Project 038 Rotorcraft Noise Abatement Procedure Development

The Pennsylvania State University, Continuum Dynamics, Inc.

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University Participants

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- P.I.: Kenneth S. Brentner, Professor of Aerospace Engineering
- FAA Award Number: 13-C_AJFE-PSU-038, Amendment No. 119
- Period of Performance: October 1, 2024, to August 30, 2025
- Tasks:
  1. Shrouded rotor noise modeling
  2. Broadband noise prediction enhancement
  3. PSUDEPSim aircraft model updates
  4. Application of noise prediction enhancements to abatement procedure analysis
  5. Demonstrate PSU Noise Prediction System (PSU-NPS) at Volpe National Transportation Systems Center (Volpe) and Federal Aviation Administration (FAA) Technical Center

Project Funding Level

The project's previous funding ended on December 31, 2023, and was not renewed until August 2024, with FAA funding of $181,000; Continuum Dynamics, Inc. (CDI; point of contact: Dan Wachspress) providing $150,000 of cost sharing in the form of a 1-yr license for the Comprehensive Hierarchical Aeromechanics Rotorcraft Model (CHARM) rotorcraft comprehensive analysis software to Penn State and the FAA or their designee. Supernal will provide $140,000 in-kind support in the form of costs accrued to collect and extract datasets from a flying testbed Bell® 407 as well as engineering hours. Due to the funding gap, task names did not change for this report.

Investigation Team

Kenneth S. Brentner, P.I., Penn State; acoustic prediction lead on all tasks
Joseph F. Horn, co-P.I., Penn State; flight simulation lead, support for all tasks
Daniel A. Wachspress, co-P.I., CDI; rotor loads, wake integration, and CHARM coupling
Mrunali Botre, co-P.I., CDI; support for rotor loads, wake integration, and CHARM coupling
Salma Ibnoukhaiber, Undergraduate Research Assistant, Penn State; broadband noise enhancement, and documentation of PSU-NPS for Volpe and other users.
Bhaskar Mukherjee, Ph.D. student (graduated August 2025), broadband noise, task overview and planning.

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Project Overview

Rotorcraft noise consists of several components, including rotor noise, engine noise, and gearbox and transmission noise. Rotor noise is typically the dominant component of rotorcraft noise to which the community is exposed upon takeoff and landing, and along the flight path of the helicopter. Rotor noise arises from multiple noise sources, including thickness noise and loading noise (the combination of these two is known as rotational noise), blade–vortex interaction (BVI) noise, high-speed impulsive (HSI) noise, and broadband noise. Each noise source has its own unique directivity pattern around the helicopter. Furthermore, aerodynamic interactions among rotors, interactions between the airframe wake and a rotor, and unsteady time-dependent loading generated during maneuvers typically increase loading noise. The combination of all potential rotor noise sources makes the prediction of rotorcraft noise highly complex, although not all noise sources are present at any given time in the flight (e.g., BVI noise usually occurs during descent, and HSI noise occurs only during high-speed forward flight).

In ASCENT Project 006, "Rotorcraft Noise Abatement Operating Conditions Modeling," the project team coupled a MATLAB®-based flight simulation code with Comprehensive Hierarchical Aeromechanics Rotorcraft Model (CHARM) aerodynamics code and Penn State's noise prediction code PSU-WOPWOP to form an integrated rotorcraft noise prediction capability for evaluating noise abatement procedures. This system calculates noise generated due to the motion and operating aerodynamic pressures on the main and tail rotor blades. The system did not model engine noise or HSI noise; however, engine noise is generally not a dominant contributor to far-field sound noise levels compared to noise from rotor blade motion and airloads. In addition, HSI occurs primarily during high-speed forward flights and is therefore not typically encountered during routine civil helicopter operations. Comparing predictions against Bell 430 flight test data (Snider et al., 2013) demonstrated reasonable agreement for select flight conditions. This system was then used to draft a plan for a flight test.

Representative helicopters were recommended for development of noise abatement procedures in ASCENT Project 38. These helicopters were selected to enable determination of whether noise abatement procedures could be developed for various categories of helicopters (i.e., two-blade light, four-blade light, two-blade medium, etc.) or whether aircraft-specific design considerations would be required. Aircraft models were established for the following aircraft: Bell 430, Sikorsky® S-76C+ and S-76D, Bell 407 and 206L, Airbus® EC130 and AS350, and Robinson® R66 and R44. Predictions were made before the 2017 FAA/National Aeronautics and Space Administration (NASA) noise abatement flight test to provide guidance for the flight test (see *ASCENT Project 038 Annual Report 2017*). After the flight test, a comparison of *A*-weighted sound pressure level time histories and sound exposure level contour plots revealed a problem in the broadband noise prediction, which was subsequently corrected (see *ASCENT Project 038 Annual Report 2018*). Initial validation comparisons demonstrated that the simulations were within several dBA of the flight test data; however, some discrepancies in the simulations (simplifications) remained, thus requiring a detailed examination. Work was also performed on the PSU-NPS, including modifying PSU-WOPWOP to output plots of the maximum dBA, as plotted in the flight test. Further work was conducted to enhance the postprocessing of noise data to enable a direct comparison with flight test data. Detailed analysis of the noise components and noise sources was performed for several helicopters in the 2017 FAA/NASA flight test (see *ASCENT Project 038 Annual Report 2019*). Further enhancements were added to compute moving averages and devise strategies for window overlapping in the post processing of predicted noise data (see *ASCENT Project 038 Annual Report 2020*). In the cases studied, de-Dopplerization (used in flight test data processing) and moving observers (used in noise predictions to eliminate Doppler effects) were demonstrated to be effectively equivalent (typically within 0.5 dB or less). Next a comparison of the effectiveness of noise abatement procedures by helicopter class was performed by using the 2017 and 2019 flight test data (see *ASCENT Project 038 Annual Report 2021*). In particular, the Bell 205, 206, and 407 aircraft were compared for various flight conditions in the flight tests. In the predictions, the Pegg broadband noise prediction did not work as well for some aircraft, and a simple scaling of the broadband noise was considered as a potential correction. Unfortunately, no clear relationship with the scaling among aircraft was observed. In addition, an analysis of the 2019 FAA/NASA flight test was performed by comparison of prediction and experimental data for 3° and 4.5° descents for both left and right turns at different bank angles (25° and 45°, respectively) for two aircraft (Bell 205 and Sikorsky S-76D). Preliminary coupling between the Penn State noise predictions system and Volpe's Advanced Acoustics Model (AAM) software was implemented (see *ASCENT Project 038 Annual Report 2022*). Expanding on preliminary work on

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shrouded rotor noise prediction that began in 2021, CHARM's panel method was used to model a duct (see *ASCENT Project 038 Annual Report 2023*). Predictions from this approach showed favorable agreement with experimental data for an isolated ducted rotor (Cuppoletti et al., 2022). This work was further extended to modeling of the EC130 tail rotor (Fenestron®), where the shroud was modeled using a lifting panel in CHARM and noise predictions (see *ASCENT Project 038 Annual Report 2024*). For the EC130 helicopter in out-of-ground-effect hover conditions, predicted sound pressure levels showed good agreement with measured data from the 2017 flight test at several ground microphone locations. The Pegg broadband noise prediction model was also rederived, revealing the foundational equations and a potential pathway for recalibrating the model for different helicopters using flight test data. ASCENT Project 038 also transitioned to using a new version of the noise prediction system developed under ASCENT Project 049. The system was revalidated against flight test data for several helicopters and maneuvers investigated over the years in ASCENT Project 038.

The objective of this continuing project is to reduce the need for flight testing of each rotorcraft of interest for continued development of low-noise operating procedures. Existing guidance in the Fly Neighborly program is based on recommendations from manufacturers, is nonmandatory, and often available for only limited rotorcraft models and design types. Other methods for developing noise abatement procedures at the FAA and NASA are empirical, based on previous flight measurements of specific aircraft. The current project enables analysis of new flight procedures and noise analysis strategies through computations. This year's efforts included further analysis and investigation of the 2017 and 2019 FAA/NASA noise abatement flight tests, development of shrouded rotor noise modeling for rotorcraft models with such features, updating the flight simulator and enhancing couplings, and preparing documentation and training materials to enable the FAA and their partners to use the PSU-NPS.

Task 1 - Shrouded Rotor Noise Modeling

The Pennsylvania State University

Objectives

Prediction of shrouded rotor noise has been a major barrier in predicting noise from helicopters such as the Airbus EC130 (with a Fenestron). The primary objective of this task is to utilize shrouded rotor noise prediction capabilities developed as part of task 38 (ASCENT Annual Report 2022-2023) and test its efficacy against flight test measurements of helicopters equipped with a Fenestron. Modeling techniques and their impact are studied and documented.

Research Approach

The 2017 NASA/FAA flight test (Watts et al., 2019) provided acoustic measurements for the EC130 helicopter in hover and various forward flight maneuvers. The shrouded tail rotor geometry was estimated based on publicly available images, including the uneven blade spacing. CHARM is used to derive airloads for the main and tail rotors along with the shroud. The stators and struts in the Fenestron are not currently modeled in CHARM.

Milestones

- Model EC130 helicopter Fenestron in CHARM and PSU-WOPWOP.
- Evaluate the acoustic impact of unevenly spaced Fenestron blades.
- Predict the noise from Airbus EC-130 aircraft flown in the 2017 FAA/NASA flight test.

Major Accomplishments

A CHARM-based lifting-line and panel representation of the EC130 helicopter rotors was developed (see ASCENT Annual Report 2023 – 2024, Task 1). The model incorporated the estimated uneven blade spacing and an extracted shroud geometry, with the rotor blades represented as flat lifting surfaces using CHARM's vortex lattice method and the shroud represented as a three-dimensional (3D) panel surface (see Figure 1). Comparisons with the 2017 NASA/FAA hover measurements showed agreement within 2 – 4 dB at several microphone locations, demonstrating the model's ability to capture key Fenestron acoustic features.

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Figure 1. CHARM panel representation of EC130 Fenestron helicopter shrouded tail rotor. (as modeled by Sagar Peddanarappagari)

A survey of shrouded-tail-rotor noise studies has provided new guidance for improving the current model. Work from Airbus and ONERA (Office National d'Études et de Recherches Aérospatiales) indicates that rotor–stator aerodynamic interaction is a dominant noise source in hover. You et al. (2016), using Unsteady Reynolds-Averaged Navier-Stokes simulations, demonstrated that rapid, periodic fluctuations in blade loading are driven by stator blockage. This suggests that CHARM's lifting-panel method should be capable of capturing first-order interaction effects once the stator blades and central shaft are included as 3D panel geometry (the present CHARM model includes only the shroud surface).

Fenestron tail rotor noise prediction in forward flight is complicated by flow separation and the increasing importance of acoustic scattering. A significant portion of the thrust needed to counterbalance main rotor torque is provided by lift on the tail rotor fin, requiring lower thrust produced by the Fenestron in forward flight. This has been found to result in significant flow separation around the hub by Gardarein et al. (2006), placing the rotor blades in a highly turbulent inflow. This behavior is also evident in the experimentally measured blade surface pressure data near the tip reported by Gardarein et al. (2010). In addition, Falissard et al. (2011) found that neglecting acoustic scattering by the cylindrical shroud can lead to discrepancies of up to 10 dBA between measured and predicted levels. Accurately modeling these acoustically important phenomena is computationally demanding: capturing separated flow typically requires well-resolved computational fluid dynamics simulations, and acoustic scattering calculations are also prone to issues in numerical convergence (Lee, 2017).

To address such challenges more generally, the Airbus Helicopters MOTUS framework (Guntzer et al., 2025) was developed to leverage flight test data to correct deficiencies in noise prediction. First, a database of de-Dopplerized noise hemispheres from flight tests that span a range of operating conditions is constructed. Filtering the high-frequency broadband noise out, tonal noise from the main and tail rotors are separated at each microphone in the hemisphere. The prediction system is then used to calculate noise at these microphones in the database. The differences between the predicted and measured noise levels for the main and tail rotors are then stored as "masks" Depending on the quality of the experimental data, these masks can be applied as a function of individual frequency bins and microphone locations, a level shift to the integrated sound pressure level that vary with microphone location, or as a uniform shift in levels applied to the entire hemisphere (independent on microphone position).

Publications

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Outreach Efforts

None.

Awards

None.

Student Involvement

Bhaskar Mukherjee, a graduate assistant, completed his PhD degree and conducted a literature review identifying key challenges in Fenestron tail rotor noise modeling, recommending approaches to improve predictions using flight test data. Salma Ibnoukhaiber, an undergraduate research assistant, completed her bachelor's degree and performed work to update and extend a user's manual for the PSU-NPS. Salma also helped prepare example cases and a distribution package for the PSU-NPS. Rupak Chaudhary, a Ph.D. student worked on the project to develop and refine PSU-NPS test cases.

Plans for Next Period

- Explore a semi-empirical approach like the Airbus Helicopters MOTUS framework to avoid the impractical computational expenses associated with modeling Fenestron tail rotor noise. Tools for main and tail rotor tonal noise separation have been developed under ASCENT Project 077 (Rachaprolu & Greenwood, 2024), thus allowing the processing of flight test data measured for EC130 (Watts et. al., 2019) and generation of the hemisphere database.
- Obtain and evaluate the "Masks" for different steady flight conditions while predicting noise during maneuvers.

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Task 2 - Broadband Noise Prediction Enhancement

The Pennsylvania State University

Objective

Helicopter broadband noise has been shown to be important for flight conditions where BVI is absent. The objective of this task (Task 8.2 in the 2023-2024 proposal) is to enhance the existing helicopter broadband noise modeling capabilities of the PSU noise prediction system. The task aims to investigate improvements in physics-based and empirical modeling methods.

Research Approach

Previous work ASCENT Project 038 by Botre (2020) and Zachos (2022) has revealed deficiencies in broadband noise predictions for several helicopters on the order of 6 decibels. However, the prediction methodology largely relied on the empirical Pegg (1979) model. The model calibrated originally from flight test data of medium-weight helicopters offers no path for re-calibration using newly measured flight test data (Watts et al., 2019). Zachos (2022) attempted scaling the Pegg model using an offset determined from flight test data (Watts et al., 2019). While this approach had limited success, it did reveal the potential benefits of re-calibrating the Pegg model. Broadband noise modeling for electric vertical take-off and landing (eVTOL) aircraft in ASCENT Project 049 has largely relied on first principle methods and can also be applied to helicopters.

Milestones

- Explore new methods for scaling Pegg model.
- Incorporate broadband noise prediction methods from ASCENT Project 049.

Major Accomplishments

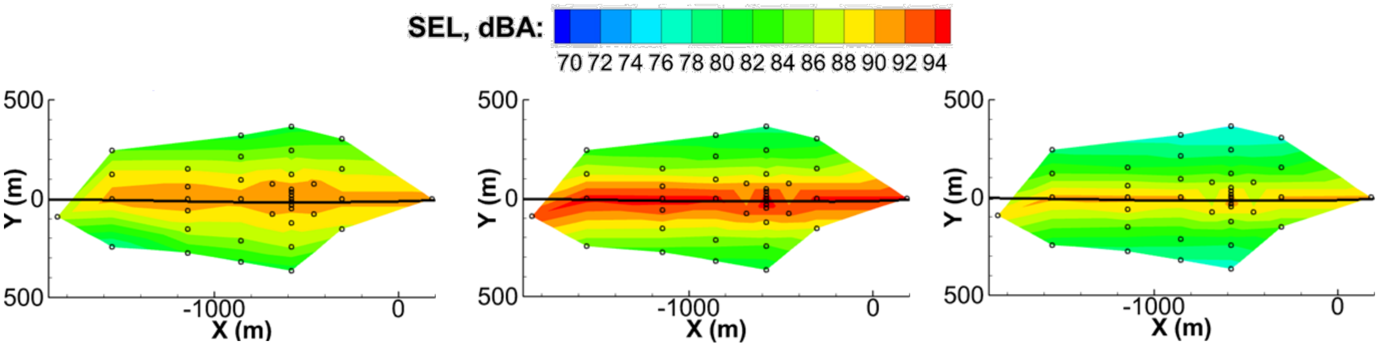
Previous work in ASCENT Project 039 by Botre (2020), Zachos (2022) revealed a trend of broadband noise overprediction by the Pegg model (Pegg, 1979) for several helicopters. During a review of the implementation of the model in PSU-WOPWOP a potentially major source of error was discovered (Mukherjee, 2025). In a discussion on the implementation of the Pegg model in PSU-WOPWOP, Goldman (2012) relates a key input variable, the mean lift coefficient of the rotor ($\bar{C}_L$) with the rotor thrust (T) as follows:

$$\bar{C}_L = \frac{6T}{\rho A_B V_T^2} \qquad \text{(Eq. 1)}$$

Here, ρ is the density of air, A_B is the rotor disk area and V_T is the rotor tip speed. However, this expression is not the same as the definition provided by Hubbard (1953) and Schlegel et al. (1966). These reports were found to be the foundation on which Pegg (1979) derived the semiempirical model (complete derivation can be found in pgs. 168 – 171, Mukherjee, 2025). Instead of the tip speed of the rotor V_T, the original expression for $\bar{C}_L$ used the speed at a distance 0.7*tip-radius ($V_{0.7}$) as follows:

$$\bar{C}_L = \frac{T}{\frac{1}{2}\rho A_B (V_{0.7})^2} = \frac{4.081T}{\rho A_B V_T^2} \qquad \text{(Eq. 2)}$$

Thus, the current implementation of the Pegg model in PSU-WOPWOP was overestimating $\bar{C}_L$ by a factor of ≈ 1.5. This in turn was shown by Mukherjee (2025, pg. 173) to result in an overprediction of 1.67 dBA to 13.39 dBA depending on the value of $\bar{C}_L$. The impact of this was demonstrated by Mukherjee (2025) when evaluating noise predictions of a Bell 206L helicopter in 80 knots level flight against flight test data (Watts et al., 2019). Figure 2 shows the sound exposure level (SEL) contours on a grid of ground microphones from three different datasets: Figure 2a shows the flight test data, Figure 2b shows PSU-WOPWOP predictions based on Goldman (2012) implementation of the Pegg model, while Figure 2c shows PSU-WOPWOP predictions based on the corrected Pegg model by Mukherjee (2025).



(a) Flight test

(b) Pegg implementation (Goldman 2012)

(c) Pegg Corrected (Mukherjee 2025)

Figure 2. Bell 206L 80 knots level flight.
(Flight test data and PSU-WOPWOP input files shared by Dr. Mrunali Botre)

Publications

Mukherjee, B. (2025). *Noise of Multirotor Electric Aircraft* [Doctoral dissertation, The Pennsylvania State University]. The Pennsylvania State University. https://etda.libraries.psu.edu/catalog/22433bxm437

Outreach Efforts

None.

Awards

None.

Student Involvement

Bhaskar Mukherjee, a graduate assistant, completed his PhD degree and documented the derivation of the Pegg model, identified and corrected a major source of overprediction by the Pegg model's implementation in PSU-WOPWOP.

Plans for Next Period

- Complete further testing of this correction to the implementation of the Pegg model in PSU-WOPWOP by evaluating noise from additional helicopter maneuvers previously documented to have overpredictions. Once confirmed, the correction will be included in a new release of PSU-WOPWOP to its users in industry, government and academia.

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Task 3 - PSUDEPSIM Aircraft Model Updates

The Pennsylvania State University

Objective

Since the transition from the old noise prediction system based on the Helosim flight simulation code (Botre, 2020), helicopter input files need to be adapted for the newly developed PSUDEPSim (Theron et al., 2020). The objective of this task is to transfer input files for helicopters from the old system and validate it with the new noise prediction system (also used in ASCENT Project 049).

Research Approach

Parameters representing the geometry, aerodynamics and dynamics of the helicopter are required for fully coupled flight simulation. Using previously documented values (Botre, 2020), new input files are to be generated based on the format in the DEPSim manual (Theron et al., 2022). Flight test trajectories are simulated using the new system, and noise results validated.

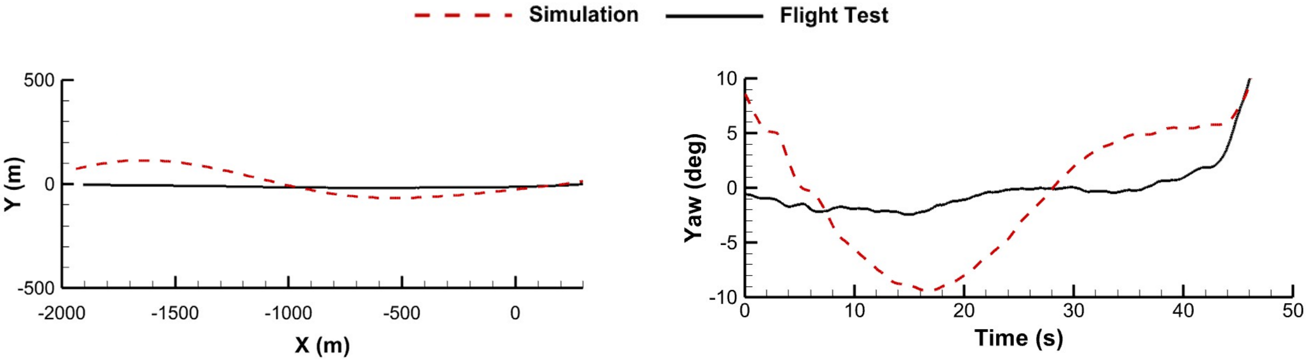
Milestones

- Generate new helicopter input files for PSUDEPSim.
- Validate noise from maneuvers from various helicopter models against measured flight test data.

Major Accomplishments

The Helosim and DEPSim flight simulation codes share very similar helicopter input file formats, both requiring the same set of parameters defining the geometry, mass, and inertia of the blades and aircraft. This allows the following helicopter models to be imported from Helosim into DEPSim with minimal changes: Robinson R44 and R66, Bell 206 and 407, and Airbus AS350. However, unlike Helosim, DEPSim is not limited to helicopters only and therefore uses a different set of input parameters for the flight controller. As a result, default values for several of these parameters are initially used for all helicopter models.

Using these default values, however, appears to result in inaccurate simulations of a given flight condition. For example, Figure 3a shows the X–Y trajectory of a Bell 206L helicopter in 80-knot level flight (+X being the direction of flight). Two datasets are plotted: flight test data (Watts et al., 2019) and DEPSim simulation results. Figure 3a, which uses the default controller input parameters, shows a trajectory deviation of nearly 100 m (≈330 ft) along the Y direction. This indicates that the trajectory-following controller has larger error in tracking the aircraft yaw angle, which is corroborated by Figure 3b.

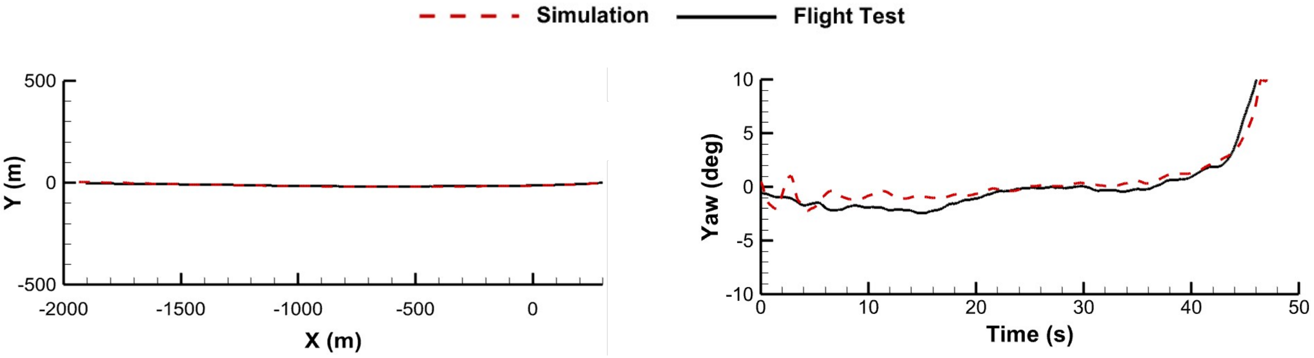


(a) Trajectory (top-view)

(b) Yaw angle

Figure 3. Trajectory tracking error in DEPSim simulation: Bell 206L, 80kts level flight.

Two issues can be observed in Figure 3b: (1) the values oscillate, and (2) they overshoot. These issues are resolved by adjusting the values of the controller damping ratio and bandwidth, which affect the magnitude of oscillations and the command response time, respectively. Adjusting these parameters leads to a significant improvement in trajectory tracking, as shown in Figure 4, where the yaw angle can now be observed to track the flight test data much more accurately.

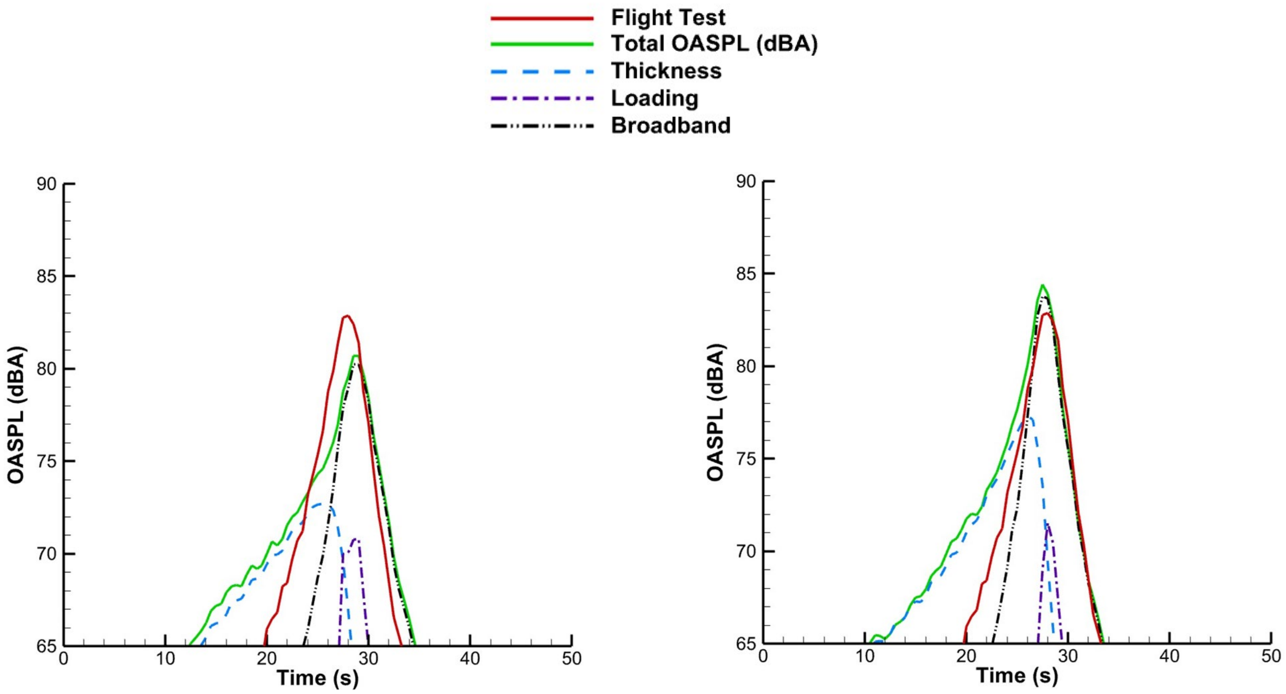


(a) Trajectory (top-view)

(b) Yaw angle

Figure 4. DEPSim simulation with tuned trajectory following controller: Bell 206L, 80kts level flight.

The impact of accurately tracking flight test data on predicted noise can be seen in Figure 5, where the variation of integrated sound pressure level (A-weighted) with time is plotted for a microphone situated right below the trajectory of the helicopter. The peak level and a 10 dBA drop is captured well once the flight control parameters are tuned (Figure 5b), thus capturing the SEL more accurately. Note that the initial overprediction is currently hypothesized to be a result of acoustic shielding by the fuselage that is not captured in the predictions.



(a) Before tuning

(b) After tuning

Figure 5. Bell 206 at 80kts level flight: Comparison of measured and predicted (Before & After tuning) A-weighted overall sound pressure level (dBA) vs. time (mic below helicopter flight trajectory)

Publications

None.

Outreach Efforts

None.

Awards

None.

Student Involvement

Salma Ibnoukhaiber, a first-year master's student in Aerospace Engineering, is working on tuning helicopter models in DEPSim and improving simulation match with flight test data.

Plans for Next Period

- Continue to improve the trajectory tracking for the Robinson R44 and R66, along with documenting the procedures used to achieve these improvements in the noise prediction system manual. The 2023–2024 ASCENT Annual Report demonstrated that the AS350 and Bell 407 helicopters could be simulated in DEPSim with acceptable accuracy. After updating the input parameters for the trajectory-following controller, the Bell 206L is now also being simulated successfully.

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Task 4 - Application of Noise Prediction Enhancements to Abatement Procedure Analysis

The Pennsylvania State University

Objective

The objective of this task is to design, test and demonstrate helicopter noise abatement procedures using the new and improved Penn State noise prediction system.

Research Approach

While previous work has demonstrated the ability of the new noise prediction system to predict noise from steady flight conditions such as hover, level flight, the system also needs to be validated against flight test data for maneuvers such as turns. Differences between predicted noise levels and measured need to be understood before using the system to generate new trajectories for noise abatement procedures.

Milestones

- Validate against maneuvers such as turns, accelerating climb etc.
- Demonstrate accuracy of the system in capturing important acoustic events such as blade vortex interactions (BVI), etc.

Major Accomplishments

It is crucial to have a robust and accurate noise prediction system in place before work on designing abatement procedures begins. A long-standing issue of broadband noise overprediction by the Pegg model was corrected as part of Task 2. With the introduction of a new trajectory-following controller in PSUDEPSim, input parameters are now being updated to improve agreement with flight test data (Task 3). The previous version of the noise prediction system, based on PSUHeloSim, successfully simulated the following aircraft: Airbus AS350 and EC130, Bell 206 and 407, Robinson R44 and R66, and Sikorsky S76D. To date, the AS350 and Bell 206 models have been successfully exported to PSUDEPSim and validated within the new noise prediction system.

In parallel, a literature review was conducted to expand the scope of this task for next year by incorporating considerations of safety and pilot workload in abatement procedure design. Existing guidance for avoiding BVI during arrival maneuvers often involves steep, decelerating descents that can require high pilot workload, particularly under tailwind conditions (Rapoza et al., 2019). PSUDEPSim provides several simulation output parameters that can support preliminary assessment of maneuver safety and workload. For example, rotor torques can be compared against model-specific limits to assess the safety margin. Actuator response can be used to assess the control authority, while rate of stick activity can be used to estimate pilot workload.

Publications
None.

Outreach Efforts
None.

Awards
None.

Student Involvement
Bhaskar Mukherjee, a graduate assistant, completed his PhD degree and coordinated improvements to the noise prediction system and identify flight simulation parameters that can be used to assess maneuver safety and pilot workload to enable development of more acceptable noise abatement procedures.

Plans for Next Period
- Formalize the processing of PSUDEPSim flight simulation output parameters for maneuvers to provide more quantitative insight into flight safety and pilot workload.
- Simulate the arrival and departure procedures from the 2017 FAA/NASA flight test with the new system and analyze the derived safety parameters.

References
Rapoza, A. S., Page, J. A. & Jacobs, E. (2019*). iFlyQuiet Procedures Demonstration: Application of Fly Neighborly Procedures in East Hampton, NY*. U.S. Department of Transportation, John A. Volpe National Transportation Systems Center. https://rosap.ntl.bts.gov

Task 5 - Update PSU-NPS Documentation and Sample Cases
The Pennsylvania State University

Objective
The objective of the current task is to generate updated documentation of the noise prediction system, including user instructions and best practices. A user manual will be distributed to FAA, Volpe, and the FAA Technical Center along with the system for beta testing.

Research Approach

A user manual with instructions on compilation, installation and usage of the system will be documented first. The manual will also contain a brief description of the theoretical background of the components of the noise prediction system. Validation cases will be provided along with a list of best user practices. Based upon the feedback received from beta testers at Penn State and partners at FAA, the manual and the system will be updated accordingly.

Milestones

- Document installation and setup of DEPSim, CHARM, and PSU-WOPWOP including the coupling.
- Describe the file structure of the input files including a list of parameters required to simulate new helicopters.
- Identify validation cases and include necessary input files for users to test the system.

Major Accomplishments

Significant progress was made this year toward finalizing the documentation and sample case materials for the PSU-NPS. The PSU-NPS manual is now nearing completion and will be delivered with the system distribution package. It serves as a comprehensive user guide for operating the modular, physics-based framework developed to simulate rotorcraft flight dynamics and predict acoustic emissions. Across eight chapters, the manual provides structured step-by-step guidance on system configuration, execution, and interpretation of results, enabling users to reliably set up simulations and understand the underlying physical modeling. The table of contents of the PSU-NPS manual is shown in Figure 6.

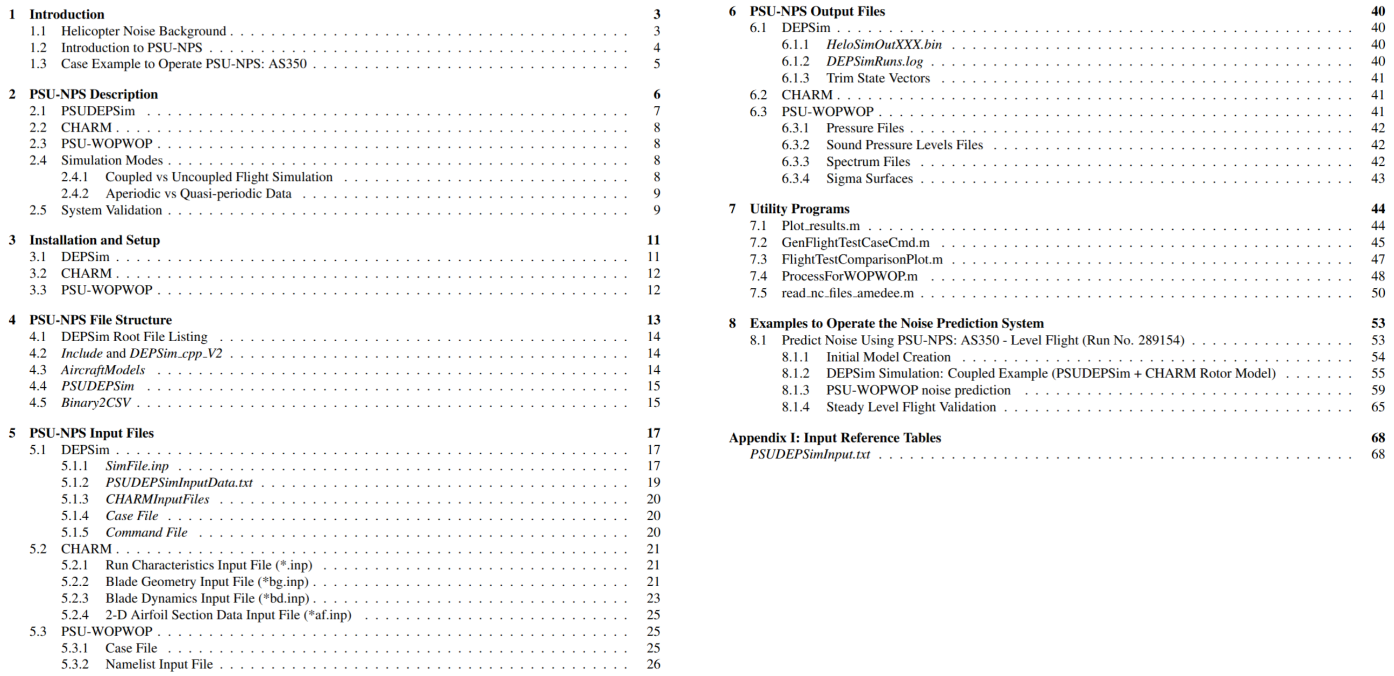

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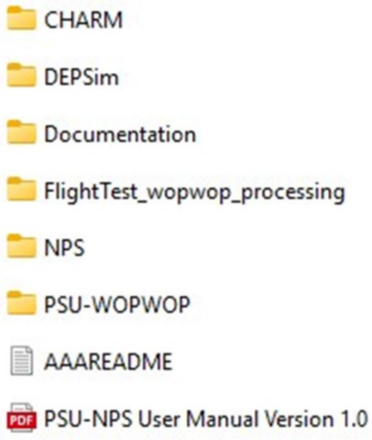
Figure 6. PSU-Noise Prediction System Manual: Table of Contents.

The manual covers both introductory and technical elements necessary for effective use of the system. It begins with background information on helicopter noise theory and introduces the AS350 maneuver example, which is used throughout the document to demonstrate the practical use of the system. Later chapters describe the main components of PSU-NPS and explain how simulation setup choices, such as selecting coupled versus uncoupled modes, or using aperiodic versus quasi-periodic data, which can influence prediction accuracy. The manual also provides instructions for installation and setup, outlines the directory structure for DEPSim and CHARM, and presents detailed explanations of all required input files, including parameter definitions and their physical meaning. Guidance on output files, available MATLAB visualization tools, and step-by-step operation examples such as the AS350 80 kts level-flight case and planned additions including the

Bell 206L and R44 examples—are also included. Instructions for using sigma-surface visualizations to support debugging of blade motion, loads, and thickness will be added as well.

In parallel with the manual, the PSU-NPS distribution package (Figure 7) has been assembled and is nearing readiness for distribution, pending final verification of all executables. The package includes the full NPS manual, a readme file describing the directory structure, and six major folders. Three folders—DEPSim, CHARM, and PSUWOPWOP—contain the system executables and example input/output files for the AS350 80-kt level-flight case, serving as baseline reference cases for validation. A documentation folder consolidates all manuals, including those for each individual code. The NPS folder contains the aircraft models (AS350, Bell 206L, Bell 407, R44, R66), case and command files, CHARM and DEPSim input files, simulation files, MATLAB analysis scripts, and an NPS_Run_Results directory where simulation outputs will be stored. The sixth folder, FlightTest_wopwop_processing, includes the executables and MATLAB scripts used to process flight-test data through WOPWOP, with CHARM serving as the tool for generating the corresponding WOPWOP input files.



CHARM
DEPSim
Documentation
FlightTest_wopwop_processing
NPS
PSU-WOPWOP
AAAREADME
PSU-NPS User Manual Version 1.0

Figure 7. PSU-Noise Prediction System Package.

Publications

None.

Outreach Efforts

None.

Awards

None.

Student Involvement

Salma Ibnoukhaiber, a first-year master's student in Aerospace Engineering, has been working on developing the user manual and packaging the noise prediction system for distribution to users in the government and industry.

Plans for Next Period

- Formalize processing of PSUDEPSim flight simulation output parameters for maneuvers to provide more quantitative insight into flight safety and pilot workload.
- Simulate arrival and departure procedures from the 2017 FAA/NASA flight test with the new system and analyze the derived safety parameters.

References

None.