# 2025 Sessions

Sheng, C., and Zhao, Q., "Hybrid RANS-LES Simulation for HVAB Rotor in Hover and Descent Flight," AIAA 2025-1843, 63rd AIAA Aerospace Sciences Meeting, Orlando, FL, January 6-10, 2025

> This study presents computational simulations of a Hover Validation and Acoustic Baseline rotor, analyzing its performance in both hover and ground effect conditions. A global hybrid simulation approach is employed, integrating the Reynolds-Averaged Navier-Stokes (RANS) turbulence model with a Large Eddy Simulation (LES) subgrid model to enhance turbulence predictions. Three key elements of this hybrid simulation strategy are highlighted: the selection of a blending method for the RANS and LES models, a high-order numerical scheme, and multibody relative grid motion and deformation to facilitate the simulation of an installed rotor. These techniques enable detailed and flexible rotor blade motions, accommodating the complex geometries and flow dynamics of rotorcraft in various flight condition.

Ku, M., Sankar, L., and Patil, M., "Aeroelastic Simulations of the HVAB Rotor in Hover Using a Hybrid Navier-Stokes/Free Wake Analysis," AIAA 2025-1845**,** 6**3rd** AIAA Aerospace Sciences Meeting, Orlando, FL, January **6**-1**0**, 202**5**

> Navier-Stokes analyses have been performed for a 66.5" radius, four bladed, Mach-scaled Hover Validation and Acoustic Baseline (HVAB) rotor. A hybrid Navier-Stokes/free wake approach is used to reduce the computational cost of the resolution of the vortex wake far below the rotor. Rigid rotors as well as deformed rotors with measured torsional deformations from test data have been considered. Good agreement with surface pressure data, radial loading, and integrated hub loads have been obtained at the three collective pitch settings considered for the elastically deformed rotor, although further improvements in the grid resolution and vortex wake resolution are likely necessary for a more accurate resolution in the tip region. The computed sectional lift and moments were used in a Euler-Bernoulli beam analysis for estimating the torsional deformations. The computed deformations were within 1 degree of the measured deformations.

Abras, J., and Hariharan, N., "Temporal Analysis of HVAB Hovering Rotor Simulations Using HPCMP CREATE™-AV Helios," AIAA 2025-1844**,** 6**3rd** AIAA Aerospace Sciences Meeting, Orlando, FL, January **6**-1**0**, 202**5**

> The isolated hovering rotor, with constant rotational speed in a no-wind environment, creates complex aerodynamic challenges. It generates a helical wake that remains close to the rotor and features unsteady behaviors like tip vortex pairing and wake breakdown, disrupting axisymmetry. This proximity intensifies the wake's influence on rotor loads, making detailed analysis crucial for understanding rotor aerodynamics in hover. However, extracting high-resolution wake details is labor-intensive, traditionally requiring extensive manual post-processing. This study introduces an automated, in-simulation method to extract vortex core properties as a time-accurate data component, significantly extending analysis durations and refining the accuracy of vortex core data. Using the HVAB rotor in hover, we validate this method by comparing automated data with experimental results, analyzing vortex trajectory, core strength, and frequency content in blade loads. Our approach offers an efficient, scalable solution for extracting and correlating complex wake physics with rotor aerodynamic loads, marking an advancement in the autonomous analysis of rotor hover dynamics.

Ozturk, I., and Sezer-Uzol, N., "Aerodynamic Investigation of Hover Using Vortex Ring Wake Model and Free Vortex Wake Model," AIAA 2025-2027**,** 6**3rd** AIAA Aerospace Sciences Meeting, Orlando, FL, January **6**-1**0**, 202**5**

> Modeling rotor inflow and wake dynamics is fundamental to understanding and improving rotorcraft performance. Especially, hover modeling plays an important role in aircraft design, aerodynamic assessments, and the development of control systems for helicopters and eVTOLs. To investigate the complexity of rotor

aerodynamics, various methodologies with different levels of fidelity can be utilized, ranging from Blade Element Momentum Theory (BEMT) to high-fidelity Computational Fluid Dynamics (CFD). In this study, AeroROTOR, a fast in-house C code developed for rotor aerodynamics, is used to investigate the hover condition. AeroROTOR consists of two rotor wake analysis models: the Vortex Ring Wake (VRW) model and the Free Vortex Wake (FVW) model, coupled with the Blade Element Theory (BET). Rotor simulations with these wake models provide detailed investigations of the wake dynamics and blade aerodynamic forces. The HVAB rotor is used as a validation case and the free wake analyses are performed to investigate the hover condition and assess the capabilities of the wake analysis models by comparing the results for the rotor aerodynamic loads and wake characteristics with the experimental data.

Duan, Z., and Wang, Z., "High-Order Wall-Modeled Large Eddy Simulation of Benchmarks from the Hover Prediction Workshop," AIAA 2025-2023**,** 6**3rd** AIAA Aerospace Sciences Meeting, Orlando, FL, January **6**-1**0**, 202**5**

> In the present study, a high-order wall-modeled large eddy simulation (WMLES) tool called hpMusic is extended to handle dynamic moving grids and employed to tackle a benchmark problem from the AIAA Hover Prediction Workshop (HPW), flow over the HVAB Rotor. A p-refinement study is performed to assess the sensitivity of the computational results with respect to different solution polynomial orders, p = 3 and 4, called p3 and p4 simulations. In addition, the computational results are compared to other simulations in the literature and experimental data when possible to further verify and validate the present simulation methodology. The p4 simulations indeed captured more turbulent scales than the p3 simulations, and the computed figure of merit with p4 also agreed better with experimental data.

Zuber, D., Larsson, J., Brehm, C., McQuaid, J., van Noordt, W., Min, B.Y., and Wake, B., "Wall-Modeled Large Eddy Simulation Using the Immersed Boundary Method of the HVAB Rotor," AIAA 2025-2024**,** 6**3rd** AIAA Aerospace Sciences Meeting, Orlando, FL, January **6**-1**0**, 202**5**

> Immersed boundary methods have historically been used for low-Reynolds-number flows or scenarios where near-wall viscous effects are less significant. However, recent research has shown that, when combined with wall-modeled large eddy simulations, these methods offer a robust solution for high-Reynolds-number flows. This work presents a WMLES-IBM solver framework within the Cartesian Higher-Order Adaptive Multi-Physics Solver for GPUs (CHAMPS+) to leverage the computational power of GPU architectures to provide higher fidelity solutions for rotorcraft problems. The CHAMPS+ WMLES-IBM solver is validated on the NASA Hover Validation and Acoustic Baseline (HVAB) rotor test case for a range of collective pitch angles, showing good agreement on overall rotor performance, blade pressure distributions and blade loadings against the US Air Force National Full-Scale Aerodynamics Complex (NFAC) test campaign. CHAMPS+ is capable of producing high fidelity solutions with minimal GPU resources at time scales that are useful for design level analysis.

Shankar, S., Polepeddi, V., Rajan, P., Desai, S., and Vu, H., "Numerical Studies of the Hover Validation and Baseline Rotor," AIAA 2025-2025**,** 6**3rd** AIAA Aerospace Sciences Meeting, Orlando, FL, January **6**-1**0**, 202**5**

> With the advent of Advanced Air Mobility (AAM), more and more novel aircraft designs employ the use of propellers or rotors for vertical lift as well as forward flight. As a result, accurate and low-cost propeller simulation capabilities are the need of the hour. This paper explores four different approaches available to model propellers and rotors in the commercially available computational fluid dynamics (CFD) software, Ansys Fluent. As part of a validation and best practice development exercise, "Step 1" of the hover prediction challenge for the HVAB Rotor as described in the AIAA Hover Prediction Workshop (HPW), is utilized for both the isolated and installed rotor cases. Rotor performance metrics made available from experiments are compared with those obtained from the CFD solver to validate the solver and infer some best practices, accuracy, and limitations of each of these modeling approaches. All approaches provide reasonable predictions

of the isolated rotor thrust and power. The Virtual Blade Model (VBM) model and transient time-accurate computations agree closely with each other, while the Multiple Reference Frame (MRF) approach underpredicts thrust and torque coefficients. The results are in line with expectations and previous studies since the blades are modeled as rigid. The installed rotor results illustrate the effect of thrust augmentation due to rotor downwash on the fuselage. These results are in line with literature for the download as a percentage of download, while some discrepancies exist for augmented thrust as a percentage of download.

Min, B.Y., Wake, B., and Lorber P., "Turbulent Transition Impact to Production Design Model- and Full-Scale Hovering Rotor Performance," AIAA 2025-1846**,** 6**3**rd AIAA Aerospace Sciences Meeting, Orlando, FL, January **6**-1**0**, 202**5**

Impact of laminar-turbulent flow transition to hovering rotor performance is assessed using both model- and full-scale rotors. Helios is used for all simulations using OVERFLOW as a near-body solver. The Langtry-Mentor transition model is validated against Hover Validation and Acoustic Baseline (HVAB) rotor test data using industry best practice modeling approach. The same modeling approach is validated with model-scale production design rotor to assess its applicability to different blade design including different airfoils, twist, and planform shape. The validated modeling approach is then used for full-scale rotor to assess impact of transition for high Reynolds-number full-scale rotor performance. The full-scale rotor performance is also compared with whirl-tower test data. For all three rotors, rotor figure of merit is compared for range of thrust against test data. Transition locations and blade loading distributions are also compared. Sensitivity studies were also performed including facility impact, control system stiffness effect, and wind impact. The current transition modeling approach showed very good correlation with both model-scale test data in integrated figure of merit. However, differences with test data were observed in detailed blade loading and surface suction pressure at outboard region where blade-vortex interaction occurs. The full-scale rotor simulation also showed reasonably good correlation in performance but with simulation results being slightly optimistic in both fully turbulent and transition model, with transition model being little more optimistic. The laminar-turbulent flow transition trend from model- to full-scale seems reasonable, although, with more uncertainties in the full-scale test results, it was hard to determine quantitative transition model impact validation. Findings from current study is used to guide future hover performance simulations, and to understand model- and full-scale rotor performance difference.

Healy, R., Anusonti-Inthra, P., and Beals, N., "Neural Network Modeling of Airfoil Aerodynamics for Rotorcraft Analysis," AIAA 2025-0270**,** 6**3**rd AIAA Aerospace Sciences Meeting, Orlando, FL, January **6**-1**0**, 202**5**

Rotorcraft performance analysis is commonly performed using blade element theory (BET) which requires airfoil coefficient lookup tables. Often, experimental airfoil data for the blade of interest is unavailable, and so it must be generated using other means (e.g. panel methods or computational fluid dynamics (CFD)). Airfoil surrogate models offer a fast alternative to custom CFD-generated data, where tables can be generated in seconds rather than hours or days. In this work, the effectiveness of surrogate modeling for BET airfoil table generation is investigated. A neural network model is trained on over 600,000 CFD simulations of UIUC airfoils, and it is found that for this dataset, a model with direct Cl, Cd, and Cm outputs outperforms one in which these outputs are parameterized using proper orthogonal decomposition (POD). Furthermore, a novel application of airfoil shape interpolation is used to synthesize 898 realistic airfoil shapes and it is found that adding the associated training data significantly improves model accuracy, particularly for Cm predictions. The resulting model shows good agreement with the validation dataset, and is able to predict Cl, Cd, and Cm to within 5% error (for 80% of the validation airfoils). This model is used to generate C81 tables for an S76 RCAS model in hover, and the predicted thrust and power are within 2.2% and 3.8% of thrust and power results generated using CFD-derived C81 tables. Therefore, this airfoil surrogate model can be used to generate CFD-quality C81 tables for novel blades with a wide range of airfoil shapes, with minimal loss in accuracy and at a fraction of the computational cost (2,000,000X faster) compared to traditional table generation methods.