JOURNAL OF AIRCRAFT
Vol. 37, No. 2, March–April 2000

Systems Analysis of Noise Abatement Procedures Enabled by Advanced Flight Guidance Technology

John-Paul Barrington Clarke*
Massachusetts Institute of Technology, Cambridge, Massachusetts 02139-4307

Advanced flight guidance technologies such as area navigation utilizing the global positioning system offer the potential to reduce the impact of aircraft noise on communities surrounding airports by enabling more flexible approach and departure procedures that reduce noise exposure to the most sensitive areas. A systems analysis is presented of noise abatement procedures enabled by these technologies. NOISIM, the primary systems analysis tool, combines a flight simulator, a noise model, and a geographic information system to create a unique rapid prototyping environment in which the user can simulate an aircraft's operation in existing and potential guidance and navigation environments, while simultaneously evaluating the aircraft's noise impact. The analysis included generic and site specific studies of approach and departure procedures using 737-200 noise estimates. The results of the generic study of approach procedures indicate that a 3-deg decelerating approach provides significant noise reductions in comparison to the baseline instrument landing system (ILS) approach and is preferred by pilots to the more complex vertically segmented approach. In a study of approaches to runway 13L at Kennedy Airport, a 3-deg decelerating approach reduced the population impacted by noise greater than 60 dBA from over 250,000 in the ILS approach to less than 70,000. The results of the generic study of departure procedures indicate that the benefits of noise abatement departures are site specific. In a study of departures from runway 4R at Logan Airport, a noise abatement departure that combined a targeted thrust cutback with a dual turn lateral trajectory reduced the population impacted by peak noise greater than 60 dBA by over 15%.

Introduction

THE impact of aircraft noise on communities is an important consideration in the siting and operation of airports.[1–3] To mitigate the impact of aircraft noise, certain airports with particularly close or sensitive communities have developed noise abatement procedures.[4] These procedures are modified versions of existing instrument flight procedures, but are often too complex to be performed under instrument flight rules (IFR) as current IFR procedures are limited by the accuracy and coverage of current guidance and navigation systems.[5] The additional guidance required to perform these noise abatement procedures is provided by the visual ground references available under visual meteorological conditions (VMC).

An example of a visual noise abatement procedure is shown in Fig. 1. Figure 1 shows the noise abatement approach to runways 13L/R at John F. Kennedy (JFK) International Airport in New York City. Because the Canarsie very high-frequency omnirange (VOR) navigation aid provides lateral guidance during the initial phases of the approach, this approach is often referred to as the Canarsie VOR approach. During the final phases of the approach, special lead-in lights provide the visual references required to complete the descending turn to the runway. The Canarsie VOR approach is designed to avoid densely populated residential communities near the airport by flying a tightly curved trajectory that keeps the aircraft as close to Jamaica Bay as possible. The Canarsie VOR approach, however, may only be performed in VMC with the ceiling greater than 800 ft and the visibility greater than 2 n mile, thus limiting its use in all weather conditions.

Recent advances in guidance and navigation technology have given the cockpit crew unprecedented capabilities in the IFR environment. Area navigation (RNAV) allows pilots to create trajectories using a series of arbitrary reference points or waypoints. The global positioning system (GPS) provides accurate position estimates at any location around the world.[6] In combination, these capabilities enable approach and departure trajectories that may be adjusted for noise considerations. The International Civil Aviation Organization (ICAO), of which the United States is a member state, has recognized the potential benefits of using advanced flight guidance technology to reduce the impact of aircraft noise. ICAO has charged its Noise Abatement Operating Measures Subgroup with the following tasks.[7]

1) Describe effective existing noise abatement operational procedures and strategies.

2) Evaluate the critical components of aircraft flight procedures that can minimize source noise emissions and community exposure.

3) Identify emerging and future airport systems technologies in the fields of flight management, air traffic control, and airport capacity that could also serve to minimize community noise exposure.

4) Conceive new operating procedures to reduce community noise exposure taking account of the emerging and future technologies identified in 3.

The analysis presented in this paper is a partial response to these tasks. In combination, the aircraft, airport, and the community form a closed system. If flight procedures are the means of operating that system, then the noise abatement procedure represents a way of operating the system with lower noise impact. To determine the appropriate noise abatement procedure to use, it is necessary to consider several coupled factors: 1) aircraft performance and trajectory, 2) noise generated by the aircraft, 3) population distribution and density, 4) flight safety and pilot acceptance, 5) guidance and navigation requirements, and 6) local atmospheric conditions.

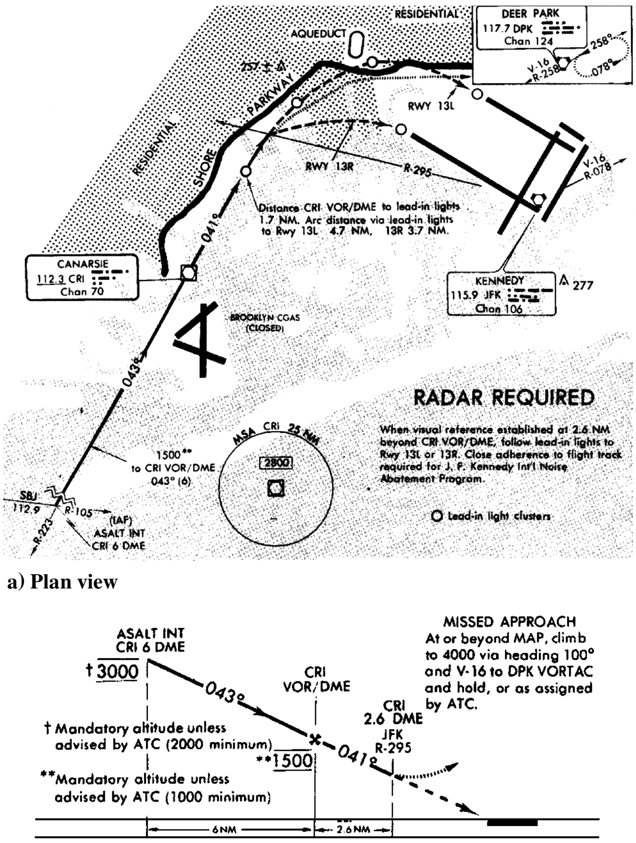
Traditionally, these factors have been considered either independently or in subsets. NOISIM, the tool presented next, provides a method of incorporating and evaluating these factors simultaneously in a rapid prototyping environment. This approach to developing noise abatement procedures incorporates the coupled relationships that exist between the factors, thus providing a comprehensive methodology for developing noise abatement solutions.

NOISIM

The primary component of the systems analysis methodology is NOISIM. This tool combines a flight simulator, a noise model, and a geographic information system (GIS) to create a unique rapid

Presented as Paper 97-0490 at the AIAA 35th Aerospace Sciences Meeting, Reno, NV, 6–9 January 1997; received 3 November 1997; revision received 28 May 1999; accepted for publication 1 June 1999.

*Charles Stark Draper Assistant Professor, Department of Aeronautics and Astronautics, Room 33-407, 77 Massachusetts Avenue.



a) Plan view

b) Profile view

Fig. 1 Canarsie VOR visual noise abatement approach to JFK runways 13L/R.

prototyping environment in which the user can simulate an aircraft's operation in existing and potential guidance and navigation environments, while simultaneously evaluating the aircraft's noise impact. Figure 2 shows the structure of NOISIM. Figure 2 shows how the flight simulator, noise model, and GIS are coupled to determine the noise impact. Pilot inputs into the flight simulator generate a trajectory that is used by the noise model to determine the noise footprint of the procedure. This footprint is combined with the population distribution and density data of the GIS to determine the noise impact of the procedure.

Flight Simulator

The flight simulator component of NOISIM has been developed at the Massachusetts Institute of Technology Aeronautical Systems Laboratory using performance data from the Boeing 737, which served as the NASA Advanced Transport Operations aircraft.[8] Figure 3 shows a diagram of the flight simulator. As can be seen, the flight simulator provides all of the cockpit interfaces found in an advanced commercial aircraft. The aircraft may be controlled either manually via the sidestick, at the state level via the mode control panel or at the trajectory level via the control display unit. This allows the trajectories to be flown as they would be in an aircraft. The simulator also allows the rapid prototyping of displays that may be required to perform specific procedures. The aircraft simulated in the analyses that follow is a 737-200 with two low-bypass ratio JT8D turbofan engines.[9] The weight of the aircraft is assumed to be 90,000 lb, and the atmospheric conditions are assumed to be the same as those in the standard U.S. atmosphere.

Noise Model

The fan and jet noise generated by the aircraft is determined using the Heidman[10] and Stone and Montegani[11] models outlined in the NASA Aircraft Noise Prediction Program theoretical manual.[12] The fan and jet noise are modeled in one-third octave bands (tertsbands)

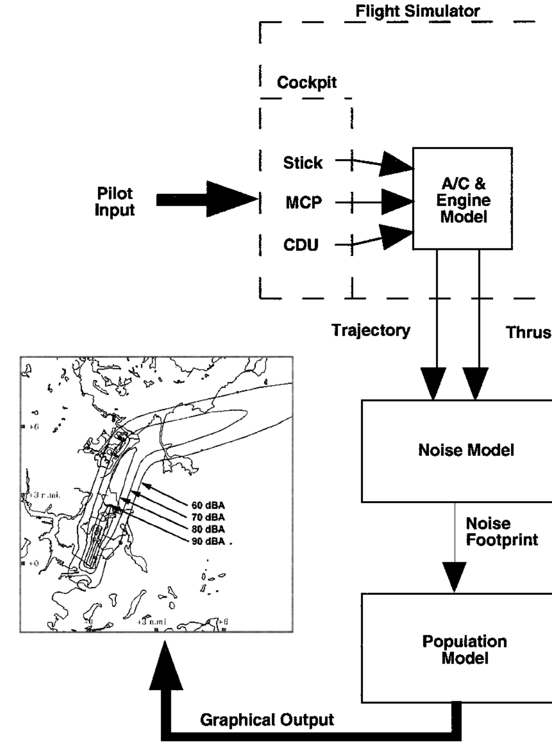


Fig. 2 Structure of NOISIM.

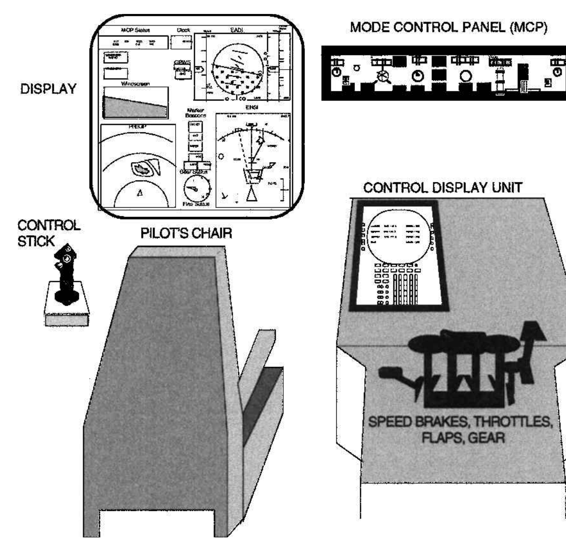


Fig. 3 Flight simulator.

and in 1-deg increments from the longitudinal axis of the aircraft. The effects of acoustic treatments were included via adjustments to the engine spectra. Atmospheric attenuation is modeled as a function of frequency, temperature and humidity.[13] Excess ground attenuation is modeled using the relationships outlined in Ref. 14.

Geographic Information System

NOISIM uses U.S. Geographical Survey landuse/landcover data and U.S. Census Bureau population density data to create a GIS that is used to calculate the residential area and population impacted by aircraft noise.[15]

NOISIM Output

NOISIM is designed to have flexible, graphical, user selectable output. In this paper the peak A-weighted sound pressure levels will be reported. Other metrics may be selected by the user, as NOISIM

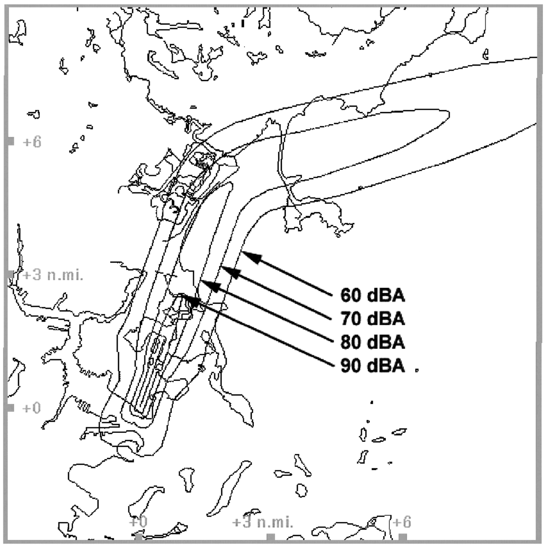


Fig. 4 Sample NOISIM output.

outputs the complete noise spectra in tertsbands. Figure 4 shows a sample NOISIM output. Figure 4 shows the peak A-weighted sound pressure levels in 10-dBA bands resulting from the existing noise abatement departure from runway 4R at Logan Airport in Boston, Massachusetts. The lowest noise level that is presented, 60 dBA, represents the typical level of personal conversation, but this threshold may be changed by the user. The values at the bottom of Fig. 4 represent the residential area and the number of people impacted by noise in the user selected noise ranges.

The noise impact calculated by NOISIM for the departure from runway 4R at Logan Airport was compared to noise measurements for the same aircraft and engine type (737-200 with JT8D engines) at two noise monitoring stations operated by the Massachusetts Port Authority.[16] The results of that comparison showed that the difference between the peak noise level predicted by NOSIM and the noise measured at the sites was 0.4 and 0.6 dBA, respectively. The time history of the unweighted sound pressure level at station 1 was also compared. The results of that comparison showed that the difference between predicted and measured values for the time that the sound pressure level is above 80 dB was less than 1 s. It should be noted that the comparison was limited, and the accuracy of NOISIM may not be as good as indicated.

Generic Study of Approach Procedures

A generic study is presented of two noise abatement approach procedures: the vertically segmented approach and the 3-deg decelerating approach. Both approaches were evaluated relative to the baseline ILS approach. In the study, the airport was assumed to be located in the midst of an area of uniform population density, and the airport boundary was assumed to be located at the runway threshold. The airport was assumed to be sufficiently large that all of the noise produced on the airport side of the threshold is contained within the airport and was not included in the noise impact.

Approach Procedures

Example profiles are shown of the ILS approach (Fig. 5a), the vertically segmented approach (Fig. 5b), and the 3-deg decelerating approach (Fig. 5c).

The ILS approach is the standard approach used by commercial aircraft. To prevent confusion with false glide slopes, aircraft are required to intercept the glide slope from below so that the 3-deg glide slope is always the first glide slope that the aircraft encounters. Because of this requirement, aircraft typical fly at low altitude for extended periods. In the example shown in Fig. 5a, the aircraft slows to 210 kn and descends to 2500 ft above the runway at some distance from the runway. During this period of level flight, the aircraft is configured for landing and reduces its speed to 140 kn. When the

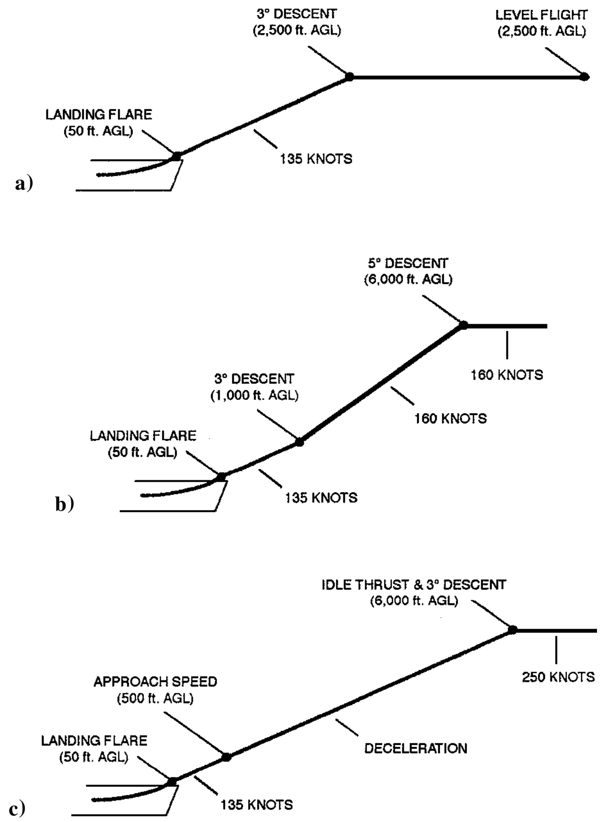


Fig. 5 Example profiles of a) ILS approach, b) vertically segmented approach, and c) 3-deg decelerating approach.

aircraft intercepts the glide slope, it begins a 3-deg descent to the runway.

The vertically segmented approach has been identified in previous work as a method of achieving significant noise benefits.[17,18] In this approach, the aircraft descends at a steeper than normal angle (greater than 3 deg) and intercepts the 3-deg glide slope from above. This approach increases the angle of descent and reduces the thrust. In the example shown in Fig. 5b, the aircraft begins a 5-deg descent at 6000 ft above the runway, then transitions to a 3-deg descent at 1000 ft above the runway. During the 5-deg segment, the aircraft maintains a speed of 160 kn. This is reduced during the transition to the approach speed of 135 kn.

The 3-deg decelerating approach is enabled by RNAV and GPS. By the use of both technologies, it is possible to create a straight or curved approach path from any point. Simple versions of the 3-deg decelerating approach could be accomplished with the ILS and distance measurements from GPS or distance measurement equipment (DME). In the example shown in Fig. 5c, the aircraft intercepted a virtual glide slope 6000 ft above the runway at a speed of 250 kn. During the descent, the aircraft decelerates at idle thrust. The final approach speed of 135 kn was achieved 500 ft above the runway, and the remainder of the approach proceeded as normal.

Noise Impact of Approach Procedures

The noise impact of the three approaches were evaluated using NOISIM. Figure 6 shows the noise impact of the three approaches. As Fig. 6 shows, the noise impact of both the vertically segmented and 3-deg decelerating approaches are comparable. Figure 6 also shows that both noise abatement approaches reduce the area impacted by peak noise greater than 60 dBA by over 50% in comparison to the ILS approach.

Pilot Acceptance of Noise Abatement Procedures

Pilot acceptance of the two noise abatement procedures was evaluated in a piloted simulator study using the flight simulator component of NOISIM. Each subject performed a total of nine approaches.

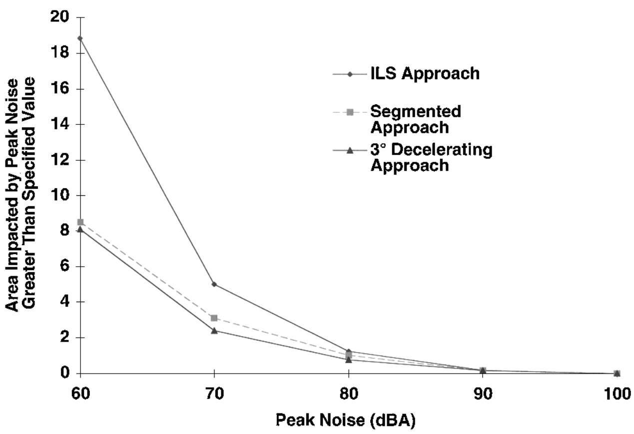


Fig. 6 Comparison of noise impact of ILS approach, vertically segmented approach, and 3-deg decelerating approach for 737-200.

Of the nine approaches, three were ILS approaches, three were vertically segmented approaches, and three were decelerating approaches. Each procedure was performed in zero wind, a tailwind of 20 kn, and windshear conditions. Four pilots participated in the study. Two of the pilots were airline captains with glass cockpit experience, and the other two pilots were certified instrument flight instructors.

All subjects completed the nine approaches without incident. When queried about their preference for a noise abatement procedure, all of the pilots selected the 3-deg decelerating approach. When queried about the difficulty of the 3-deg decelerating approach in comparison to the ILS approach, none of the pilots indicated that the 3-deg decelerating approach was more difficult. When queried about the difficulty of the 3-deg decelerating approach in comparison to the vertically segmented approach, all of the pilots said that it was easier. Half of the pilots said that it was much easier, whereas the other half said it was somewhat easier. When queried about their rationale for choosing the 3-deg decelerating approach, all of the pilots indicated that they preferred the stabilized flight path of the 3-deg decelerating approach.

Specific Study of Approach Procedures

The 3-deg decelerating approach, identified in the generic study as the noise abatement approach that provides the best combination of noise reduction and pilot acceptance, was evaluated in a study of approaches to runway 13L at JFK. Three approaches were evaluated: the baseline ILS approach, the Canarsie VOR approach (the existing noise abatement approach), and a 3-deg decelerating approach.

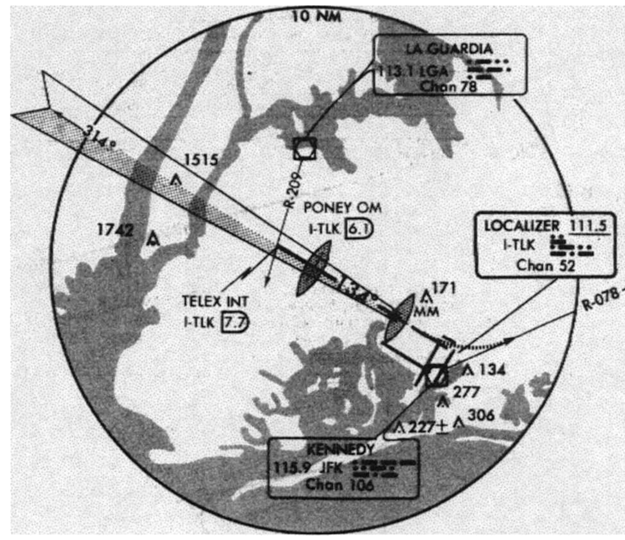
Noise Impact of ILS Approach

Figure 7 shows the ILS approach to runway 13L at JFK. To avoid conflicts with traffic departing and approaching Newark and La Guardia Airports, aircraft that are performing the ILS approach are vectored toward the fix TELEX from the south at low altitude to intercept the ILS at an altitude of 2000 ft.

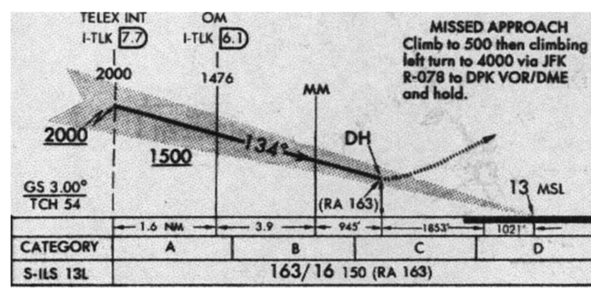
Figure 8 shows the noise impact of the ILS approach. As Fig. 8 shows, over 250,000 people are impacted by peak noise greater than 60 dBA. Communities near TELEX are heavily impacted during the turn onto the final approach, as the thrust of the aircraft must be increased during the turn to maintain a constant altitude. This scenario illustrates the adverse noise effects of low-altitude vectoring.

Noise Impact of Canarsie VOR Approach

When the weather conditions are favorable (i.e., visibility > 2 n mile and ceiling > 800 ft), aircraft on approach to runway 13L may perform the Canarsie VOR approach procedure shown in Fig. 1. The noise impact of this procedure is shown in Fig. 9. As Fig. 9 shows, the number of people impact by peak noise greater than 60 dBA is significantly reduced when aircraft use the Canarsie approach inasmuch as the trajectory is closer to Jamaica Bay.



a) Plan view



b) Profile view

Fig. 7 ILS approach to JFK runway 13L.

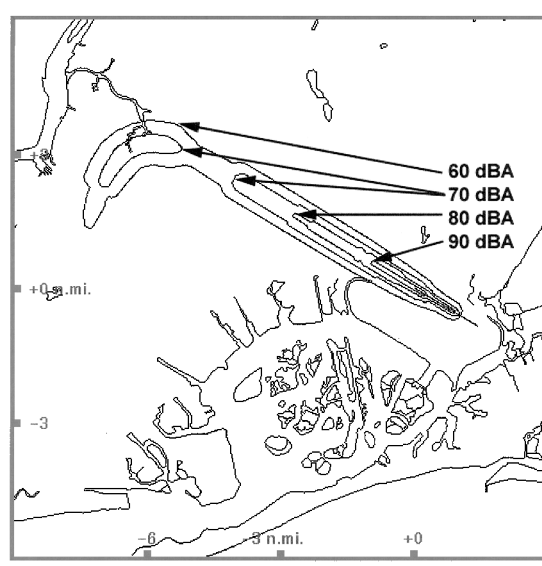


Fig. 8 Noise footprint and impact of ILS approach to JFK runway 13L.

Noise Impact of 3-Degree Decelerating Approach

Figure 10 shows the noise impact of the 3-deg decelerating approach in those communities impacted by the ILS approach. This approach has a very similar ground track to the existing ILS approach, but the aircraft is in an idle descent throughout the approach, with no level segments at constant speed.

Comparison of Approach Procedures

Figure 11 shows the noise impact of the three approaches to runway 13L at JFK. Both noise abatement approaches provide significant noise reductions relative to the ILS approach (Fig. 11).

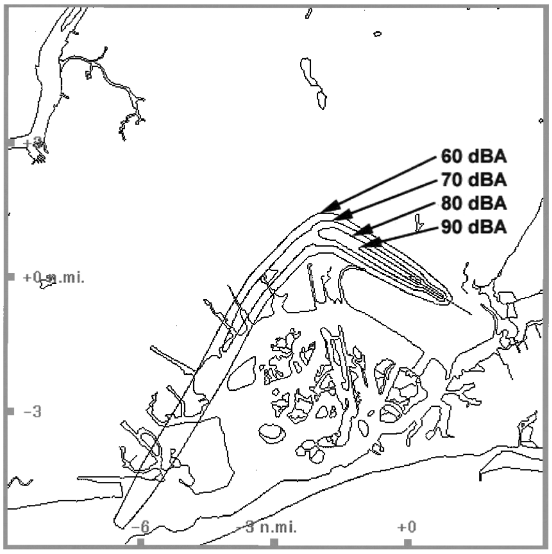


Fig. 9 Noise footprint and impact of canarsie VOR approach to JFK runway 13L.

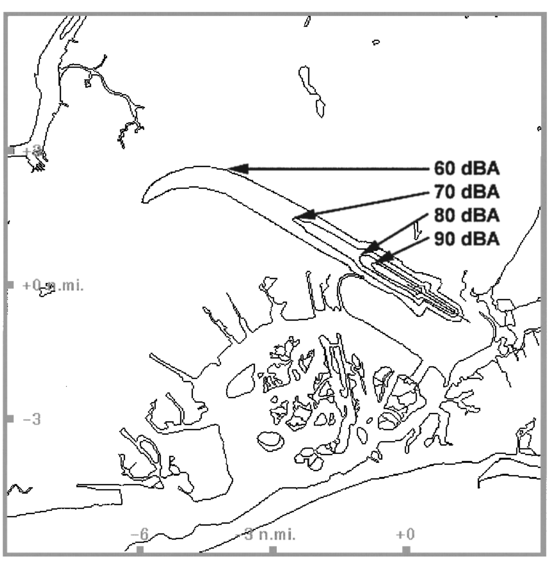


Fig. 10 Noise footprint and impact of 3-deg decelerating approach to JFK runway 13L.

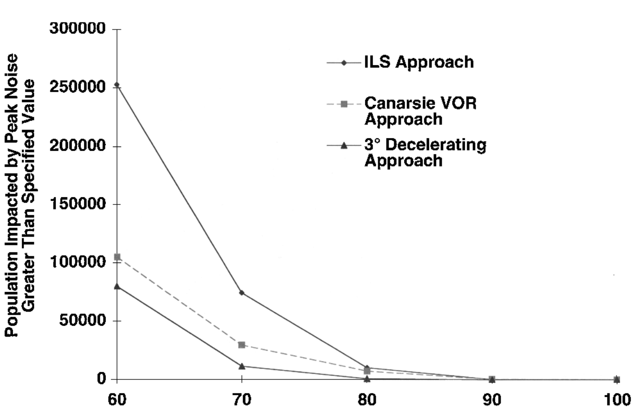


Fig. 11 Comparison of noise impact of ILS approach, canarsie VOR approach, and 3-deg decelerating approach to JFK runway 13L.

Figure 11 also shows that the noise impact of the 3-deg decelerating approach is comparable to the noise impact of the Canarsie VOR approach. Unlike the Canarsie VOR approach, however, the 3-deg decelerating approach may be performed in instrument meteorological conditions (IMC). The number of people impacted by noise greater than 60 dBA is reduced from over 250,000 during the ILS approach to less than 70,000 during the 3-deg decelerating approach. Although the 3-deg decelerating approach appears to provide reductions at the higher noise levels, variability in the altitude that the final approach speed is achieved may diminish these reductions.

Generic Study of Departure Procedures

This section presents the results of a generic study of two noise abatement departure procedures: the ICAO noise abatement departure and the thrust cutback departure. Both departures were evaluated relative to a baseline departure consisting of a full thrust takeoff with reduced thrust climb. In the study, the airport was assumed to be located in the midst of an area of uniform population density, and the airport boundary near the departure end of the runway was assumed to be 2 mile from the runway threshold. The airport was assumed to be sufficiently large that all of the noise produced on the airport side of that boundary was contained within the airport and was not included in the noise impact.

Departure Procedures

Example profiles are shown of the baseline departure (Fig. 12a), the ICAO noise abatement departure (Fig. 12b), and the thrust cutback departure (Fig. 12c).

The baseline departure is a full thrust takeoff with reduced thrust climb. As shown in Fig. 12a, the aircraft retracts its landing gear and accelerates to an initial climb speed of 170 kn after takeoff. At 800 ft above the runway altitude, the thrust is reduced to climb thrust, and the aircraft accelerates to a maneuver speed of 210 kn. At 3000 ft above the runway altitude, the aircraft accelerates to an enroute climb speed of 250 kn.

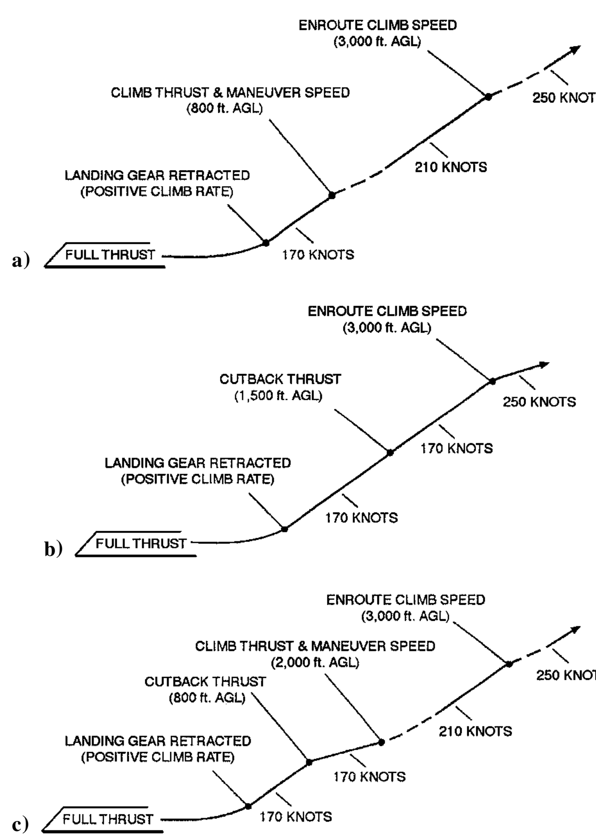


Fig. 12 Example profiles of a) baseline departure, b) ICAO noise abatement departure, and c) thrust cutback departure.

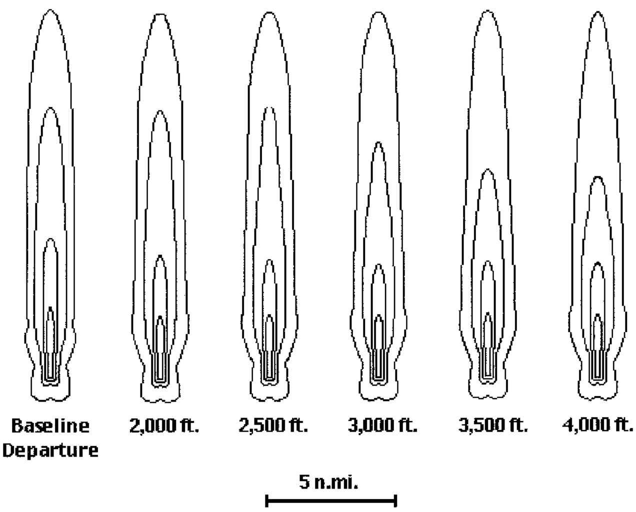


Fig. 13 Noise footprint for ICAO noise abatement departure relative to baseline departure in Fig. 12a vs height aircraft accelerates to 250-kn enroute climb speed.

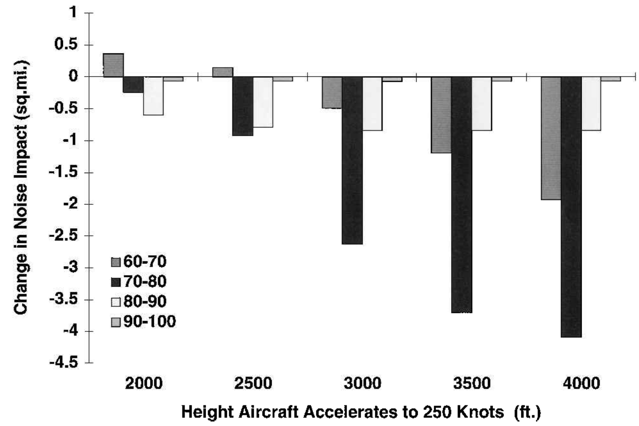


Fig. 14 Noise impact of ICAO noise abatement departure relative to baseline departure in Fig. 12a vs height aircraft accelerates to 250-kn enroute climb speed.

The ICAO noise abatement departure is designed to reduce the total area impacted by aircraft noise. As shown in Fig. 12b, the aircraft retracts its landing gear and accelerates to an initial climb speed of 170 kn after takeoff. At 1500 ft above the runway altitude, the thrust is reduced to climb thrust while the aircraft maintains its initial climb speed. At 3000 ft above the runway altitude, the aircraft accelerates to an enroute climb speed of 250 kn.

The thrust cutback departure is designed to reduce the noise at a specific location. As shown in Fig. 12c, the aircraft retracts its landing gear and accelerates to an initial climb speed of 170 kn after takeoff. At 800 ft above the runway altitude, the thrust is reduced to a level that is lower than the climb thrust, while the aircraft maintains its initial climb speed. At 2000 ft above the runway altitude, the thrust is increased to climb thrust, and the aircraft accelerates to a maneuver speed of 210 kn. At 3000 ft above the runway altitude, the aircraft accelerates to an enroute climb speed of 250 kn.

Noise Impact of ICAO Departure

Figure 13 shows the noise footprints for the ICAO noise abatement departure vs the height that the aircraft accelerates to its enroute climb speed. The noise footprint for the baseline departure in Fig. 12a (with an area of 45 mile^2 impacted by noise greater than 60 dBA) is included for reference. Figure 13 illustrates the changes in the size and shape of the noise contours as the acceleration height is changed. As Fig. 13 shows, the length of the 70-dBA contour is significantly reduced as the acceleration height is increased from 2500 to 3500 ft, but is not reduced significantly as the acceleration height is increased from 3500 to 4000 ft.

Figure 14 shows the noise impact in 10-dBA bands of the ICAO noise abatement departure relative to the baseline departure in Fig. 12a vs the height that the aircraft accelerates to its enroute climb speed. The area exposed to 70–80 dBA noise is reduced significantly as the acceleration height is increased from 2500 to 3500 ft, but this rate of reduction diminishes with further increases in height (Fig. 12a). Figure 12a also shows that the ICAO noise abatement departure reduces the total area exposed to noise greater than 60 dBA.

Although the results of this study are based on a uniform population density, they give an indication of the general trends in the noise impact of the ICAO noise abatement departure as the height that the aircraft accelerates to its enroute climb speed is changed. The actual noise impact, however, depends on the population distribution and density in the communities surrounding the airport.

Noise Impact of Thrust Cutback Departure

Figure 15 shows the noise footprints for the thrust cutback departure vs the height that climb thrust is resumed. The noise footprint

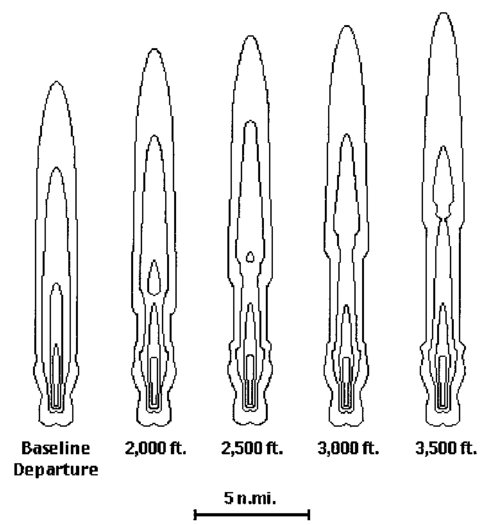


Fig. 15 Noise footprint for thrust cutback departure relative to baseline departure in Fig. 12a vs height climb thrust resumed.

for the baseline departure in Fig. 12a is also included for reference. Figure 15 shows that if climb thrust is resumed at 2000 ft, the 80-dBA contour separates into two sections, where the section farthest from the runway corresponds to the noise impact after climb thrust is resumed. For the 2500-ft case this section has almost disappeared inasmuch as the maximum noise impact after climb thrust is resumed is approximately 80 dBA. Figure 15 also shows that the length of the 70-dBA contour increases up to the height where the farthest section of the 80 dBA separates from the ground, then decreases with further increases in the height when climb thrust is resumed.

Figure 16 shows the noise impact in 10-dBA bands of the thrust cutback departure relative to the baseline departure in Fig. 12a vs the height that climb thrust is resumed. As Fig. 16 shows, the area exposed to 70–80 dBA noise is greater than in the baseline departure when climb thrust is resumed at 2000 and 2500 ft, but is less than in the baseline departure when climb thrust is resumed at 3000 and 3500 ft. Figure 16 also shows that the area impacted by noise greater than 80 dBA does not decrease any further if climb thrust is resumed above 3000 ft.

Comparison of Departure Procedures

These results illustrate the complex trade between higher intensity noise exposure area change and lower intensity noise exposure area change that must be made when selecting a noise abatement departure. The actual noise impact is dependent on the population around the airport and can be determined using NOISIM.

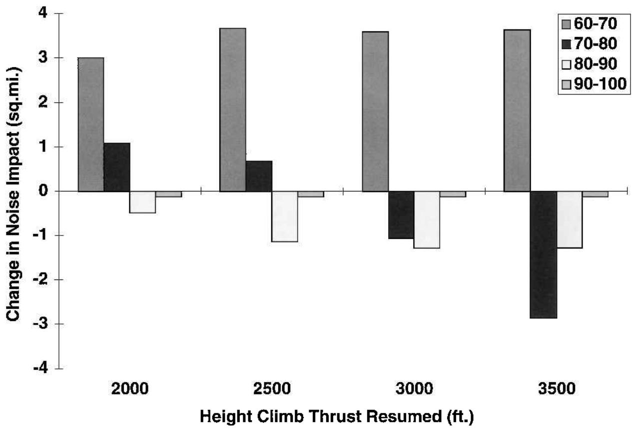


Fig. 16 Noise impact of thrust cutback departure relative to baseline departure in Fig. 12a vs height climb thrust resumed.

Specific Study of Departure Procedures

Logan Airport (BOS) is less than 2 mile from downtown Boston and is adjacent to several residential communities in the Boston metropolitan area. The close proximity of these residential areas limit airport operations. One instance where noise restrictions limit aircraft operations is the departure from runway 4R.

Existing Noise Abatement Departure

Jet aircraft departing from runway 4R are required to perform a noise abatement departure designed to reduce the noise impact in these residential communities. In the existing procedure, the pilot maintains the runway heading until the aircraft is 4 n mile from the DME beacon located at the airport. At this point the pilot changes the aircraft's heading to 90 deg and flies toward the Atlantic Ocean. The noise impact of the existing noise abatement departure was shown in Fig. 4. The results shown represent the noise impact of an aircraft that follows the noise abatement procedure precisely.

RNAV Enabled Noise Abatement Departure

The results of the generic studies indicate that a thrust cutback would be beneficial to the East Boston community adjacent to the departure end of the runway. The noise footprints derived during the generic study of thrust cutback departures were used to determine the noise impact in that community as a function of the height that climb thrust is resumed. This investigation showed that for heights greater than 2000 ft, the noise reduction in the communities adjacent to the departure end of runway 4R was independent of the height at which climb thrust is resumed, and so a height of 2000 ft was selected for the RNAV noise abatement procedure.

Performing a thrust cutback, however, increases the dimensions of the noise footprint, especially at locations farther away from the runway. If a thrust cutback was combined with the lateral trajectory of the existing noise abatement departure, the noise reductions achieved during the thrust cutback would be offset by increased noise impact at locations farther away from the runway. To compensate for the increase in the dimensions of the footprint, RNAV was used to create a lateral trajectory that better matches the area of low noise sensitivity.

Figure 17 shows the noise footprint, area impacted, and the number of people impacted during this RNAV enabled noise abatement departure. As Fig. 17 shows, the addition of a second turn allows the trajectory to be adjusted to match the area of low noise sensitivity. Thus, using NOISIM, the type of noise abatement procedure and the parameters of that noise abatement procedure may be selected based on the population distribution in the affected communities.

Comparison of Departure Procedures

Figure 18 shows the total noise impact of the existing and RNAV enabled noise abatement departure from runway 4R at BOS. As

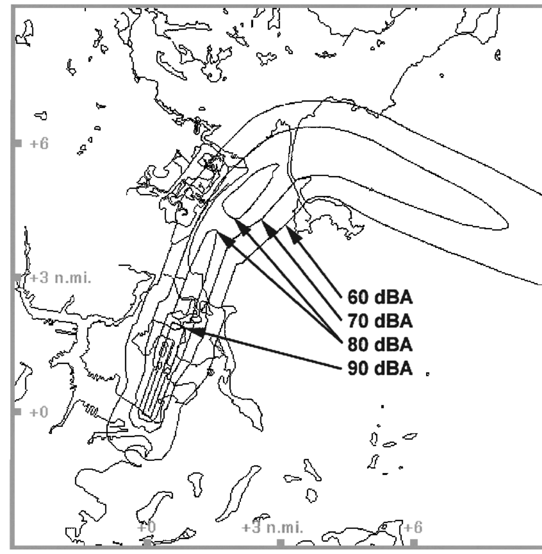


Fig. 17 Noise footprint and impact of RNAV enabled noise abatement departure from BOS runway 4R.

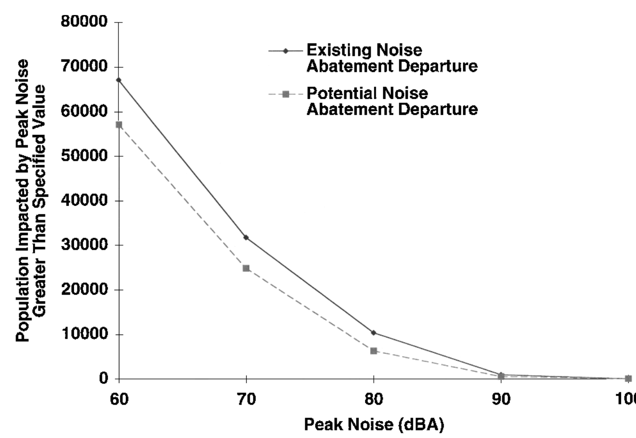


Fig. 18 Comparison of noise impact of existing and RNAV enabled noise abatement departures from BOS runway 4R.

the diverging curves in Fig. 18 indicate, the RNAV enabled noise abatement departure reduces the number of people impacted at all noise levels, and the number of people impacted by noise greater than 60 dBA is reduced from 67,079 to 57,091, a 15% reduction.

Conclusions

NOISIM has been developed as means of developing, evaluating, and comparing noise abatement procedures. This systems analysis tool combines a flight simulator, a noise model, and a GIS to create a unique rapid prototyping environment in which the user can simulate an aircraft's operation in existing and potential guidance and navigation environments, while simultaneously evaluating the aircraft's noise impact. NOISIM was used in generic and site specific studies of approach and departure procedures for the 737-200.

In the generic study of approach procedures, a vertically segmented approach and a 3-deg decelerating approach were evaluated as a means of reducing the noise impact during approach. The noise impact of both procedures were found to be comparable, but the 3-deg decelerating approach was preferred by pilots.

In the site specific study of approaches to runway 13L at JFK, the 3-deg decelerating approach was found to provide comparable noise reduction to the existing visual noise abatement approach, but unlike the existing noise abatement procedure, the 3-deg decelerating approach could be performed in IMC. The 3-deg decelerating approach reduced the population impacted by noise greater than 60 dBA from over 250,000 in the ILS approach to less than 70,000.

In the generic study of departure procedures, it was found that the dimensions of the noise footprint varied significantly with changes in the parameters that define both the ICAO noise abatement departure and the thrust cutback departure. Because the noise impact depends on the population distribution and density around the airport, the evaluation and implementation of these and other departure procedures requires a tool such as NOISIM that can incorporate population distribution and density into the noise impact.

In the study of departures from runway 4R at BOS, a noise abatement departure procedure was developed using the results of the generic study. In the procedure, a thrust cutback is performed to reduce the noise impact in the residential communities adjacent to the departure end of the runway. The capabilities of RNAV and GPS were used to design a lateral path that directs the aircraft more precisely through an area of low noise sensitivity. The improved lateral precision compensates for the increase in the dimensions of the noise footprint that result from the thrust cutback. When the RNAV enabled departure was used in place of the existing noise abatement departure, the number of people impacted by noise greater than 60 dBA was reduced from 67,079 to 57,091, a 15% reduction. This reduction may be less for other types of aircraft.

Acknowledgments

This work was supported by the NASA Grant NAG-1-1531. The author would like to acknowledge R. John Hansman of the Massachusetts Institute of Technology, Clemans A. Powell and Kevin Shepherd of NASA Langley Research Center, and Nancy Timmerman of the Massachusetts Port Authority for their advice and support.

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