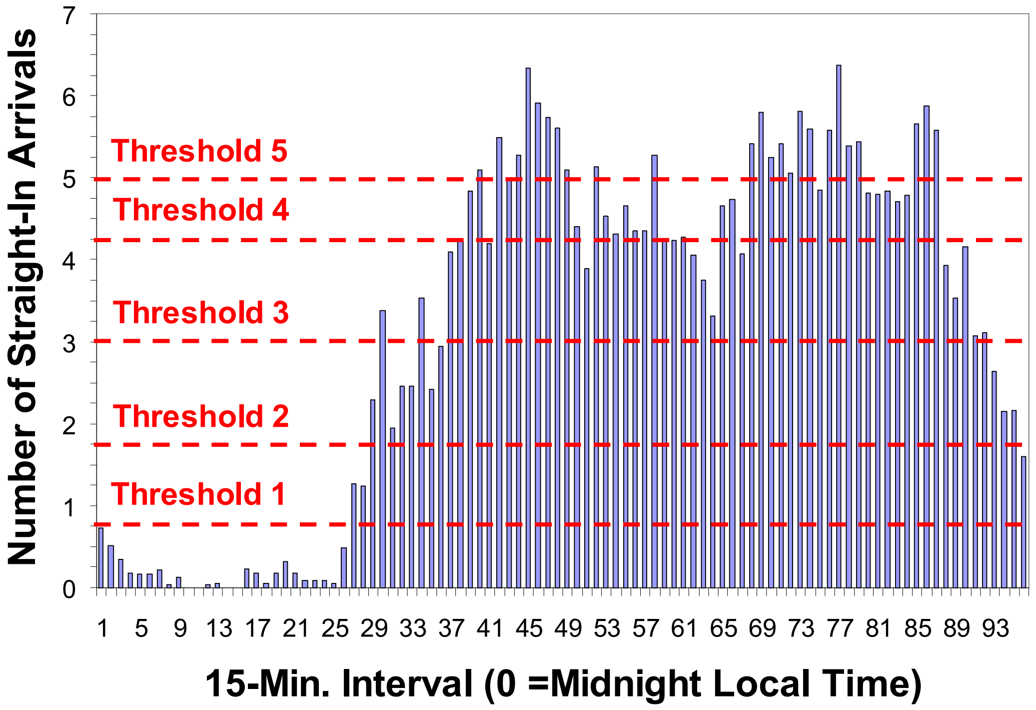


Table 1: CDA Operation Percentages

[redacted]

BASELINE FLIGHT PROFILE DEFINITIONS

The baseline aircraft flight profiles used were derived directly from radar data. Every modeled baseline flight operation follows the flight profile and ground track observed in the radar data for that operation. Example altitude vs. track distance values for the baseline flight profiles from several of the modeled arrival routes are displayed in Figures 3-5.

Figure 3: Baseline West Flow Straight-In Arrivals

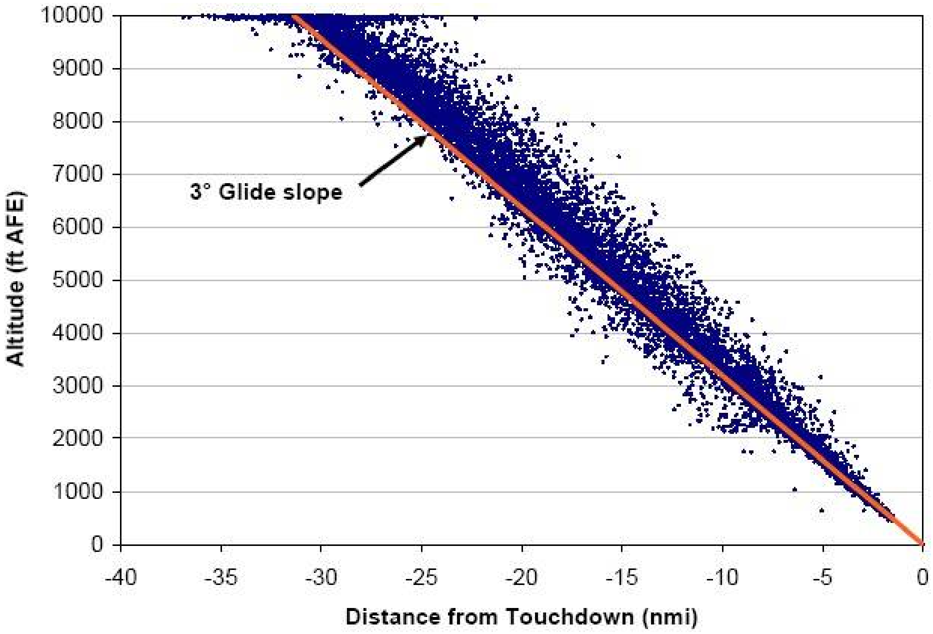


Figure 4: Baseline West Flow Downwind (Short, Mid, and Long) Arrivals

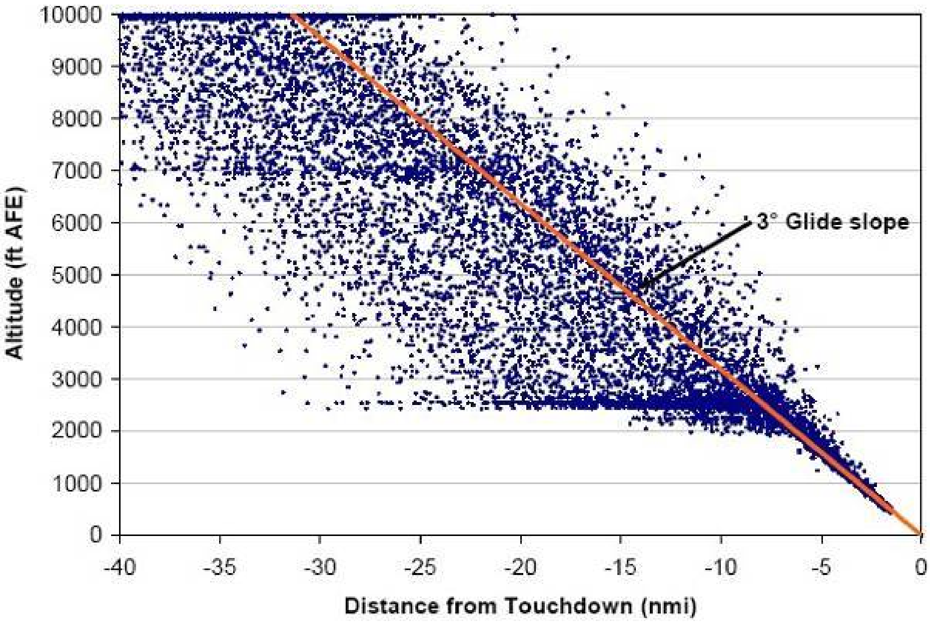
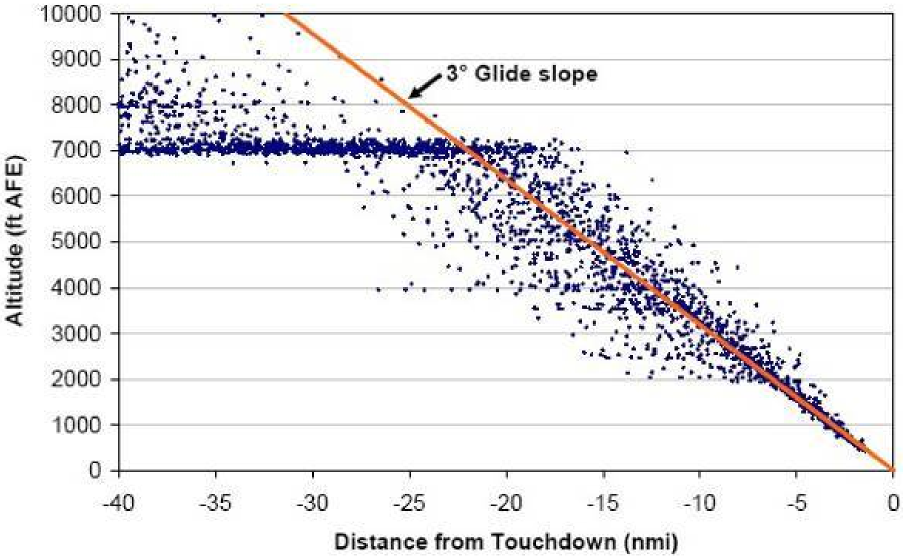


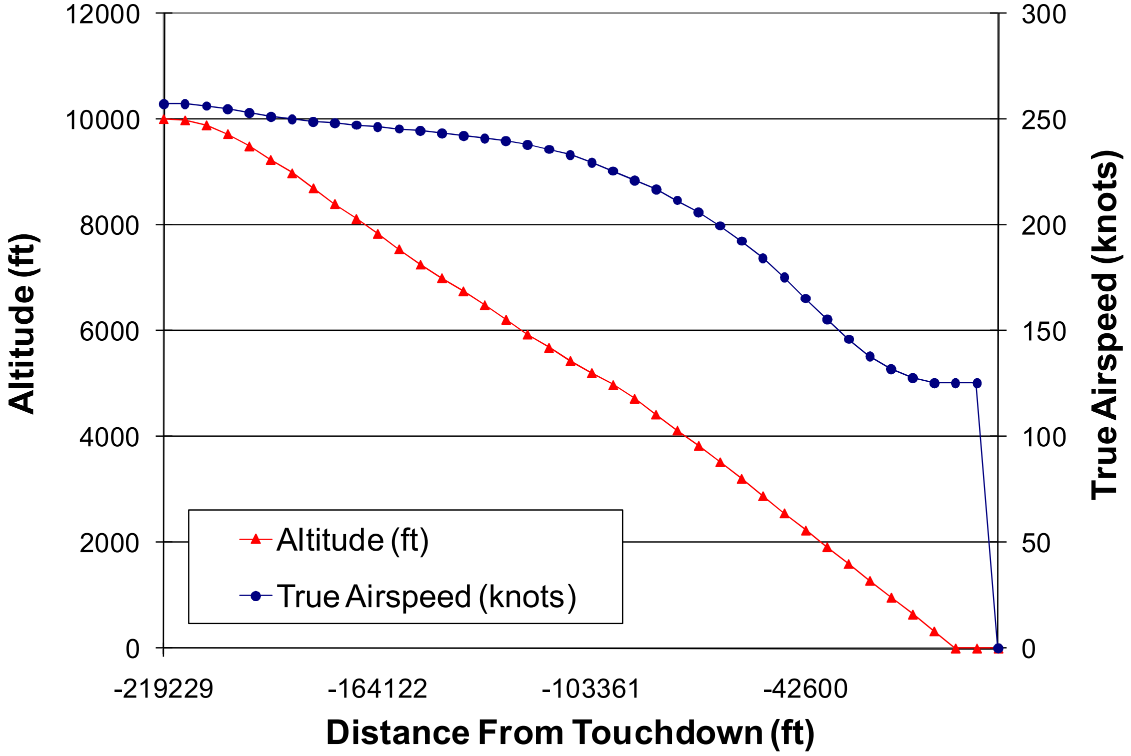
Figure 5: Baseline West Flow Southern Arrivals



CDA FLIGHT PROFILE DEFINITIONS

Detailed CDA procedures have not yet been defined for all arrival routes at the modeled airport, however CDA procedures for one arrival route (West Flow Straight-In) can be observed from post CDA implementation radar data set used within this analysis. All modeled CDA profiles are based on these actual observed profiles. The fourteen day post implementation radar data set was used to define aircraft-type specific CDA profiles (altitude and speed vs. distance) by determining the average profile from the trajectories of all observed CDA operations for a given aircraft type. CDA speed schedules were also adjusted to remain consistent with operation-specific aircraft weight values, using the baseline scenario's weight value for each operation. Figure 6 includes an example CDA profile for one aircraft type. This figure exemplifies that the observed CDA profiles were often similar but not identical to the idealized constant 3 degree glideslope followed in the manufacturer-supplied default profiles typically used for environmental modeling.

Figure 6: Example Boeing 737-700 CDA Profile



CALCULATING NOISE AND EMISSIONS FROM RADAR AND HYPOTHETICAL CDA TRAJECTORIES

Radar data can provide more realistic arrival trajectories than the single manufacturer-supplied trajectory for each aircraft available in the ANP database. Radar data, however, is missing some of the information needed for environmental modeling, most importantly aircraft power or thrust values along the flight path. Several groups currently have processes for determining aircraft thrust levels from radar data using the aircraft performance data and flight path calculation equations contained in SAE-AIR-1845 and ECAC Doc 29. The latest revision of ECAC Doc 29 also indicates that this can be done, however no detailed, standardized guidance exists for this kind of process. Therefore a new methodology for deriving aircraft thrust levels from aircraft position data such as radar has been developed for this capability demonstration, and is being updated based on lessons learned from each round of analysis. The SAE A-21 Committee on Airport Noise and Emissions Modeling is currently investigating the best methodology to be used and also the uncertainty that can be expected when using such a methodology as part of the process for creating a guidance document on the subject, and is evaluating the methodology developed for this capability demonstration as part of this effort.

DNL CONTOUR COMPARISONS

Day Night Average Sound Level (DNL) contours were calculated for each of the nine scenarios (Baseline or No-CDA, Threshold 1-5, All-CDA, and Actual CDA). Table 2 details the change in DNL contour areas relative to the Baseline scenario for arrival operations only. For most contour levels, as the number of CDA operations increases (as represented by the progression through the Threshold 1-5 and All CDA scenarios) the size of the contour decreases, as would be expected. The benefit due to CDAs generally increases as the contour level decreases, representing the effects of the greater differences between the baseline and CDA profiles at higher altitudes and greater distances from the airport. While this paper presents results at relatively low DNL contour levels to show the affects at greater distances from the airport that are in line with the flight profile changes, it is important to keep in mind that benefits at these low DNL levels may not be realized in the real world due to ambient noise level constraints.

In the region very close to the airport (associated with higher level DNL contours), little difference would be expected between the noise produced by baseline and CDA profiles, as they both typically fly the 3-degree glideslope. These contours have very small areas to start with and relative area comparisons between them are therefore very sensitive to modeling inputs. It is suspected that the change in contour areas seen in this demonstration is due to small noise differences driven by small speed differences between the baseline and CDA profiles. This issue will be investigated further.

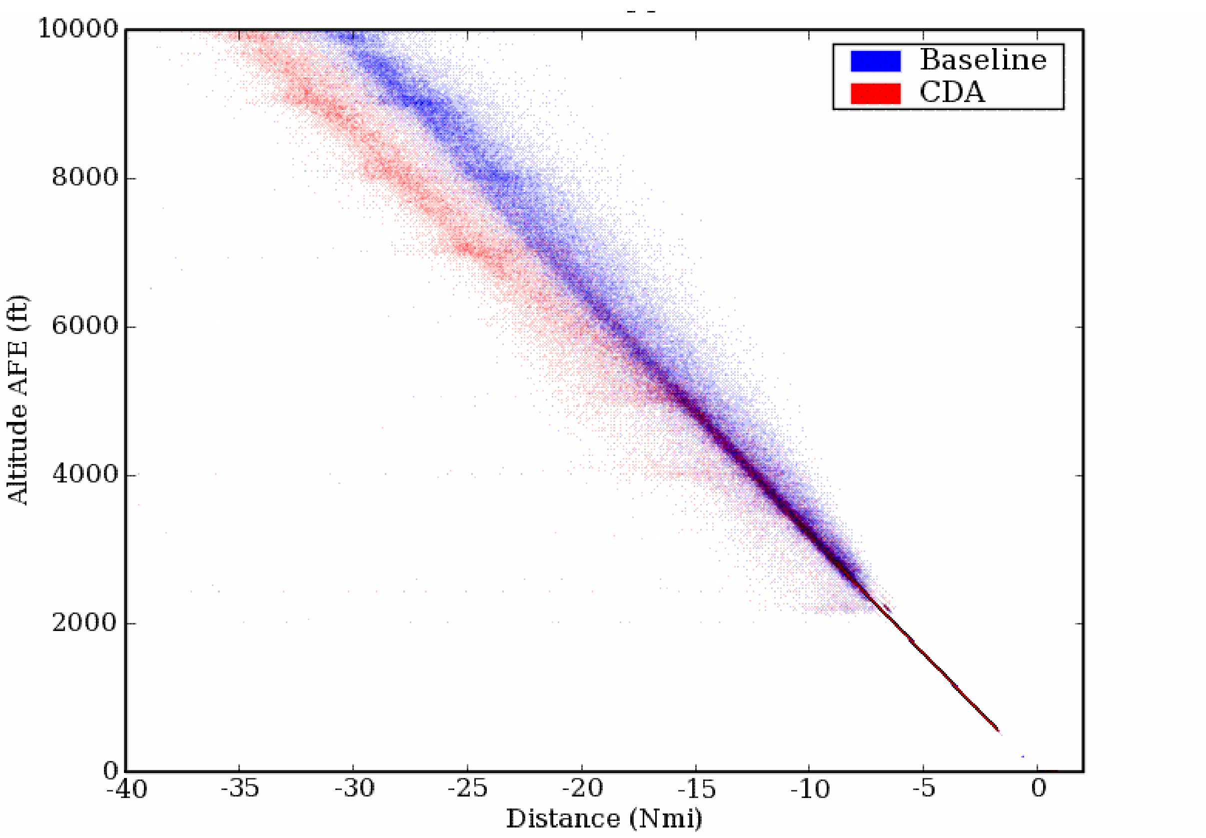
Table 2: Arrivals-Only DNL Contour Area Differences

DNL (dB)	% Change in Area Relative to Baseline						
	Threshold 1	Threshold 2	Threshold 3	Threshold 4	Threshold 5	All CDA	Actual CDA*
45	-8.0%	-14.1%	-19.7%	-20.0%	-20.0%	-20.2%	13.7%
50	-4.3%	-6.6%	-9.0%	-9.5%	-9.7%	-10.0%	8.3%
55	-2.8%	-4.3%	-5.9%	-6.6%	-6.9%	-7.4%	4.8%
60	-1.7%	-2.6%	-3.7%	-4.4%	-4.6%	-5.0%	3.3%
65	-0.7%	-1.2%	-1.9%	-2.2%	-2.4%	-2.6%	2.6%
70	-0.8%	-1.5%	-2.2%	-2.6%	-2.9%	-3.5%	2.4%
75	0.4%	0.0%	0.4%	0.4%	0.4%	0.4%	3.7%
80	-2.0%	-2.0%	-2.0%	0.0%	0.0%	-2.0%	3.9%

* Modeled increase influenced by unaccounted for non-standard aircraft configurations during baseline straight-in arrivals

The Actual CDA scenario differs from the other scenarios in that CDAs are only implemented on the one arrival route included in the actual CDA implementation, so it would be expected that Actual CDA contour area differences would be smaller due to the reduced number of CDAs involved. The Actual CDA scenario is unique in that it shows an increase in DNL contour areas due to the CDA implementation. This is attributed to the fact that the baseline operations on the West Flow Straight-In arrival route follow very steep and fast trajectories, and must make use of non-standard aircraft configurations (i.e. full flaps at high altitudes and speed brakes) to achieve them. These non-standard aircraft configurations are not obtainable from radar trajectory data, and were therefore not accounted for when modeling the baseline profiles and determining noise and thrust levels. In addition, current standard airport noise modeling methods do not explicitly account for the additional airframe noise caused by extended flaps or speed brakes. As CDAs attempt to avoid these types of non-standard configurations by design, the CDA operations were forced to fly shallower and slower (and therefore noisier when airframe noise is not accounted for) trajectories than the baseline flights. A comparison of the CDA and comparable baseline flight trajectories is shown in Figure 7. It is expected that if the baseline non-standard aircraft configurations and airframe noise were accounted for in the modeling process that the CDA implementation would have resulted in reductions to DNL contour areas for the Actual CDA scenario.

Figure 7: Baseline and CDA West Flow Straight-In Arrivals



Departure noise typically dominates DNL contours around airports, so it is important to take departure noise into account when looking at the impacts of CDAs. Table 3 details the change in DNL contour areas relative to the Baseline scenario when accounting for both arrival and departure operations. As would be expected, the contour area reductions due to CDA implementation are smaller relative to the arrivals-only numbers when departure noise is taken into account.

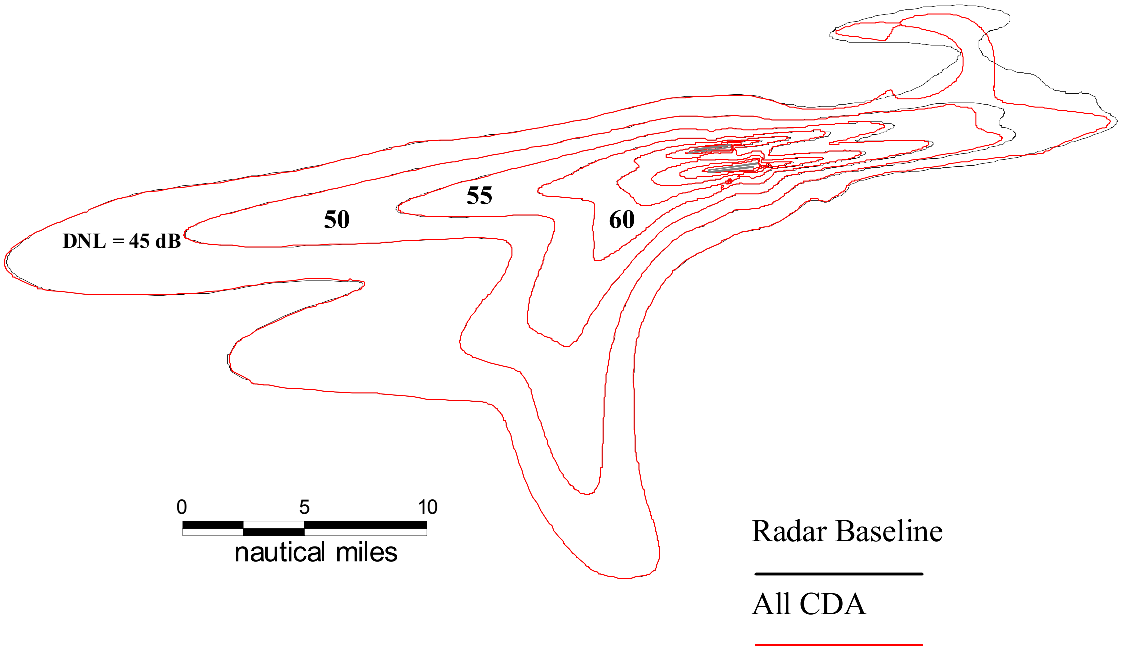
Table 3: Arrivals and Departures DNL Contour Area Differences

DNL (dB)	% Change in Area Relative to Baseline						
	Threshold 1	Threshold 2	Threshold 3	Threshold 4	Threshold 5	All CDA	Actual CDA
45	-1.4%	-2.7%	-3.9%	-4.0%	-4.0%	-4.0%	-8.1%
50	-0.8%	-1.3%	-1.7%	-1.8%	-1.9%	-2.0%	-5.0%
55	-0.7%	-1.0%	-1.3%	-1.4%	-1.5%	-1.6%	-4.3%
60	-0.4%	-0.7%	-0.9%	-1.0%	-1.1%	-1.2%	-4.7%
65	-0.2%	-0.4%	-0.5%	-0.6%	-0.6%	-0.7%	-5.0%
70	-0.2%	-0.3%	-0.4%	-0.5%	-0.6%	-0.7%	-3.9%
75	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-5.7%
80	-0.1%	-0.3%	-0.1%	-0.2%	-0.1%	0.0%	-8.2%

It is also important to note that while Table 2 shows an increase in contour areas for the Actual CDA scenario due to the modeling limitations discussed above, Table 3 shows a marked decrease in contour areas for the Actual CDA scenario when departures are taken into account. This is due to the effect of other airspace changes that occurred along with the CDA implementation, in this case the removal of a hold-down for a prominent departure route. The Actual CDA scenario is the only scenario that includes the effects of non-CDA airspace changes, and in this case the non-CDA change dominates the noise impacts.

Figure 8 presents overlays of the DNL contours from the baseline and all-CDA scenarios. Significant changes occur in the general shapes of the outer contours on the eastern (right) side of the airport where the noise is dominated by West Flow arrivals, in addition to a substantial decrease in overall areas in this region. These changes in shape can be attributed to the affects of the concentrated ground tracks being followed by the CDA operations relative to the dispersed ground tracks observed in the radar (baseline) data and shown in Figure 1. The CDA ground tracks do not have the horizontal dispersion typically associated with the baseline ground tracks. Relative to the baseline, the CDA ground tracks concentrate the sound exposure and thus increase the DNL contour lengths along their centerlines, but also tend to reduce the width of the contours for this same reason. The net change is an increase in the overall contour area.

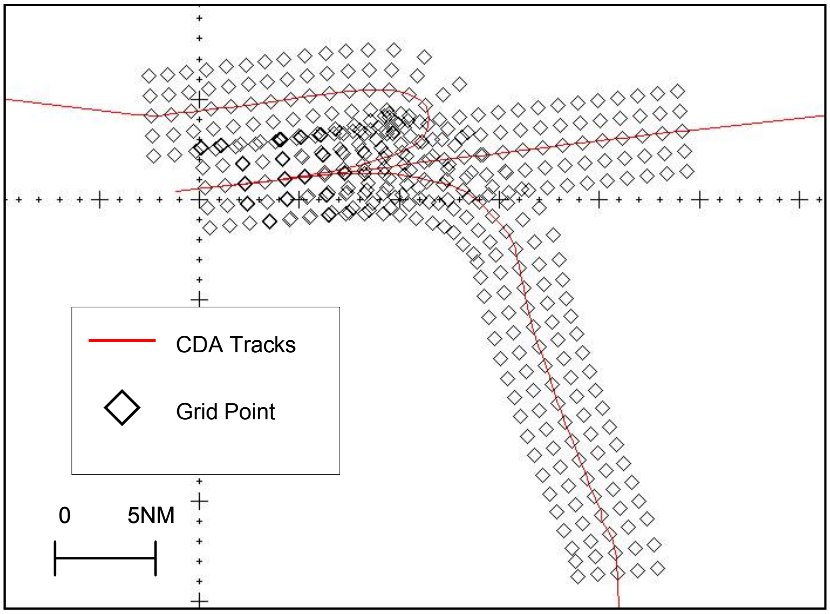
Figure 8: Baseline and All-CDA DNL Contour Overlays



SEL GRID POINT COMPARISONS

As noted above, the trajectories flown on the ten arrival routes vary significantly from one another. To evaluate the noise benefits of CDAs relative to the trajectories observed for each individual arrival type, A-Weighted Sound Exposure Levels (SEL) were calculated at a series of grid points. The locations of these grid points are specified in one nautical mile increments along each of the CDA ground tracks, which represent average or nominal tracks. The grid points are defined along the centerline of each CDA ground track as well as perpendicular to each ground track, with the perpendicular spacing between the points also equal to one nautical mile. Figure 9 displays the grid point locations defined along the CDA ground tracks for one of the airport runways.

Figure 9: SEL Grid Point Locations



SEL values were calculated at grid points along the appropriate ground track for only West Flow Straight-In and only West Flow Downwind Mid flight operations for all baseline profiles on baseline ground tracks. SEL values were also calculated in the same manner for flight operations for all CDA profiles on CDA ground tracks. These two sets of SEL values allow for the evaluation of the benefits of CDAs relative to each of the two types of baseline flight profiles observed from the radar data. Figure 10 contains the relative differences between these two sets of SEL values for each arrival route, CDA minus baseline. Differences are given at grid points along the centerline of the appropriate CDA ground track as well as at grid points perpendicularly offset from the CDA ground track.

Figure 10: Runway 24R SEL Comparison

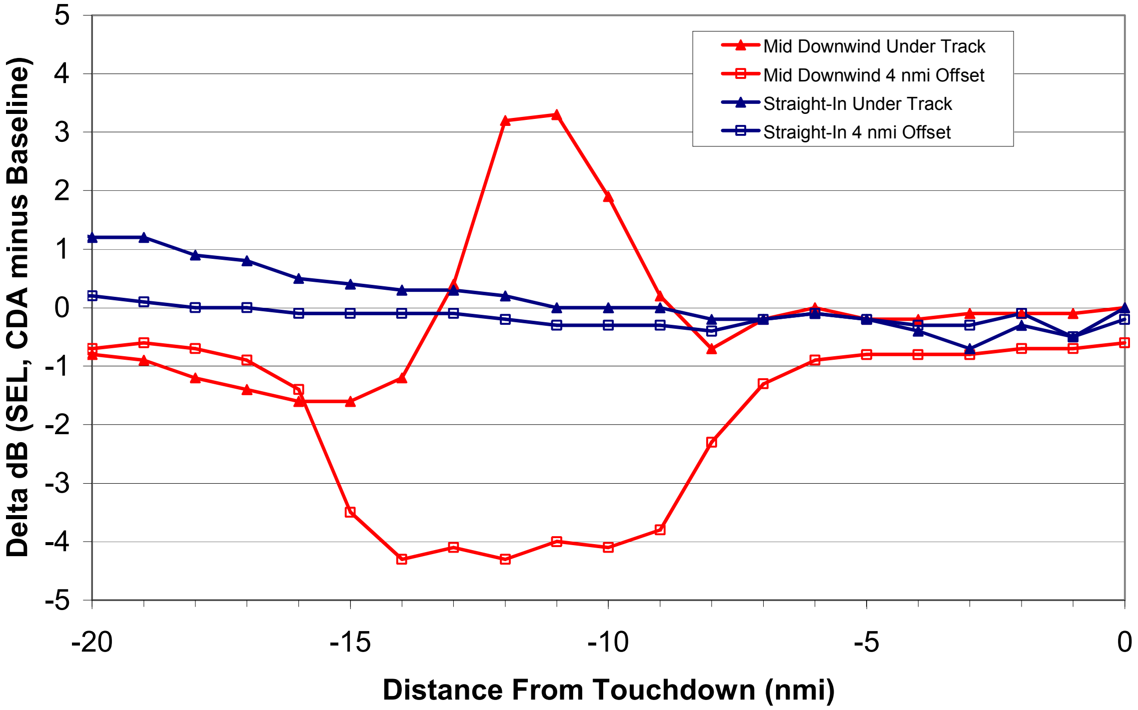


Figure 10 shows very small differences in noise levels from CDAs relative to the Straight-In arrival trajectories. This is to be expected as the CDA profiles used in this demonstration are derived from the Straight-In arrival trajectories. A greater benefit due to CDAs is shown relative to the Mid Downwind arrival trajectories. For this arrival type, at certain track distances, CDAs cause an increase in SEL levels along the CDA ground track centerlines. The increasing noise at these track distances is due to differences in ground track dispersion between the baseline and CDA ground tracks noted above. At these same track distances, the grid points offset from the centerline show significant noise benefits due to CDAs.

EMISSIONS AND FUEL BURN COMPARISONS

Airport-wide fuel burn and emissions levels were calculated for each of the nine scenarios (Baseline or No-CDA, Threshold 1-5, All-CDA, and Actual CDA). Table 4 includes fuel burn and emissions level comparisons below 10,000 ft AFE for arrival operations only, while Table 5 includes comparisons below 10,000 ft AFE for both arrivals and departures.

Table 4: Emissions and Fuel Burn Differences Below 10,000 FT AFE - Arrival Only

	Percent Change from Baseline								
Scenario	CO	THC	NMHC	VOC	NOX	SOX	PM10	PM25	FUEL
Baseline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Threshold 1	-6.0%	-2.0%	-2.0%	-2.0%	-11.9%	-11.2%	-8.8%	-8.8%	-11.2%
Threshold 2	-8.4%	-3.0%	-3.0%	-3.0%	-19.4%	-17.7%	-14.0%	-14.0%	-17.7%
Threshold 3	-9.7%	-3.1%	-3.1%	-3.1%	-26.2%	-23.5%	-18.3%	-18.3%	-23.5%
Threshold 4	-6.6%	-0.7%	-0.7%	-0.7%	-27.4%	-23.8%	-18.8%	-18.8%	-23.8%
Threshold 5	-3.3%	2.8%	2.8%	2.8%	-28.3%	-23.9%	-19.1%	-19.1%	-23.9%
All CDA	1.0%	8.5%	8.5%	8.5%	-30.0%	-24.2%	-19.8%	-19.8%	-24.2%
Actual CDA	3.1%	2.4%	2.4%	2.4%	-1.2%	-0.3%	-0.5%	-0.5%	-0.3%

Table 5: Emissions and Fuel Burn Differences Below 10,000 FT AFE – Arrivals and Departures

	Percent Change from Baseline								
Scenario	CO	THC	NMHC	VOC	NOX	SOX	PM10	PM25	FUEL
Baseline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Threshold 1	-4.5%	-0.1%	-0.1%	-0.1%	-0.8%	-1.7%	-0.6%	-0.6%	-1.7%
Threshold 2	-6.4%	-0.2%	-0.2%	-0.2%	-1.2%	-2.7%	-1.0%	-1.0%	-2.7%
Threshold 3	-7.4%	-0.2%	-0.2%	-0.2%	-1.7%	-3.6%	-1.3%	-1.3%	-3.6%
Threshold 4	-5.0%	0.0%	0.0%	0.0%	-1.7%	-3.7%	-1.3%	-1.3%	-3.7%
Threshold 5	-2.5%	0.2%	0.2%	0.2%	-1.8%	-3.7%	-1.3%	-1.3%	-3.7%
All CDA	0.8%	0.5%	0.5%	0.5%	-1.9%	-3.7%	-1.4%	-1.4%	-3.7%
Actual CDA	10.2%	-11.7%	-11.7%	-11.7%	-6.9%	-4.1%	-2.6%	-2.6%	-4.1%

In all of the hypothetical CDA implementation scenarios fuel burn levels decreased with increasing use of CDA profiles. Emissions levels changes were mixed depending on the pollutant. For CO, THC, NMHC, and VOC, a reduction in thrust and therefore fuel flow generally results in increases in the emissions indices (EIs). Fuel burn and emissions are also influenced by the total flight time. As mentioned previously, within the Actual CDA scenario CDA implementation was limited to one arrival route where the flight paths followed in the Baseline scenario were actual steeper in glideslope than the CDA flight paths. This fact shows up in the flat to increased fuel burn levels when looking at arrivals only for these scenarios as in Table 4. Airspace changes on the departure side make up for the flat to increased fuel burn levels from the arrival side, as presented in Table 5.

NOISE AND EMISSIONS INTERDENDENCIES

It is intuitive to think that CDA implementation would be a “win-win” situation when considering both noise and emissions. After all thrust levels and flight time drive both the noise generated and fuel burned by an aircraft, emissions are a direct product of burning fuel, and CDAs are designed to reduce both thrust and flight time. However as the noise and emissions results above show, it is possible to reduce noise and yet increase emissions of certain pollutants. Of the theoretical implementation scenarios, the All-CDA scenario resulted in the greatest reduction in noise but also caused the greatest increase in CO, THC, NMHC, and VOC. Other hypothetical scenarios that showed a lesser reduction in noise are actually better from the standpoint of these pollutants. This is yet another example of the fact that the emissions of all pollutants do not behave similarly under a given change in conditions, and that these different types of behavior need to be considered when deciding to implement or when evaluating the benefit of operational mitigation strategies such as CDAs.

DISCUSSION

This AEDT demonstration represents an initial effort to model the airport-wide noise, emissions and fuel burn benefits of CDAs using AEDT. As such, it has several limitations that are likely to affect the results. These limitations will be addressed, to the extent possible, in future CDA modeling analyses. These limitations include:

a) Unknown CDA Implementation Issues

Details on the full extent to which CDAs can realistically be implemented at the modeled airport are not available at this time. Details on any airspace design changes necessary to accommodate CDAs at the modeled airport for each arrival route are also not known at this time. An attempt to get around the first issue was made by modeling a range of CDA implementation levels for this demonstration, but it is difficult to quantify the exact benefits due to CDAs without knowing the actual level of CDA implementation. While this analysis did look at the airspace changes due to CDA implementation on one arrival route, changes required to implement CDAs on other arrival routes could significantly affect the actual benefits to be derived from CDA implementation.

b) Limited Aircraft Performance and Noise Data

The AEDT database relied upon for this demonstration does not include flight performance coefficients for arrival operations for most Airbus aircraft and a number of newer Boeing aircraft. This precludes flights from these important aircraft types being included in the demonstration. In addition, the ANP database within AEDT does not include coefficients for the calculation of idle thrust levels, which results in potential under-prediction of thrust levels when aircraft are at idle for both baseline and CDA profiles. Nor does it include noise data for aircraft at idle thrust levels or any way of distinguishing between engine and airframe-generated noise. Therefore the calculated noise levels are extrapolated down from higher thrust levels without consideration of the airframe component during the extrapolation. More investigation is needed to determine how these data limitations combine to affect the overall result. If this type of analysis is to be done in support of significant ATM design decisions, data for additional aircraft types will likely need to be added to the AEDT/ANP databases.

c) Limited Use of Wind Data

The atmospheric data used for this demonstration were simply averaged temperature, pressure, and wind speed values at ground level obtained from Aviation Routine Weather Report (METAR) data for the four days for which radar data were obtained. A lack of actual wind speed and direction values for various altitudes matching the conditions that each radar trajectory actually encountered reduces the ability to accurately determine aircraft thrust values from radar data.

Despite these limitations, the AEDT CDA modeling capability demonstration is an important first step towards the goal of a robust capability to model the environmental benefits of CDAs, which is supports the goal of more wide-spread CDA implementation. This type of effort serves to identify gaps in current environmental modeling methods and data, and also serves as a platform for new development to fill those gaps.

SUMMARY

CDA operations can have significant noise, fuel burn, and emissions benefits. The extent of these benefits can vary between areas around the airport depending on the differences between existing flight profiles and ground tracks and CDA profiles and ground tracks. The FAA is developing the capability of modeling the overall benefits, as well as the extent to which they may differ around an airport in its AEDT. This capability is of the utmost importance to the ATM community when evaluating CDA implementation efforts, and also when doing trade-off comparisons between different operational mitigation options.

There are several gaps in both available data required for environmental modeling and methods normally used for defining aircraft flight profiles that may reduce the ability to accurately quantify benefits due to CDAs. More robust CDA analyses in support of ATM decisions will require these gaps to be filled, including the inclusion of performance data for more aircraft types within the AEDT/ANP databases and standardized methods for defining realistic distributions of current non-CDA arrival profiles using aircraft position data from sources such as radar.

ACKNOWLEDGEMENTS

This work was funded by the U.S. Federal Aviation Administration Office of Environment and Energy, under the FAA/Volpe General Working Agreement and Contract Numbers DTFAAC-05-D-00075 and DTFAWA-05-C-00044. The AEDT effort is co-managed by Lourdes Maurice and Gregg Fleming. The author would like to thank Clifford Hall and Philip Soucacos of CSSI Inc. in Washington, D.C., and Chris Roof of the U.S. Department of Transportation’s Volpe Center in Cambridge, MAfor their contributions to this effort.

REFERENCES

1. Dinges, Eric, (2007) “Determining the Environmental Benefits of Implementing Continuous Descent Approach Procedures “, 7th USA/Europe Air Traffic Management R&D Seminar, July 2007.

2. Clarke, John-Paul, et al. (2006), “Development, design, and flight test evaluation of a continuous descent approach procedure for nighttime operation at Louisville International Airport” Report No. PARTNER-COE-2005-002, January 2006.

3. van Boven, Michel, Hullah, Peter, (2006), "Sourdine II Results of noise and emission analyses" WP5 D5.4, June 2006.

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

5. European Civil Aviation Conference (2006), "Report on Standard Method of Computing Noise Contours around Civil Airports", ECAC.CAEC Doc 29, Third Edition, 2006.

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

7. Hall, Clifford, et al. (2007), "Emissions & Dispersion Modeling System (EDMS) 5.0 User's Manual", Report No. FAA-AEE-07-01, Washington, D.C., Federal Aviation Administration.

8. Kim, Brian, et al. (2007), "System for assessing Aviation's Global Emissions (SAGE), Part 1: Model description and inventory results", Transportation Research Volume 12D, Part D: Transport and Environment, ISSN 1361-9209, July 2007.

9. Grandi, Fabio (2007), "The Fleet and Operations Module (FOM) within the FAA's Aviation Environmental Design Tool (AEDT)", Air Traffic Management Research and Development, 2007.

10. den Braven, W., Schade, J., (2003), "Concept and Operation of the Performance Data Analysis and Reporting System", SAE Advances in Aviation Safety Conference (ACE), Montreal, September 8-12, 2003, paper number 2003-01-2976.

11. Ren, Liling, (2006), "Modeling and Managing Separation for Noise Abatement Arrival Procedures", Ph.D. Thesis, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge, MA, 2006

KEY WORDS

Continuous descent arrival, noise, emissions, fuel burn, environmental benefits.