In Situ Development and Application of Fly Neighborly Noise Abatement Procedures for Helicopters

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ABSTRACT

In recent years significant effort has been expended to support and enhance the Helicopter Association International (HAI) Fly Neighborly Program, including focused FAA/NASA flight test programs and helicopter noise model development as well as application efforts conducted with university and industry support. Two of the challenges often faced in implementing Fly Neighborly flight operations can be the lack of available noise abatement procedure information for specific helicopter models and/or difficulties in adapting existing noise abatement procedure information to a given heliport operation. This paper provides an overview of in situ development of Fly Neighborly (FN) approach procedures that would assist operators in addressing these issues, using the Bell 407 as a case study, and examining the application of Fly Neighborly recommendations to a specific helicopter operation, the November Noise Abatement Procedure at East Hampton New York Airport. This work leveraged findings from the joint NASA-FAA-DOD flight test program conducted in 2017 and first principles helicopter noise modeling developed under the FAA ASCENT program by Penn State University in conjunction with the Advanced Acoustic Model (AAM).

INTRODUCTION

In recent years significant effort has been expended to support and enhance the Helicopter Association International (HAI) Fly Neighborly Program (References 1 and 2) including focused Federal Aviation Administration (FAA) and National Aeronautics and Space Administration (NASA) flight test programs, as well as helicopter noise model development and application efforts conducted with industry support. As part of this effort, the FAA has tasked the Volpe National Transportation Systems Center with finding the means for further implementing the growing body of noise abatement information and maneuvering flight noise data into the existing Fly Neighborly (FN) framework. The elements of the HAI Fly Neighborly Program include providing generic and model-specific guidance on low noise helicopter operation (Figure 1), pilot/operator training materials and courses, and guidance on improving community relations.

Two of the challenges often faced in implementing FN flight operations can be the lack of available noise abatement flight procedures information for specific helicopters and/or difficulties in adapting existing noise abatement flight procedure information to a given heliport operation. The former can leave an operator guessing as to what flight procedure changes would prove effective for noise abatement, while the latter can prove problematic in achieving Fly Neighborly noise abatement within operational constraints, including prescribed arrival/departure routes and poor weather conditions.

This paper provides an overview of in situ development of Fly Neighborly approach procedures that would assist operators in addressing these issues, first using the Bell 407 as a case study for employing auditory techniques to self-develop Fly Neighborly flight procedures and then assessing implementation issues in the application of Fly Neighborly recommendations to a specific helicopter operation, the November noise abatement arrival route at the East Hampton New York Airport (KHTO). This work leveraged findings from the joint NASA-FAA-DOD (Department of Defense) flight test program (Reference 3) conducted in 2017, first principles helicopter noise modeling (Reference 4) developed under the Aviation Sustainability Center, or ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment program by Penn State University in conjunction with the Advanced Acoustic Model (AAM, see Reference 5), and the Fly Neighborly and iFlyQuiet Demonstration conducted at East Hampton Airport. The paper details the progress made, the Fly Neighborly operator recommendations which were developed as part of this research that are being promulgated in the FAA Fly Neighborly *WINGS* training program (Reference 6) and additional research needs including the development of low noise procedures for VFR/low ceiling conditions.

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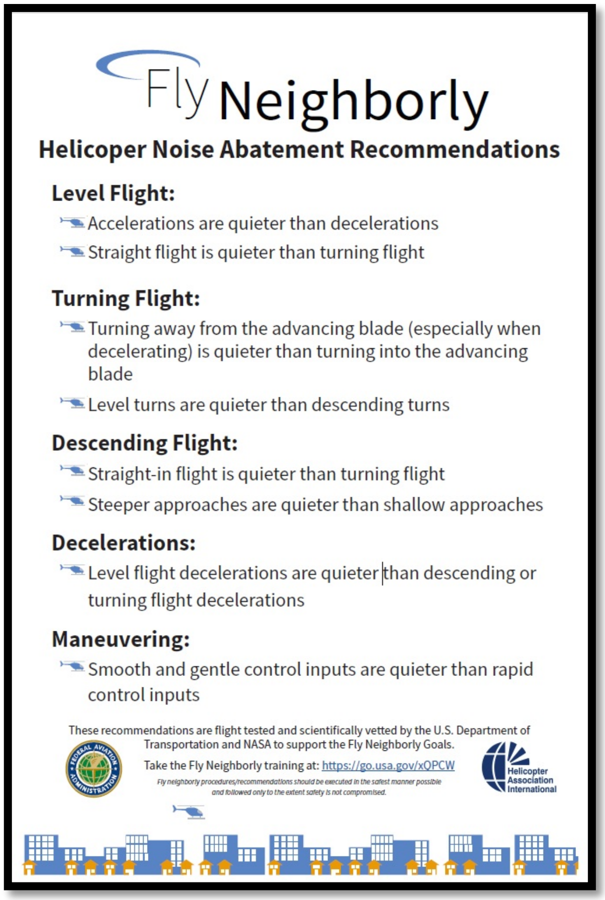


Figure 1. Fly Neighborly Tips Document based on 2017 Joint NASA-FAA-DOD Flight Tests

AUDITORY TECHNIQUES FOR DEVELOPING FLY NEIGHBORLY NOISE ABATEMENT PROCEDURES

Auditory techniques can be an effective method for developing and implementing Fly Neighborly noise abatement flight procedures for a specific helicopter operation. This method utilizes the human ear to evaluate noise levels and characteristics on the ground during helicopter operations. By listening to both the existing and modified descent conditions, for example, an evaluation of improvements to a helicopter flight operation can be identified and implemented.

Auditory techniques were utilized to identify potential Fly Neighborly approach procedures for the Bell 407, in particular looking to reduce or eliminate blade vortex interaction (BVI) noise typically emitted during descent conditions. The Bell 407 was one of the six helicopters flown in a joint NASA-FAA-DOD noise test program conducted in 2017 to measure descent and maneuvering noise levels and define noise abatement approach and maneuvering procedures (Reference 3). Testing was conducted over large ground-based microphone arrays at test sites located at Eglin Air Force Base in Florida and Amedee Army Airbase at the Sierra Army Depot in California. An overlay of the microphone array deployed at Amedee is shown in Figure 2.

Although auditory techniques were employed to evaluate noise abatement approach conditions for all six helicopters in the 2017 test program, the Bell 407 test is perhaps the best test case for demonstrating *in situ* definition of Fly Neighborly (FN) procedures using auditory techniques. High winds during the first part of the Bell 407 test at Amedee forced a delay in the descent condition testing that in turn delayed the onsite generation of noise metrics and contours being used during the test to evaluate test results. Because of this delay, the definition of noise abatement procedures had to be made solely from field observations to provide the same-day recommendations needed to meet the test schedule. These auditory field observations were conducted by two of the co-authors at a primary listening post located approximately 3500 ft before the nominal landing point and approximately 200 ft laterally displaced from the reference flight track to the advancing rotor side. This listening post was nearest to Mic # 37 in the Amedee microphone array as shown in Figure 2.

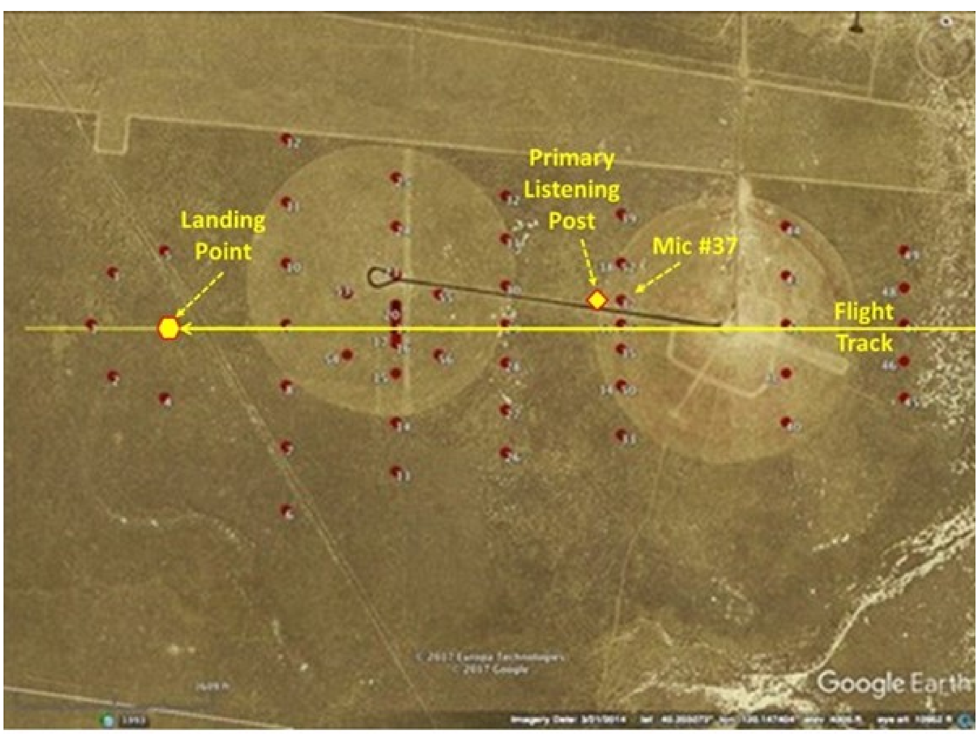


Figure 2. Overlay of Microphone Array at Amedee

The listening post established for testing of the Bell 407 proved effective in identifying low noise approach procedures, providing global noise benefits, i.e., improved noise levels and characteristics over the full area impacted by operations, for the Bell 407 as well as the other five helicopters included in the 2017 test program. Many helicopter operations, however, are likely to require Fly Neighborly procedures tailored for a specific noise sensitive area(s). The same auditory approach conducted for the Bell 407 can be used at other listening posts located to address Fly Neighborly needs for these noise sensitive areas. Examples of Fly Neighborly approach procedures tailored to specific operational situations are discussed later in this paper.

Bell 407 Field Notes (10/12/2017)

- D39 – pretty good, long but no/minimal BVI [14°, 40 kts]
- D38 – again good, some early BVI on 1st run, no/minimal BVI on second run [12°, 40 kts]
- D30 – minimal BVI, a few burbles (flight path corrections?), pretty good [12°, 60 kts]
- D32 – early BVI (LF & transition?), then good [12°, 80 kts]
- D29 – TR buzz early, some but not much BVI near OH, good overall [10.5°, 80 kts]
- D27 – TR buzz early, LF impulsive somewhat stronger, some descent BVI, pretty good [10.5°, 60 kts]
- D22 – some BVI until OH, not too bad [9°, 60 kts]
- D24 – some BVI until OH, not too bad, more TR buzz early [9°, 80 kts]
- D26 – LF impulsive, some BVI before OH, less TR buzz, overall louder [9°, 100 kts]
- D17 – more intensive BVI until OH, some retreating BVI [7.5°, 60 kts]
- D19 – some BVI through OH, OK [7.5°, 80 kts]
- D35 – BVI until near OH, some retreating BVI, looong duration [6°, 40 kts]
- D12 – BVI until near OH, intensive near OH, strong retreating BVI [6°, 60 kts]
- D14 – BVI until near OH, intensive period near OH, less retreating BVI [6°, 80 kts]
- D16 – BVI until near OH, intensive blade slap period near OH [6°, 100 kts]
- D34 – strong BVI until OH, some retreating BVI, looong duration [4.5°, 40 kts]
- D9 – strong BVI until near OH [4.5°, 80 kts]
- D33 – strong BVI until OH, some retreating BVI, again looong duration [3°, 40 kts]
- D2 – strong BVI until nearing OH, maybe slightly better than 6°, 60 kts [3°, 60 kts]
- D4 – steady strong BVI until near OH, then sharp increase near OH [3°, 80 kts]
- D6 – BVI until OH, maybe a little better than at 80 kts (incl. shorter duration) [3°,100 kts]
- D36 – long & slow, increasing BVI until OH, some late retreating BVI [7°, 40 kts]
- D37 – some BVI to OH, some retreating BVI, better than 7° before OH, worse than 7° after OH, 2nd run better than 1st [9°, 40 kts]

Figure 2. Field Observations for Bell 407 Descent Condition Testing

The field observations made for each individual descent condition tested for the Bell 407 on October 12, 2017 are shown in Figure 3. Note that all airspeeds in Figure 3 and throughout the discussion of auditory techniques are indicated airspeeds (kts IAS or KIAS). Asummary of the field observations is shown in Figure 4.

As discussed above, a same day requirement for definition of noise abatement procedures for testing precluded availability/use of noise metrics or noise contour data to identify noise abatement test conditions for the Bell 407. Recommended test conditions were based on field observations only and the existing Bell 407 Fly Neighborly guidance provided on the HAI website. The considerations included in defining recommended noise abatement test conditions included safety, flyability, passenger acceptability, duration/operational costs and routing. The recommended approach noise abatement test conditions are shown in Figure 5. Noise abatement procedure testing for the Bell 407 was then conducted on October 13, 2017 based on these recommendations.

Bell 407 Field Notes Summary (10/12/2017)

1. Field observations indicated that, in general, significant blade vortex interaction (BVI) noise, including periods of very distinctive BVI noise sometimes referred to as "blade slap", occur for descents at low to moderate descent rates (ROD) at all tested airspeeds.
2. Although objectional noise characteristics, including BVI and very long duration, were observed at 40 kts for all glideslopes tested up to ~ -9°, no/minimal BVI was observed for -12 or -14° glideslopes at 40 kt with the caveat on long duration. The -12° and -14° results at 40 kts indicated that deceleration during descent down to 40 kts is feasible for noise abatement.
3. Best noise results were observed for steep angle approaches (-10.5° and -12°) at 60 to 80 kts.
4. Field observations did not support use of 500 fpm descent at 40 kts for noise abatement as per the currently recommended Fly Neighborly guidance, but that the current FN guidance could be utilized with an increase in the ROD to approximately 1000 fpm at 40 kts.
5. The field observations further indicated that noise abatement and Fly Neighborly approach conditions are achievable at reasonable descent rates for airspeeds higher than 60 kts up to 90 kts with or without deceleration.

Figure 3. Summary Field Notes for the Bell 407

Recommended Bell 407 Noise Abatement Test Conditions:

1. Constant -14° descents at 60 kts, -12° descents at 60 and 80 kts, and -10.5° descents at 80 kts to hover taxi at landing point.
2. A decelerating noise abatement procedure transitioning from an 80 kt level flight to a 1000 fpm (16.67 fps) ROD then decelerating the aircraft to 40 kt at 1 to 2 kt/sec while maintaining 1000 fpm ROD, then holding the 40 kt airspeed at a minimum 1000 fpm ROD until hover taxi at landing point.
3. Currently recommended Fly Neighborly procedure, i.e., level flight deceleration to 40 kts at 2.0, 2.5 and 3.0 kt/sec followed by a descent at 500 fpm to hover taxi at landing point. (Note that prior test descent data indicated that the constant 40 kt segment should be performed at close to 1000 fpm to get effective noise abatement, but data acquired at 500 fpm could be combined with the prior 40 kt data at -14° to estimate effectiveness with ROD increased to 1000 fpm.)
4. A decelerating noise abatement procedure transitioning from an 80 kt level flight to a -9° glideslope (1200 – 1300 fpm) then decelerating the aircraft to 40 kt at 1 to 2 kt/sec while maintaining -9°, then holding the 40 kt airspeed at a minimum 1000 fpm ROD until hover taxi at landing point.

Figure 5. Onsite Recommendations for Noise Abatement Test Conditions for the Bell 407

The noise abatement approach test conditions proved successful at Amedee, leading to the draft Bell 407 Fly Neighborly approach procedures shown in Figure 6. Having multiple recommendations provide two levels of flexibility for specific applications, one beingthe option to choose Fly Neighborly descent conditions to meet operational needs/restrictions, and the second being flexibility in better matching Fly Neighborly procedures to routing options/requirements.

Note that Fly Neighborly procedures are typically developed using clean aircraft configurations. One finding of the Amedee test program was that Fly Neighborly recommendations need to provide additional guidance for higher drag aircraft configurations with external equipment to account for resulting drag-induced decreases in aircraft pitch attitude. This is particularly important when high pitch angle, steep descent angle approaches are being used for noise abatement. The ranges of descent rates given in Figure 6 are intended to cover aircraft configurations varying from clean, “low” drag configurations to dirty, “higher” drag configurations, with reduced noise achievable at the lower descent rates for clean(er) configurations and at the higher descent rates for higher drag configurations.

Subsequent to the definition of noise abatement test conditions for the Bell 407, noise metric and contour data became available to further evaluate the descent flight conditions tested on October 12, 2017 and the noise abatement flight conditions tested on October 13, 2017. Noise contour plots for baseline and the recommended noise abatement approach test conditions are shown in Figure 7 through Figure 17.

Draft Bell 407 Fly Neighborly Recommendations

The Bell 407 can emit higher noise levels, including significant blade vortex interaction (BVI) noise also known as blade slap noise, for low angle/low ROD (“high” power) approaches and is quietest for high angle/high ROD (“low” power) approaches. In general, avoid low angle/low rate-of-descent approaches. Noise abatement can be achieved during approach per the following recommended procedures listed in approximate order of effectiveness:

1. Reduce airspeed in level flight to 60 KIAS, then initiate descent at a ROD of 1300 fpm (+/- 200 fpm) [12°+/- 2° descent angle] while maintaining airspeed. Maintain constant descent as long as practical, decelerating as quickly and closely to landing as practical.
2. Reduce airspeed in level flight to 80 KIAS, then initiate descent at a ROD of 1700 fpm (+/- 200 fpm) [12°+/- 2° descent angle] while maintaining airspeed. Maintain constant descent as long as practical, decelerating as quickly and closely to landing as practical.
3. Reduce airspeed in level flight to 80 KIAS, then initiate descent at a ROD of 1000 fpm [~7° descent angle] while maintaining airspeed. While maintaining ROD, rapidly reduce airspeed to 40 KIAS (~2 kt/sec deceleration) either near to landing or earlier if needed to minimize noise impacts over a noise sensitive area. Maintain 40 KIAS and ROD until transition to landing.
4. Reduce airspeed in level flight to 80 KIAS, then initiate descent at a 9° descent angle (approx. 1250 to 1350 fpm initial ROD) while maintaining airspeed. Prior to landing, rapidly reduce airspeed to 40 KIAS (~2 kt/sec deceleration) while maintaining descent angle, then maintain 40 KIAS and ROD until transition to landing.
5. Prior to initiating descent from cruise, decelerate rapidly (~3 kt/sec) to 40 KIAS in level flight or shallow descent at a rate below 250 fpm. Setup an approach glideslope into the landing area by increasing the rate-of descent to 900 to 1000 fpm at 40 KIAS, then maintain 40 KIAS and ROD until transition to landing. In general, this procedure should not be used from cruise below 1000 ft and deceleration should be initiated as close to initiating descent as practical.
6. For some operations, low angle approaches at 60 to 80 KIAS may prove to be an effective Fly Neighborly procedure if approaches can be conducted over less noise sensitive routes (highways, industrial areas, water, etc.) with any noise sensitive areas at least several hundred feet to both sides of the flight track and several hundred feet past the landing point.

Figure 6. Draft Recommendations for Bell 407 Fly Neighborly Approach Procedures

Two conditions identified as baseline conditions for evaluating the benefits of tested noise abatement procedures for the Bell 407 are shown in Figures 7 and 8. Figure 6 shows the noise contours obtained for a 6º degree approach at 60 kt IAS representative of an FAA noise certification approach condition for the Bell 407. The field observations for this condition were “BVI until near overhead (OH), intensive near OH, strong retreating blade BVI after OH.” Figure 8 shows the noise contours obtained for a descent condition representative of the final descent segment of the Bell 407 approach Fly Neighborly guidance obtained from the HAI website, i.e., a 500 fpm rate-of-descent (ROD) at 40 kt IAS. The field observations for this condition were “long & slow, increasing BVI until OH, some late retreating blade BVI.” In general, all of the descents conducted at 40 kt IAS had long durations with significant BVI content at the shallower descent angles.

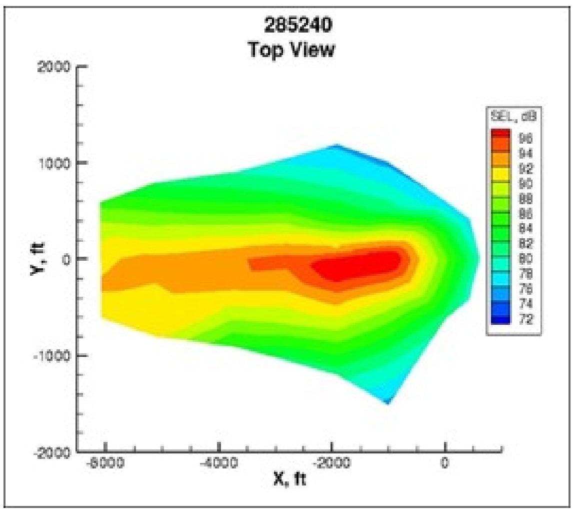


Figure 7. Noise Contour Plots for Bell 407 Noise Certification Approach Condition (6º at 60 kt IAS) ***(Source: NASA)***

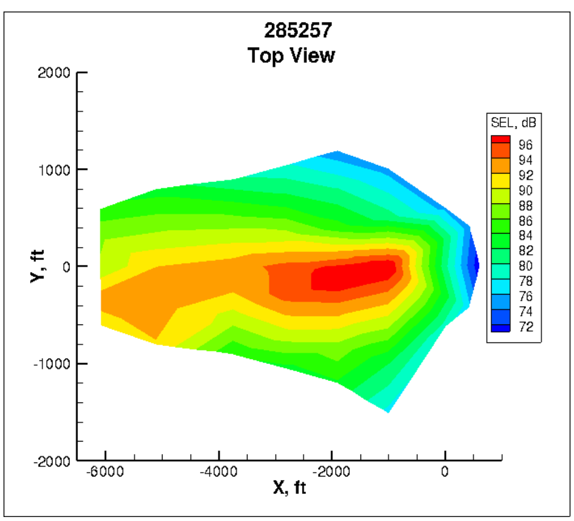


Figure 8. Noise Contour Plot for Final Segment of Current Bell 407 Fly Neighborly Approach Procedure (40 kt IAS at 500 fpm) ***(Source NASA)***

Noise contour plots for the Bell 407 approach noise abatement test conditions as recommended in Figure 5 are shown in 9 through Figure 17. Figures 9 and 10 show two options (Recommendations 1 and 2 in Figure 6) for increasing ROD to minimize BVI noise and increasing airspeed to reduce duration as compared to the current Bell 407 Fly Neighborly final descent condition shown in Figure 8. Although the 12º, 80 kt IAS condition shown in Figure 10 may prove too steep for flyability/passenger acceptability, these conditions are intended to provide descent conditions with acceptable combinations of safety, flyability, passenger acceptability and duration/cost.

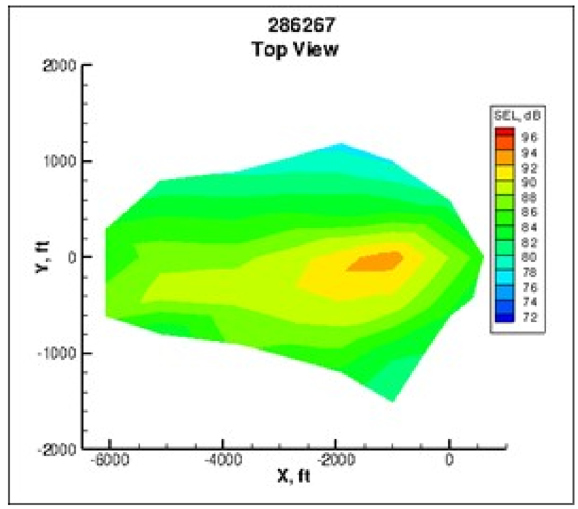


Figure 9. Noise Contour Plots for Tested Bell 407 Noise Abatement Recommendation #1 ***(Source: NASA)***

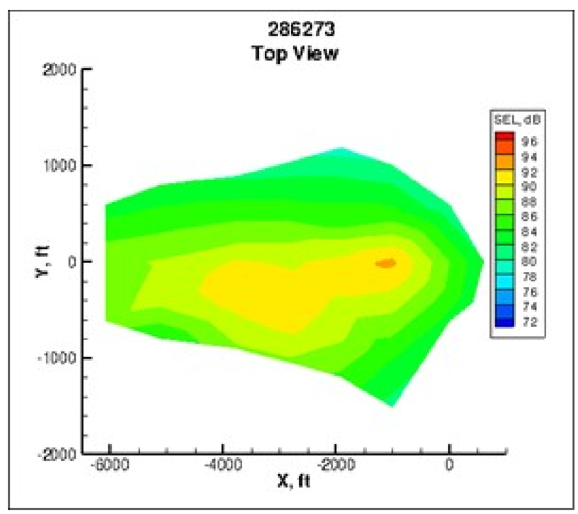


Figure 10. Noise Contour Plots for Tested Bell 407 Noise Abatement Recommendation #2 ***(Source: NASA)***

For comparison, Figure 11 shows the benefits of modifying the descent rate tested for the Figure 8 contours from approximately a 12º to approximately a 14º glide slope. This steeper descent rate would provide significant further noise abatement benefits if otherwise acceptable for a flight operation. The field observations for the flight conditions tested in Figure 9, 10 and 11 indicated some impulsive noise before initiating descent including transition BVI but good to excellent noise characteristics after transition with minimal to no BVI observed during descent. The best descent condition with no BVI noise was observed for the 14º descent at 60 kt IAS.

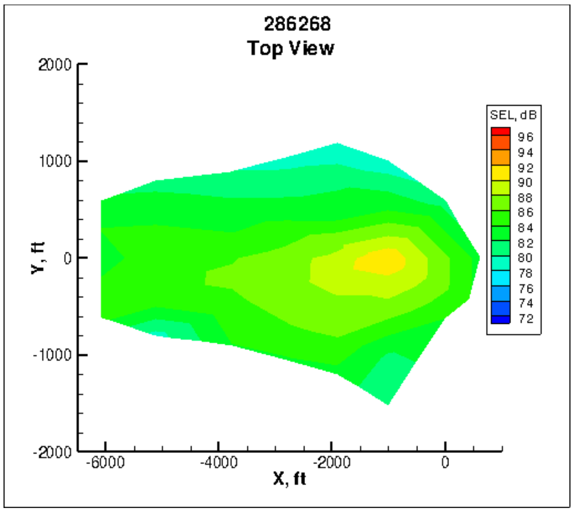


Figure 11. Noise Contour Plots for Tested Bell 407 Noise Abatement Modified Recommendation #1 ***(Source: NASA)***

Figures 12 and 13 show noise contours for two Bell 407 approach conditions utilizing deceleration to reduce BVI noise (Recommendations 3 and 4 in Figure 6). Deceleration forces pitch up the helicopter main rotor such that the effective aerodynamic descent rate is steeper rate than that of the nominal descent rate. Hence, deceleration can be used to transit without emitting BVI noise through regions of airspeed-ROD combinations subject to high BVI noise emissions under static descent conditions. Figure 12 shows noise contours obtained for a 2 kt/sec deceleration rate from a cruise airspeed at a constant ROD of 1000 fpm while Figure 13 shows noise contours obtained for a 2 kt/sec deceleration rate at a constant 9º glide slope. No field observations were made for these two conditions as the deceleration segment for each was initiated at the test listening post, precluding valid observations for the subsequent deceleration to the landing point.

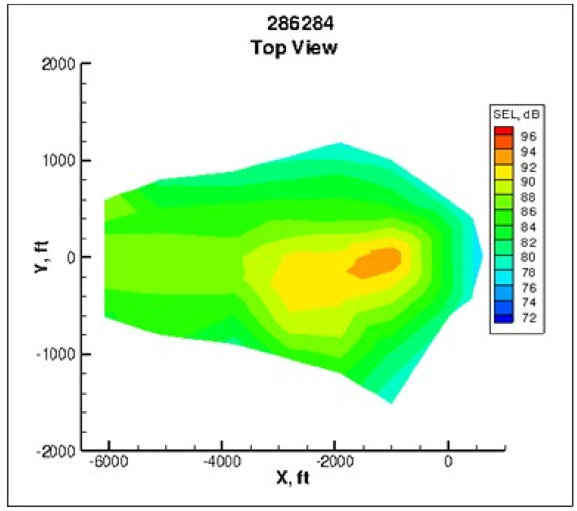


Figure 12. Noise Contour Plots for Tested Bell 407 Noise Abatement Recommendation #3 ***(Source: NASA)***

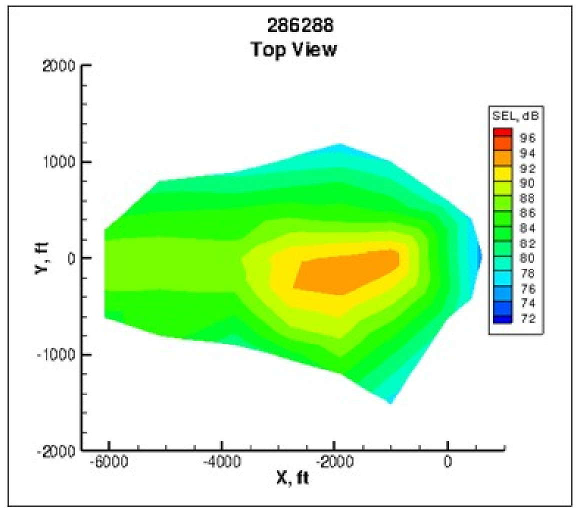


Figure 13. Noise Contour Plots for Tested Bell 407 Noise Abatement Recommendation #4 ***(Source: NASA)***

At high deceleration rates, passenger acceptability can become increasingly unacceptable, but 2 kt/sec is considered within an acceptable range for many flight operations. It is recommended that the deceleration phase be initiated as near to landing as possible for both of these descent conditions. For the noise contours obtained in Figures 12 and 13, deceleration was initiated approximately 3500 ft from the landing point, well within the area covered by the microphone array. If deceleration is conducted too early relative to the landing point, a post-deceleration transition to a constant descent condition, such as provided in Recommendation 1, may be necessary to achieve satisfactory Fly Neighborly results.

Figures 14, 15 and 16 address use of and modifications to the current Bell 407 Fly Neighborly approach recommendation obtained from the HAI Fly Neighborly website. This procedure includes a deceleration in level flight/shallow descent followed by a constant descent condition of 500 fpm at 40 kt IAS. As noted in the previous paragraph, deceleration can provide an effective aerodynamic descent condition that reduces BVI noise. In level flight and/or shallow descent conditions, deceleration can aerodynamically put a helicopter into an effective descent condition that increases BVI noise generation. In an attempt to avoid this possibility, the current Bell 407 recommendation was tested using high deceleration rates in the level flight portion prior to initiating the constant airspeed descent segment of 500 fpm at 40 kt IAS. As indicated in Figures 14 and 15, a deceleration rate of 3 kt/sec was needed before acceptable noise reductions were achieved during deceleration in level flight. This deceleration rate may prove too high for passenger acceptability. Note that the current Bell 407 recommendation states that the deceleration can be performed in a shallow descent condition of up to 250 fpm. Doing so should somewhat reduce the minimum deceleration rate to achieve acceptable noise results. It is also possible that BVI noise can also be avoided by performing a very slow deceleration in level flight.

The current Bell 407 Fly neighborly approach guidance recommends a final descent segment of 500 fpm at 40 kt IAS. As noted previously, this condition was found to be a long duration, high noise condition as indicated in Figure 8. Testing at much higher descent rates for a 40 kt airspeed, however, demonstrated that the impulsive BVI noise content at 500 fpm could be substantially eliminated, although at 40 kt the noise duration remains long. Doubling the rate of descent to 1000 fpm proved effective, as shown in Figure 16. Combining the higher ROD with higher deceleration in the level flight/shallow descent segment of the procedure should provide significant improvements to the procedure as currently defined. This combination is included as recommendation 5 in the draft Fly Neighborly guidance provided in Figure 6.

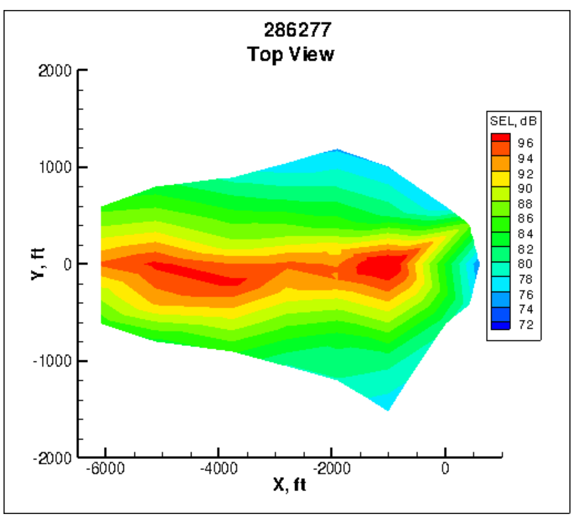


Figure 14. Noise Contour Plot for Current Bell 407 Fly Neighborly Approach Procedure (Level Flight Decel at 2.5 kt/sec, then 40 kt IAS at 500 fpm) *(Source NASA)*

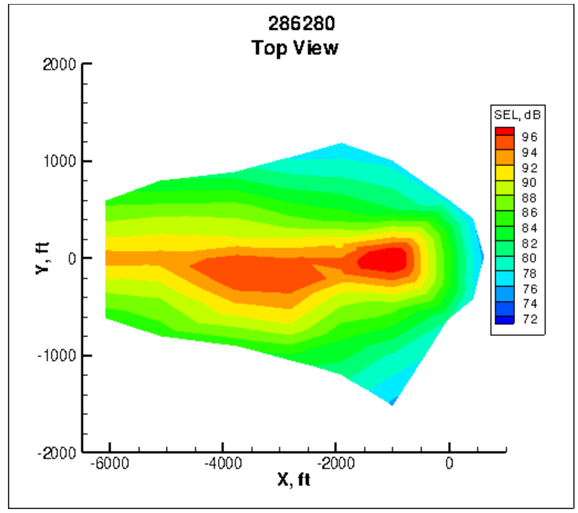


Figure 15. Noise Contour Plot for Current Bell 407 Fly Neighborly Approach Procedure (Level Flight Decel at 3 kt/sec, then 40 kt IAS at 500 fpm) *(Source NASA)*

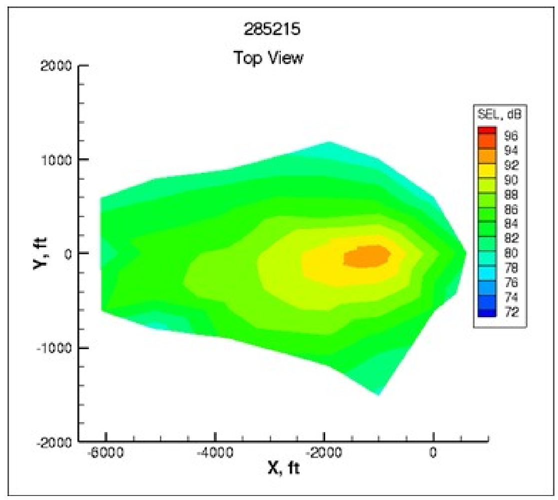


Figure 16. Noise Contour Plot for Final Segment of Current Bell 407 Fly Neighborly Approach Procedure with Doubling ROD (40 kt IAS at 1000 fpm) *(Source NASA)*

The first five draft Bell 407 Fly Neighborly recommendations were all developed using a single listening post intended to identify more global noise reduction benefits, i.e., noise reductions over the full area impacted by the helicopter operations. As noted previously, the location of noise sensitive areas for specific helicopter operations may necessitate different listening posts and tailored noise abatement procedures. One such case is shown in Figure 17, which depicts a shallower angle approach, 3° at 60 kt IAS, with high noise levels near the flight track but significantly decreased noise levels at larger lateral displacements from the flight track. This was included as Recommendation 6 in the Fly Neighborly recommendations provided in Figure 6, but was not derived using auditory techniques during testing as noise at these high lateral displacement locations was not observed during the test. This recommendation was subsequently derived solely from the noise contours provided by NASA after the recommendations obtained via auditory techniques, and was included to provide guidance for operations where lateral noise reductions needed to be optimized and near flight track noise was not an issue. As might be expected from the noise contours in Figure 17, the field observation for this descent condition was “strong BVI until nearing OH, maybe slightly better than 6º, 60 kts.”

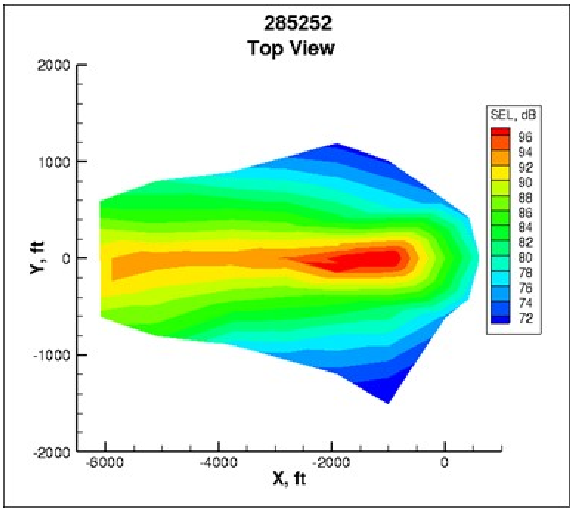
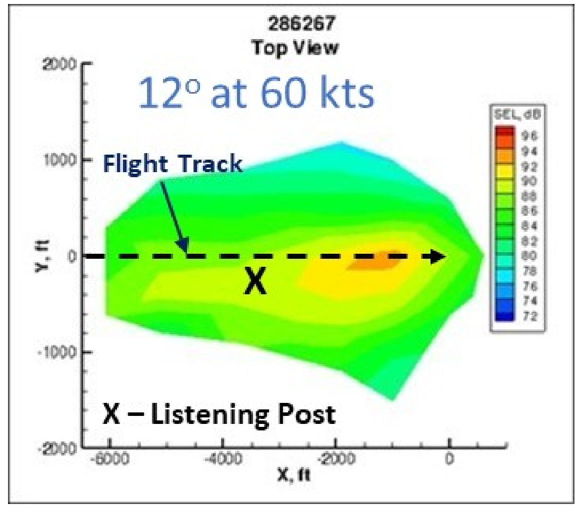
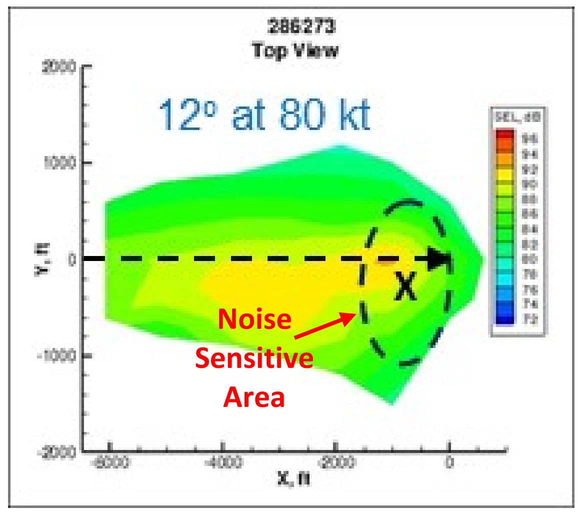


Figure 17. Noise Contour Plots for Tested Bell 407 Noise Abatement Recommendation #6 ***(Source: NASA)***

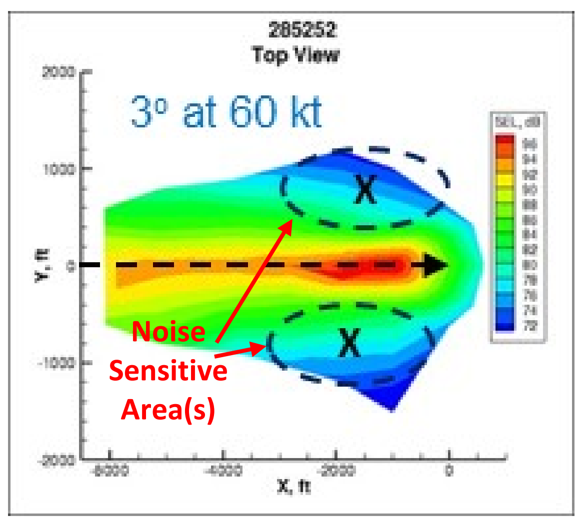
Many considerations go into developing and implementing Fly Neighborly procedures for a specific helicopter operation. As indicated in the discussions above, location of noise sensitive areas and routing opportunities/needs/restrictions are two primary considerations. Noise sensitive areas will often drive the best Fly Neighborly solutions. Figures 9, 10 and 17 are repeated in Figure 18 with overlays of noise sensitive areas and related listening posts. In Figure 18, Figure (a) represents the global noise abatement objective with the listening post used for the Bell 407 testing, where Recommendation 1 for the Bell 407 might be the best solution, while Figures (b) and (c) represent two potential cases with localized noise sensitive areas. The situation in Figure (b) could occur, for example, for a landing pad at a hospital surrounded by residential neighborhoods, leading to use of Recommendation 2 as the best solution to minimizing noise issues adjacent to the hospital. The noise sensitive areas in Figure (c) represents situations where the helicopter operation has noise sensitive areas located at higher lateral distances from an approach route which can be located over an industrial area, water or other area with low noise sensitivity. These three cases show that a single Fly Neighborly approach recommendation is unlikely to be universally applicable or optimum, and that the best Fly Neighborly solution is likely to be operation/site dependent.



(a) Global Noise Reductions



(b) Noise Sensitive Area Close to Landing Point



(c) Noise Sensitive Area(s) at Higher Lateral Distances from Flight Track

Figure 18. Examples of Global (a) and Noise Sensitive Area-Specific Listening Posts (b, c) and Fly Neighborly Approach Procedures

FLY NEIGHBORLY AND iFlyQuiet DEMONSTRATION AT EAST HAMPTON AIRPORT

A Fly Neighborly and iFlyQuiet Demonstration was conducted at East Hampton Airport (KHTO) in East Hampton, NY over the weekend of September 7-10, 2018. An objective of this effort was to evaluate available noise resources and information for implementing noise abatement procedures in an existing operation. Another goal of this demonstration was to evaluate the noise abatement characteristics of the published KHTO November noise abatement procedure and potentially provide recommendations for modifying the existing procedure for improved Fly Neighborly effectiveness.

The Fly Neighborly and iFlyQuiet Demonstration included outreach to operators flying into and out of East Hampton Airport, coordination with an operator volunteering to participate in the demonstration, GoPro cockpit video recordings during approaches to KHTO, noise measurements at several locations adjacent to the November arrival route, and recommendations for modifications to the November arrival noise abatement procedures to potentially enhance noise abatement effectiveness.

Procedures Demonstration Objectives

The Fly Neighborly and iFlyQuiet Demonstration was conceived to explore the nuances and limitations of practical application of Fly Neighborly Procedures. It was structured to answer questions such as: Do operators have sufficient understanding of the procedures to implement in daily operations? Are there impediments to implementation? Is additional training or guidance needed to overcome these impediments?

Working with individual operator partners and helicopter operator organizations, the noise abatement procedures developed during past test programs, including the joint 2017 NASA-FAA-DOD flight test program, were used to inform the development of site-specific, realistic noise abatement procedures. This procedures demonstration was planned to be conducted jointly with operator partners and organizations operating at a selected site.

A rigorous acoustic measurement campaign was not the focus of this demonstration effort. Rather, the primary focus was to provide concrete evidence that noise abatement procedures can be tailored and implemented in a specific location through interaction with operators. The benefits of implementing site-specific noise abatement procedures were to be verified through a limited amount of *in situ* acoustic measurements along with acoustic modeling and simulations. To summarize, the primary objectives were to:

- Engage with operators on the implementation objectives – document these interactions
- Understand and document the impediments to operator implementation of noise abatement procedures
- Design site-specific noise abatement procedures
- Ask the operators to fly these procedures and collect data for verification
- Provide recommendations for wider promulgation of FN techniques
- Obtain operator/pilot feedback and document examples of implementation into normal routines

In addition to understanding the practical application of noise abatement procedures, the demonstration was documented such that additional training and outreach materials may be produced. Documentation in the form of the 'raw' materials needed to produce before and after abatement comparisons suitable for outreach and FN education were compiled in the form of:

- Cockpit Video(s)
- Aircraft tracking and performance data
- Ground-based audio recordings and sound-level time-histories
- Narratives of results

Site Selection

The Fly Neighborly and iFlyQuiet Demonstration was best suited to an area with an existing problematic helicopter noise situation, as these areas are likely the most challenging in terms of implementation and thus more likely to produce a wealth of 'lessons learned'. These areas are also likely to gain the most benefit from any procedures developed. Partner organizations indicated that East Hampton, NY airport operations (recommended by the Eastern Region Helicopter Council or ERHC), Los Angeles / Hollywood, CA (Hollywood sign tours, recommended by the Los Angeles Area Helicopter Operators Association or LAAHOA), and Palm Beach, FL airport would be suitable sites. Of these, East Hampton was considered to have the most beneficial balance of route, operations, and aircraft fleet and was selected for the procedures demonstration. East Hampton Airport (KHTO) has three established helicopter noise abatement arrival and departure procedures designated as the November Arrival, Echo Departure and Sierra Arrival/Departure Procedures (Reference 7).

The Bell 407 and Sikorsky S-76 are both commonly used for operations into and out of the East Hampton Airport, so analysis was conducted in advance for both airframe types to understand the potential opportunities for noise reduction.

Identifying Partner Operators

Potential operators were identified by working with the Eastern Region Helicopter Council (ERHC) who informed their membership via email of the procedures demonstration opportunity and its benefits, and solicited voluntary participation. ERHC also reached out directly to several operators with a significant number of operations into and out of East Hampton Airport. Contact was made between prospective operators and the authors, and discussions with two specific operators were very fruitful in understanding existing helicopter noise abatement procedures at KHTO.

Baseline Approach Information from Operators at KHTO

The majority of helicopter arrival operations at KHTO follow the recommended November Arrival procedure as the transition from the prescribed 'North Shore Route' to KHTO. The November Arrival is described as follows, where November 1, 2 and 3 are the designated waypoints (Reference 7):

*Arrivals from the west proceed to "November 1" (N40*57.37 W072*27.16) at or above 3500 feet, continue to "November 2" (N40*58.41 W072*20.43) at or above 3000 feet, to "November 3" (N40*58.14 W072*17.60) at or above 2500 feet, then to the airfield.*

Two operators of Bell 407 and Sikorsky S-76 aircraft confirmed that they comply with the November noise abatement route, flying as quickly as possible and descending into the airport as steeply as possible, noting some difficulties doing so if put in to a holding pattern by the airport control tower due to traffic, or if wind conditions preclude achieving a sufficiently steep descent angle. These difficulties provided some potential for evaluating the benefits of reduced cruise speeds in level flight and extended steep angle and/ or higher speed shallower angle descents into the airport.

Based on discussions with one operator regarding procedures primarily for the S-76 aircraft, the following was discovered:

- Weather permitting, S-76 helicopters fly the North Shore route at 3600 – 3700 ft and further off shore than the smaller single engine helicopters to avoid congestion.
- Flight speed on the November route from Waypoint C1 through Waypoint N2 is typically 140 kt.
- Normal procedure is to descend to 3000 ft and decelerate to 120 kt between the N2 and N3 waypoints, using autopilot with a 500 fpm descent rate.
- After N3, pilots must execute a steep angle approach (12^{o} – $14+^{o}$) to get down to the airport, decelerating to ~67 kt to provide some cushion above a 65 kt minimum airspeed. The typical descent rate into the airport is 2000 fpm and pilots typically fight "float" during this descent, indicating the aircraft is near autorotation for the final approach segment.
- In tailwind conditions, ground speeds are higher and descent angles are lower. On higher tailwind days a dog leg is sometimes needed during the approach to be able to get down to the airport, adding a left turn before the airport then a final right turn into Runway 16/22 the airport.
- Two main landing areas are the Runway 16/22 north ramp and the Main Ramp.
- Approaches are performed with minimal variation from the prescribed flight track when flying the November noise abatement route into the airport.
- With ceilings at 2000 ft or lower, VFR approaches are required by local Air Traffic Control and helicopters must execute approaches from lower altitudes, precluding use of the November Arrival procedure which requires altitudes at 2500 to 3500 ft. VFR is sometimes required for cloud decks higher than 2000 ft.

Baseline Takeoff Information from Operators at KHTO

One operator also provided the following information:

- Normal procedure is a horizontal Cat A takeoff.
- Difficult to get to specified 1500 ft altitude by Waypoint E1. Takeoff is quick as possible at a 270-280 heading at 98% torque, 1800 fpm and 60-70 kt. They must get above 60 kt to enable use of the Flight Management System (FMS).
- Passenger comfort (sensation of being pushed into the seat) can be an issue during takeoffs due to G levels, more so in turns.
- A 3000 ft altitude and cruise condition flight is typical by the E2 waypoint.
- During special VFR conditions, departure is directly north from airport, climbing to ceiling-limited altitude and proceeding to shoreline as directly as possible to minimize the exposed population.

Modified S-76 Approach Procedures for KHTO

The application of existing Fly Neighborly guidance to the existing November Arrival procedure was evaluated as part of the Fly Neighborly and iFlyQuiet Demonstration. Identification of potential modifications to the published procedure utilized the operator feedback on KHTO operations described above, along with the existing S-76 Fly Neighborly procedure guidance based on prior testing and acoustic modeling, to evaluate potential outcomes and refine procedures. Key application constraints included minimal or, if possible, no changes to the November route (latitude, longitude, and prescribed minimum altitudes), balancing source noise vs. duration tradeoffs, passenger comfort/acceptability and pilot workload. As a result, the recommended modifications focused on airspeed in cruise, and deceleration and descent rates on final approach. To accommodate changes in descent conditions, an additional waypoint was added to the current November procedure for each recommended procedure modification.

A total of four modified noise abatement routes were evaluated for the S-76 aircraft. Two modified routes, (November 1 (Nov 1) and November 2 (Nov 2)) were defined to follow the precise November route, *including* executing the course change at waypoint N3, but included two newly-defined waypoints N2A and N3A as intermediate points and to facilitate communication with operators. The routes are noted and described as follows (see Figure 19):

- Nov 0 - the current November procedure
- Nov 1 - Maintain 3500' to N3A, then steep angle approach into KHTO per current procedure, transitioning to approx. 2000 fpm descent, adjusted for wind conditions as needed. Continue approx. 2000 fpm descent until decel to the Landing Decision Point (LDP) near the airport.
- Nov 2 - Execute moderate decel after N1 to achieve 120 kt prior to reaching South Fork. Prior to reaching N2, execute slow to moderate decel to achieve 100 kt at N2. Prior to reaching N2, execute slow to moderate decel to achieve 100 kt at N2. Transition to approx. 1400 fpm descent, adjust for wind conditions as needed. Continue approx. 1400 fpm descent until decel to the LDP near the airport.

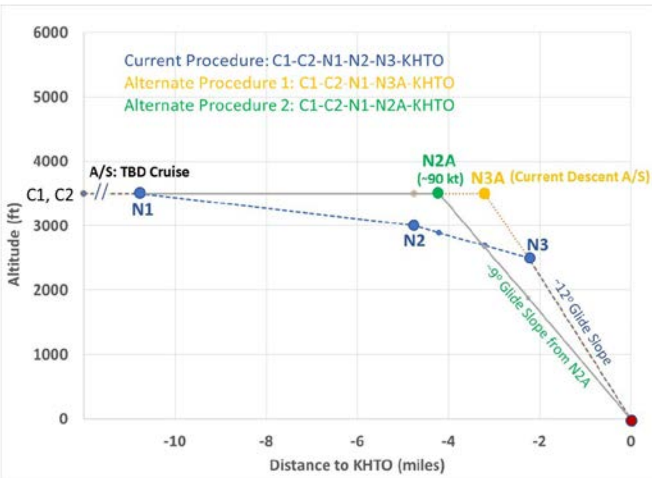


Figure 19. Current (blue) and Proposed (yellow and green) East Hampton Airport (KHTO) November Noise Abatement Descent Procedures

The Nov 1 procedure was intended to maintain the maximum altitude as long as possible prior to descent to the airport, while the Nov 2 procedure was intended to evaluate the relative effectiveness of a less steep, higher airspeed approach procedure potentially providing better flyability and passenger comfort.

Two additional routes that execute similar alternative descent conditions, but eliminate the course changes at waypoint N3 to proceed directly to the airport from waypoint N3A (Nov 1-alt) and waypoint N2B (Nov 2-alt) were similarly defined. These two additional routes each incurred some deviation from the precise November Arrival route (see Figure 20) that was deemed acceptable.

Noise Model Evaluation of S-76 Approach Procedures for KHTO Airport

AAM was used to predict and evaluate the potential noise benefits of the modified November noise abatement procedures for the Sikorsky S-76. Predicted noise spheres were first calculated by PSU[4] over a broad range of airspeeds and descent rates using the comprehensive, physics-based, whole vehicle helicopter noise modeling framework under development at Penn State under FAA ASCENT Project 38. These noise spheres were then used in AAM to assess ground level noise impacts.

Predictions were made for the current November procedure (Nov 0), and the four modified procedures The AAM predicted flight track (Mid-0) and noise benefits at lateral points 1000, 2000 and 3000 ft to the North (N) and South (S) of the flight track of the Nov 1, Nov 2, Nov 1-alt and Nov 2-alt alternative November noise abatement procedures are shown in Figure 21.

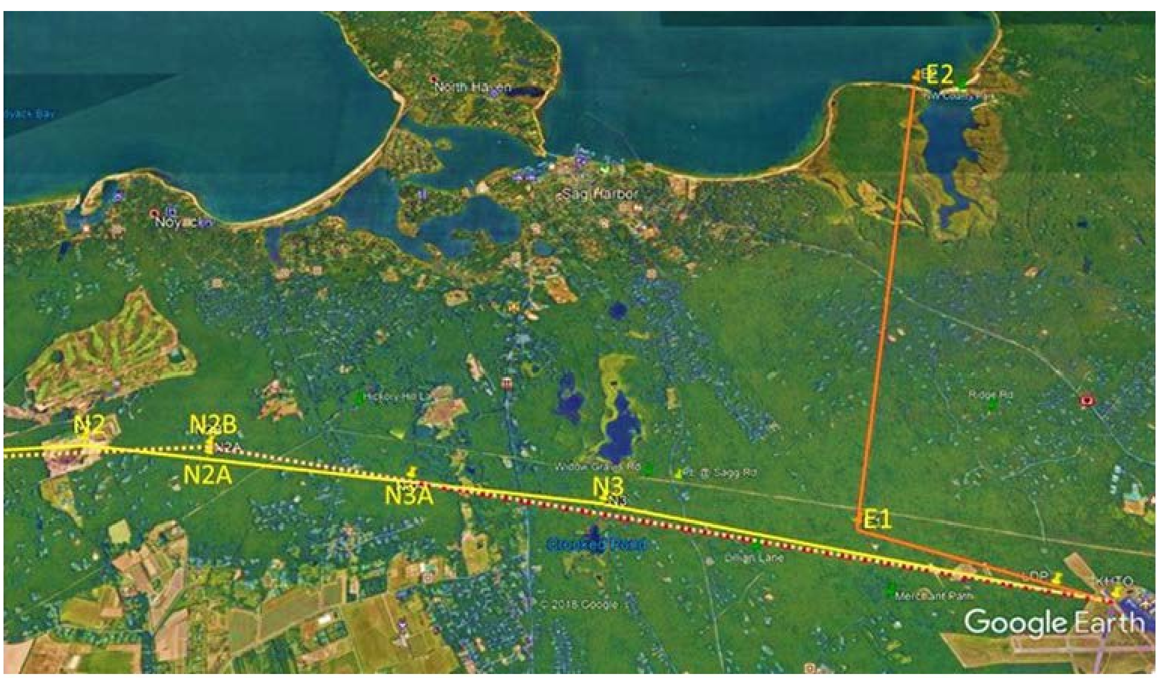


Figure 20. Flight Tracks for Current and Proposed East Hampton Airport (KHTO) November Noise Abatement Arrival Procedures

In general, the predictions indicate that noise benefits are achievable and also show the potential impacts of the slight route changes incurred for the Nov 1-alt and Nov 2-alt direct-to-airport descents.

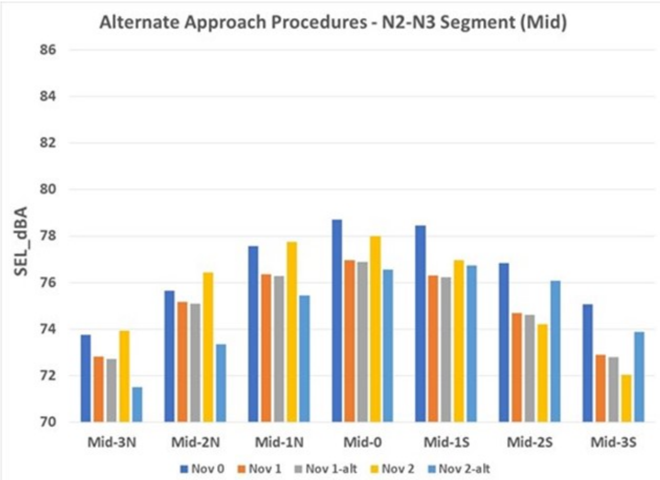


Figure 21. Advanced Acoustic Model (AAM) Predicted Flight-Track (Mid-0) Benefits and Lateral Noise Benefits at 1000, 2000 and 3000 ft to the North (N) and South (S) of the Flight Track for Alternative November Procedures

Modified Bell 407 Approach Procedures for KHTO

Potentially improved Fly Neighborly approach procedures for the Bell 407 approach noise were identified as part of the Fly Neighborly and iFlyQuiet Demonstration. In conjunction with operator feedback on KHTO operations described above, the 2017 joint NASA-FAA-DOD test data and resulting Bell-407-specific draft recommendation (Figure 6) were used to identify potential descent profile modifications to the published November noise abatement route for helicopter arrivals into the airport. Key application constraints again included no/minimal changes to the November route, source noise vs. duration tradeoffs, passenger comfort/acceptability and pilot workload.

Similar to the S-76, two Bell 407 alternative descent procedures, consistent with the Bell 407 draft FN Recommendations 1 and 4 in Figure 6, were identified, one an extension of the current steep angle approach to maintain the 3500 ft altitude until initiating descent (waypoint N3A in Figure 19) and the second establishing a 9º approach condition at higher airspeed (80 kt) into the airport intended to achieve noise abatement with reduced pilot workload. New waypoints either on the precise November route (N2A and N3A) or skipping waypoint N3 for direct descent into the airport with small deviations from the current route (N2B and N3A) were defined. These procedures were nearly identical to the alternative S-76 procedures with the exception of an 80 kt airspeed for the 9º descent (rather than the 90 kt airspeed as indicated in Figure 19).

Communicating Low-Noise Procedures with Operators

After phone discussions with the operator pilots describing the potential additional noise reductions for modified approaches, one operator flying S-76 helicopters agreed to participate in the Procedures Demonstration. A Bell 407 participant operator could not be identified and enlisted within the project and test schedule constraints. The S-76 operator agreed to perform two of the modified approach procedures, one maintaining altitude at 3500 ft then executing an extended steep angle approach to the airport and a second executing a reduced cruise speed (120 kt) followed by a longer 9º approach at a higher airspeed of 90 kt. This agreement fit well with the noise monitoring schedule (see below). In addition, the operator agreed to install GPS "pucks" and GoPro cameras on the S-76 aircraft to record operations into and out of East Hampton Airport during the test period and provide daily flight schedules to better coordinate test operations in East Hampton.

The discussions with operators also included the potential benefits of performing takeoffs at slightly slower speeds (up to 10 kt below best rate of climb airspeed) to increase climb angles, but it did not appear to be a significant change from current operations, so the planned modified procedures concentrated on the November approach procedures.

Data Collected During Demonstration

During the period September 7-10, 2018, seven noise / video / observer sites were selected to monitor operations into the airport on the November arrival route and the Echo departure route (Figure 22). Data and observations were collected for 6-9 hours per day during this period, according to the anticipated schedule of operations. Acoustic and photo/video data collected at these locations include the following:

- One-third octave-band sound level time history at 100 ms intervals (10 Hz to 20 kHz)
- Continuous audio recordings (wav)
- Photos

Operational and tracking data for individual flights were obtained from various sources during and post-test:

- Observer logs of overflight time, aircraft type (if identifiable) and qualitative observations of sound quality
- Precision GPS data for flights with the partner operator (1-second samples from on-board GPS)
- Publicly-available track data from sources such as FlightAware and FlightRadar24

In total, one or more types of the data listed above were recorded by the authors and pilot/operators during the demonstration test period for 46 unique flights. Of these 46 flights, 34 had both acoustic and at least one form of tracking data. Five of these flights had both precision tracking data

Figure 22. Noise monitoring locations S0-S6 (red markers) and flight track waypoints N1, N2 and N3 (yellow markers)

obtained by the partner operator and acoustic data collected at least one of the monitoring locations. It is these five flights with precision tracking and acoustic monitoring data which have been selected for further analysis.

Results and Outcomes of the Fly Neighborly and iFlyQuiet Demonstration

Poor weekend weather conditions (including rain) curtailed and constrained helicopter operations at East Hampton Airport during the demonstration. The vast majority of operations utilized VFR approach procedures, defaulting to a route known as the 'power line' route. These conditions precluded use and 'testing' of both the current and alternate November arrivals.

The as-flown VFR procedures for the five flights with precision tracking and acoustic data were evaluated nonetheless, to determine what, if any, information could be gleaned and to provide further evidence that procedural differences can affect and mitigate noise impacts on the ground.

For each of the five flights, the following information was evaluated:

- Sound-level time history data and basic summary metrics (maximum sound level, sound exposure level) at each monitor location
- Recorded audio files at each monitor location
- Tracking data (1-second samples) – latitude/ longitude, altitude, and airspeed; from these glide slope, rate-of-descent, and deceleration rate were computed

The tracking data in particular proved useful for examining and evaluating the noise abatement qualities of each flight. Data plots were generated for each of the five flights and four operational parameters of interest (altitude, rate-of-descent, glideslope and deceleration rate). As an example, Figure 23 shows a plot of rate-of-descent vs distance to the airport for an S-76 arrival on Sept 8. The red circle in the plot indicates a portion of the flight where BVI may have been produced due to the low-rate-of-descent.

The recorded audio clips, where available, were then used to confirm/deny the assessments made using tracking data alone. In the vast majority of cases, it was clear from the audio clips that BVI was produced as expected/predicted based on the tracking data.

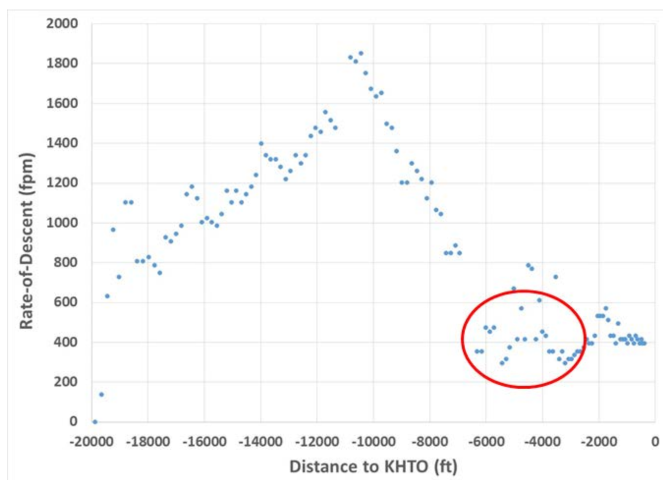


Figure 23. Rate-of-descent (fpm) vs distance to KHTO airport (ft) for S-76 arrival operation on Sept 8. Period of low ROD from 7,000 to 2,000 ft before arrival at airport (red circle) may result in BVI noise

Development of Training and Outreach Materials

Based on the results and outcomes of the demonstration, it was agreed that a number of training and outreach materials would be developed from the experiences and documentation obtained. These materials include:

1. Cockpit noise overlay video with ground-based audio recordings. These videos demonstrate the noise generated (as a 'heatmap') for a particular flight as seen from the pilot's perspective. Figure 24 shows an example screenshot.
2. Acoustic animations of the prescribed current/alternate November arrival and the as-flown VFR arrivals. An acoustic animation demonstrates noise generated from a plan view or eagle-eye perspective.
3. Animated plots of the aircraft tracking data (similar to Figure 23) with audio clip overlay – such that the viewer can both 'see' the aircraft track/performance and hear the resulting sound generated at the ground.
4. Step-by-step example of how FN procedures were developed for HTO
5. Practical limitations - Lessons learned

For development of items 1 and 2 (the cockpit overlay video and the acoustic animations), the AAM was used in conjunction with the 1-second tracking data to predict noise exposure from the as-flown arrivals for the Sikorsky S-76.

Figure 24. Example screenshot of cockpit noise overlay video. This video depicts an S-76 approach to KHTO (https://www.youtube.com/watch?v=GyMHk85MPYE).

For the cockpit overlay video, noise exposure footprints were generated at ½ second intervals and overlaid on the cockpit video footage, using knowledge of aircraft altitude, airspeed, pitch, and bank angle. The final video also makes use of the ground-based audio recordings, which form the basis of a video soundtrack, allowing viewers to both see the noise generated from the cockpit vantage and hear the noise generated as it is received on the ground. Markers were overlaid on the video footage to depict the location of the recording stations. The final video can be accessed here: https://youtu.be/GyMHk85MPYE.

CONCLUSIONS

Auditory techniques proved effective for identifying and developing Fly Neighborly approach procedures for minimizing BVI noise emissions for a specific helicopter model, in this case a Bell 407. These techniques are expected to be equally effective in identifying Fly Neighborly approach procedures addressing noise sensitive areas for specific helicopter operations.

As a result of the observed helicopter operations including the S-76 testing during the East Hampton demonstration effort, it became apparent that low noise procedures should also be developed for bad weather conditions, in particular when low cloud ceilings push Visual Flight Rule (VFR) operations to lower flight altitudes that may preclude use of established noise abatement procedures or to operations subject to Special VFR routing. As noise abatement procedure development via both modeling and testing has typically been performed for clean aircraft configurations in near pristine weather conditions only, the lessons learned also provide insights to planning future development efforts that could help close gaps between noise abatement research and real-world applications.

Based on interactions with operators and observational data gathered during the design, development and execution of the iFlyQuiet Procedures Demonstration at East Hampton Airport, general and site-specific observations can be drawn.

Broadly-applicable iFlyQuiet Observations

Helicopter flight operations are very dynamic and not nearly as prescribed or regular as they are for fixed wing operations.

Contacted operators were generally aware of basic Fly Neighborly (e.g. fly higher) but tend not to tailor specific procedures for noise outside of the existing published voluntary low noise procedures.

These operators are open to guidance and suggestions and willing to adapt appropriately, with technical assistance. This would suggest that additional outreach, training and guidance could be beneficial.

Defining low noise procedures for situations with low ceiling VFR flight or other low altitude operations (e.g., news-gathering, search-rescue, air tours) would be beneficial to operators.

Hampton-Specific iFlyQuiet Observations

Voluntary low noise flight procedures are followed when possible, but often weather conditions and/or ATC direction preclude their use.

Although poor weekend weather conditions (including rain) precluded use of the November arrival noise abatement procedures during the demonstration, the poor weather/VFR conditions also curtailed helicopter operations during demonstration, to some extent mitigating overall noise impacts.

The voluntary November procedure is already a very steep angle final approach that requires high pilot workload to execute, especially under tailwind conditions. Alternative descent profiles could be equal or lower noise and easier to fly, improving both pilot workload and passenger comfort.

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