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NUMERICAL ANAYSIS OF BOUNDARY LAYER INJESTION FOR ELECTRIFIED AFT-FUSELAGE PROPULSION

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INTRODUCTION & AIM

The rapid growth of the aviation industry, along with increasing environmental concerns and stricter emission regulations, has led to a strong push toward more efficient aircraft designs. In recent years, the focus has shifted from purely aerodynamic improvements to more integrated approaches that consider both airframe and propulsion system together. In this context, *Boundary Layer Ingestion (BLI)*, has emerged as a promising concept where the aft-propulsor ingests the low-momentum boundary layer flow over the aircraft, enabling partial recovery of the wake energy and improved propulsive efficiency.

This study aims to numerically investigate an aft-fuselage BLI configuration and quantify its impact on aerodynamic performance and propulsive efficiency across multiple flight conditions.

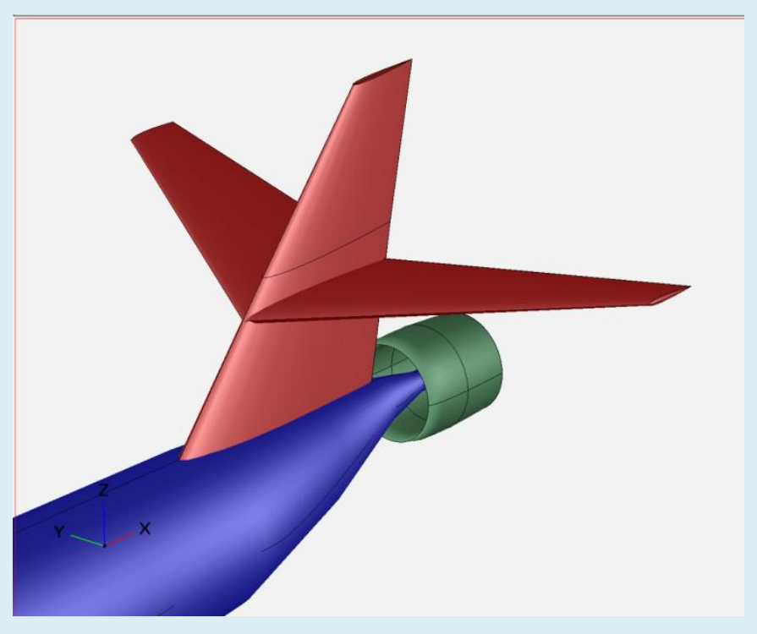

Figure 1. Aft-fuselage BLI geometry

Despite significant interest in BLI, existing studies primarily focus on cruise conditions; there is limited comparative analysis that separates the effects of geometric modifications from propulsion integration, along with a lack of consistent evaluation across different flight phases. Furthermore, the relationship between wake momentum recovery and propulsive power savings remains insufficiently quantified.

This study addresses these gaps by performing a CFD analysis to evaluate BLI performance across configurations and operating conditions.

METHOD

Approach:

Numerical analysis using CFD (ANSYS Fluent)

Three configurations developed:

- ➢ Reference (baseline)
- ➢ Cruciform tail (to isolate geometry effects)
- ➢ BLI configuration (0% and 20% thrust)

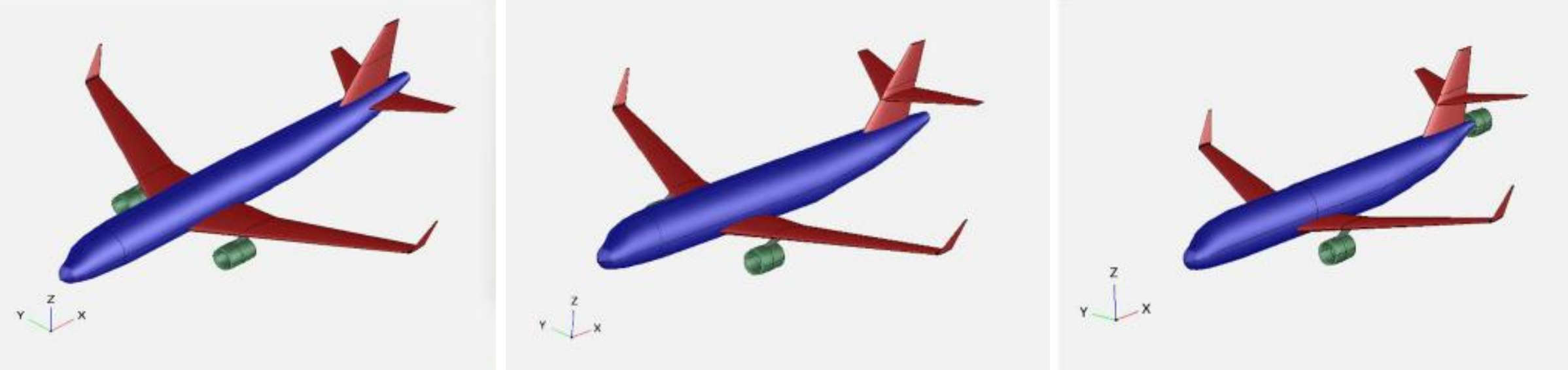

Figure 2. Baseline (left), Cruciform (middle), and BLI geometry (right)

Geometry:

- Simplified narrow-body aircraft based on A320 (Narrow-body aircraft dominate global aviation, comprising over 60% of the active fleet, with Airbus and Boeing accounting for nearly 80% of aircraft in service *(IATA, Global Commercial Aircraft Fleet Report, 2025)*
- Developed parametrically in OpenVSP

Meshing

- Unstructured mesh with Body of Influence (BOI) refinement
- Inflation layers (0.001 m) for boundary layer resolution
- Final mesh: ~8 million cells
- Mesh independence verified using drag coefficient (C_n)
- Average $Y^+ \approx 70–90$
- Switched from k–ω SST to Spalart–Allmaras turbulence model due to higher than recommended Y^+

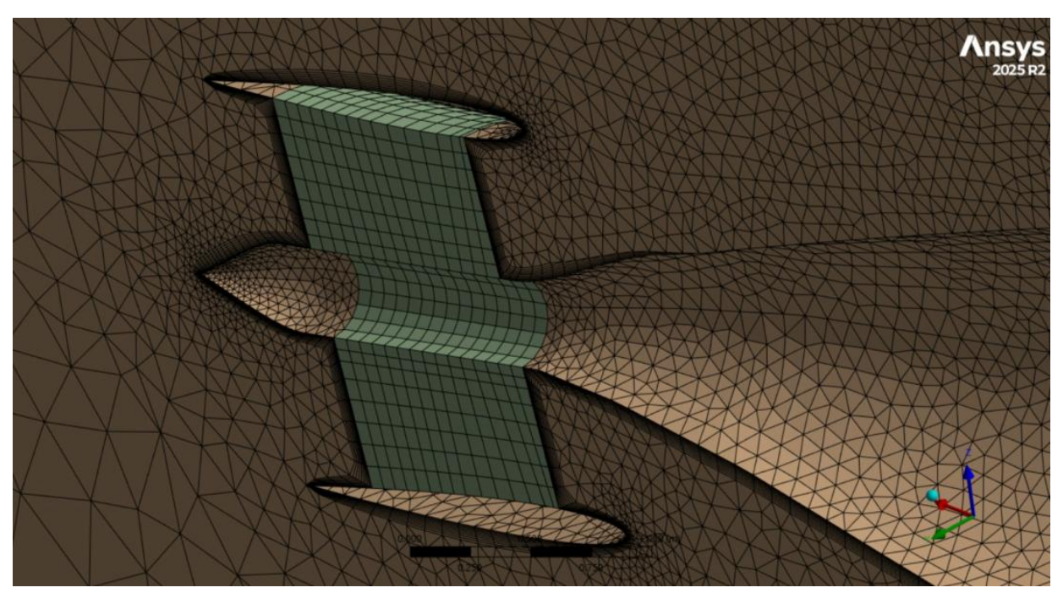

Figure 3. Engine Sub-Domain connected to primary fluid domain

Solver Setup and Propulsion Modelling

- Steady compressible flow, air modeled as ideal gas (Sutherland's Viscosity), ISA conditions (cruise ~11 km)
- Thrust added per unit volume in specific cell zone conditions (simplified engine)

RESULTS & DISCUSSION

Reference Geometry Performance:

- Direct validation is limited due to proprietary A320 data
- Approximate validation at cruise using: L/D ≈ 16; Lift=Weight ≈ 700 kN→ Estimated drag ≈ 35 kN
- CFD model predicts higher drag:≈ 55 kN (Difference attributed to: 1. Simplified geometry, 2. Unoptimized wing design)

Effect of Cruciform tail and BLI (0% Thrust):

- Cruciform and passive BLI (0% thrust) configurations were analyzed to isolate the effect of geometry alone
- Both cases show: Increase in drag, Reduction in aerodynamic efficiency (L/D)
- Geometric modification alone does not improve performance

Effect of BLI (20% Thrust):

- Reduction in drag and improvement in L/D
- Indicates effective wake momentum recovery

Power Saving Coefficient (PSC):

Originally introduced by Smith in early BLI analyses, the Power Saving Coefficient (PSC) serves as a standard metric for quantifying propulsion power savings in boundary layer ingestion systems.

- Cruise PSC ≈ 14–15% (ideal)
- Realistic PSC ≈ 7–10% (accounts for electrical transmission losses, fan distortion
- and efficiency)

Flight Phase	Takeoff	Climb	Cruise	Descent	Landing
Total Thrust	240000	200000	55000	30000	40000
Change in Cd	-1.85	-0.73	-3.2	-1.4	0.52
Change in L/D	4.36	1.31	1.71	2.54	-2.22
PSC	4.85	13.96	14.29	12.72	5.04

Table 1. Comparison of Thrust, Drag Coefficient (Cd), Lift-to-Drag Ratio (L/D), and PSC across Flight Phases

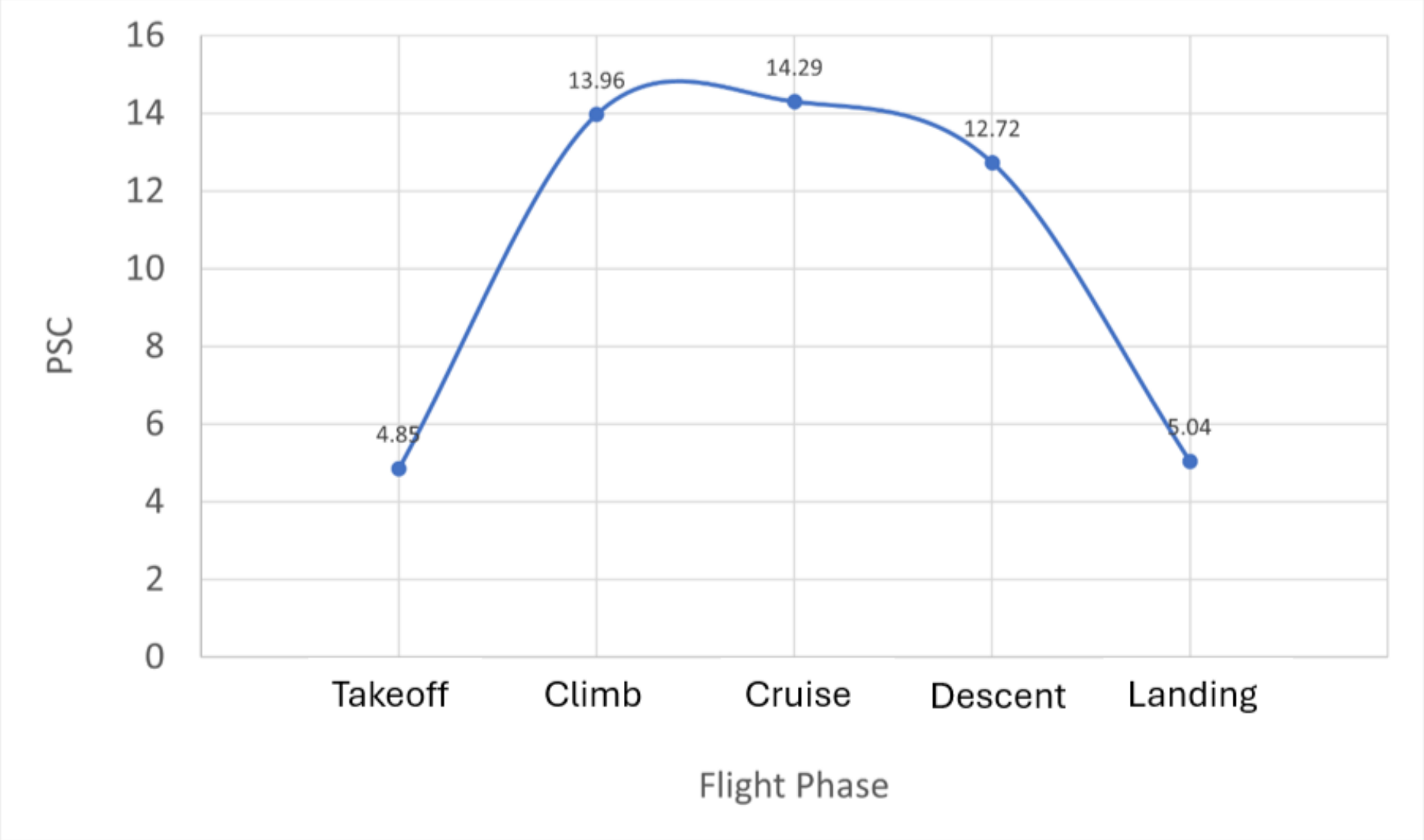

Figure 4. Variation of Power Saving Coefficient across Flight Phases

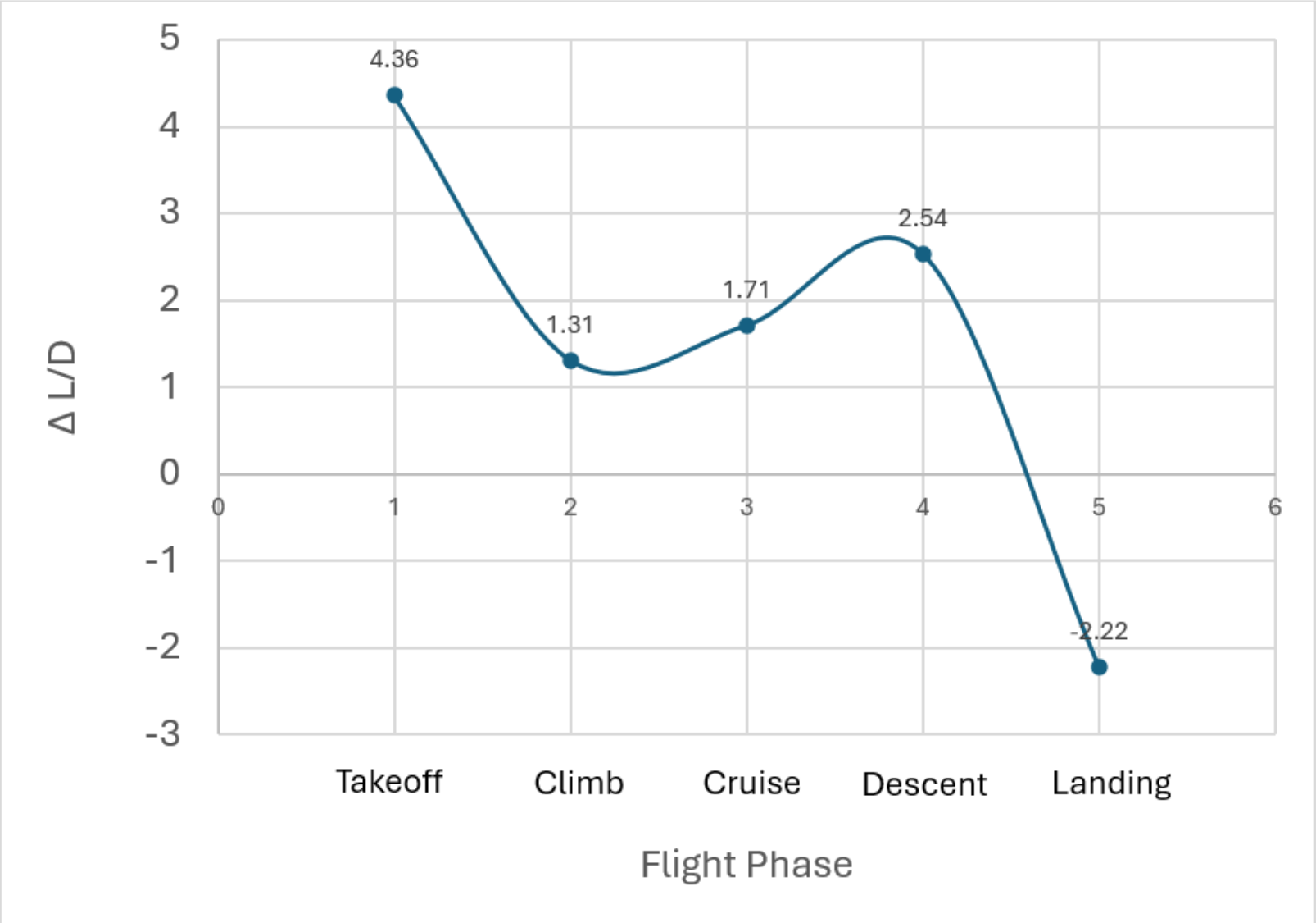

Figure 5. Variation of Lift-to-Drag ratio across Flight Phases

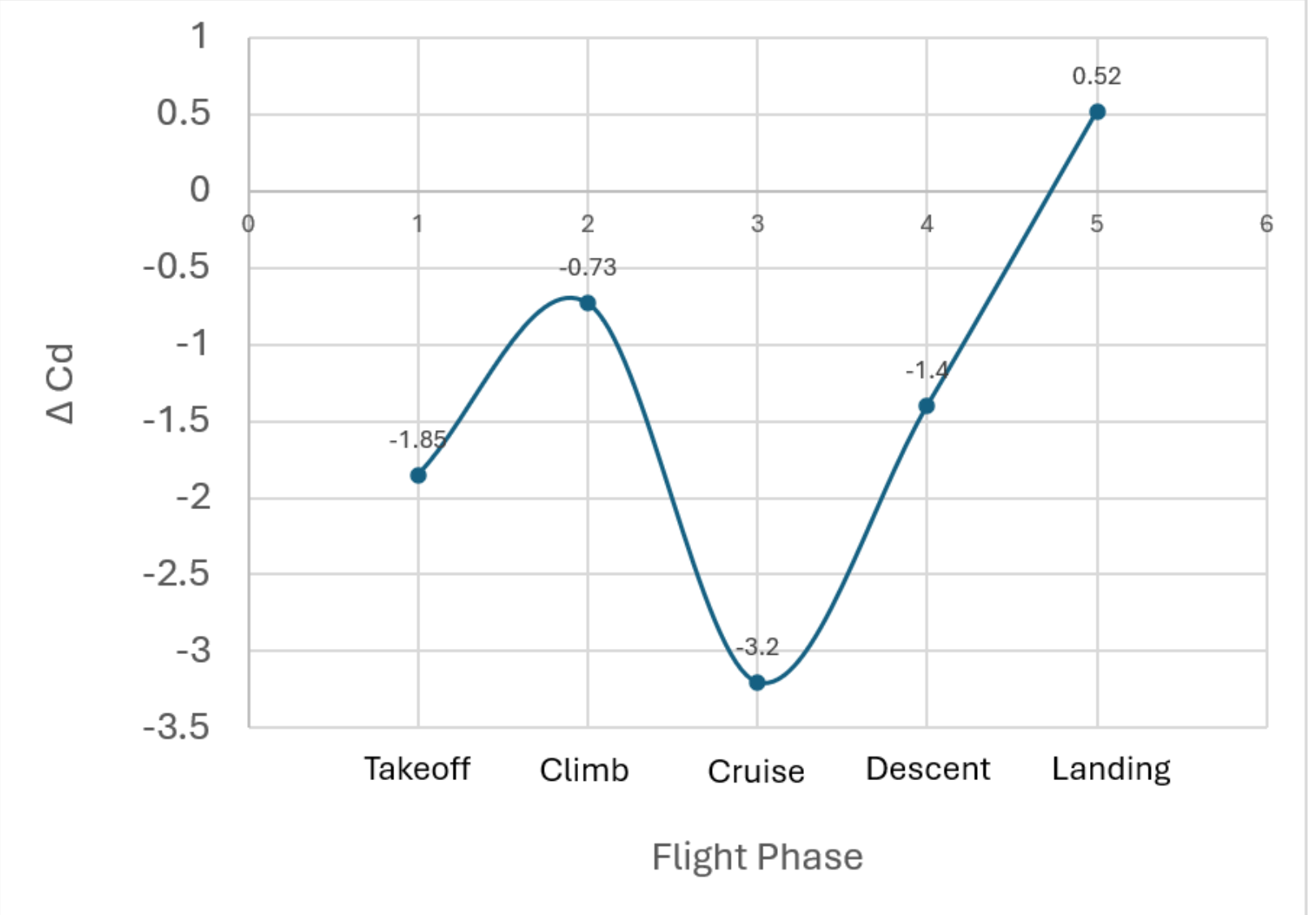

Figure 6. Variation of Drag Coefficient across Flight Phases

Key Observations:

- PSC is highest in cruise, climb, and descent
- Lower PSC in takeoff and landing possibly signifying higher dependence on Angle of Attack (AoA)
- Cd and L/D variations seem to be influenced by thrust and atmospheric conditions

CONCLUSIONS

- ➢ Active BLI demonstrates reduction in drag and improvement in aerodynamic efficiency
- ➢ Maximum PSC observed in steady flight phases (cruise, climb, descent)
- ➢ Lower PSC in takeoff and landing highlights influence of AoA and operating conditions
- ➢ BLI proves effective as a propulsion–airframe integration strategy for improving efficiency

Even with a simplified and non-optimized geometry, the BLI configuration demonstrates measurable performance improvements, highlighting its potential when the thrust distribution between main engines and the BLI propulsor is tuned for each flight phase.

FUTURE WORK/REFERENCES/ACKNOWLEDGMENT

Future work will focus on simulations across additional flight conditions with varying thrust distributions, along with refined meshing to enable usage of the k–ω SST turbulence model as well as study inlet distortion.

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REFERENCES

[1] N. G. M. Moirou, D. S. Sanders, and P. Laskaridis, "Advancements and prospects of boundary layer ingestion propulsion concepts," *Progress in Aerospace Sciences*, vol. 143, p. 102257, 2023.

[2] International Air Transport Association (IATA), 2025 https://www.iata.org/en/publications/economics/reports/the-global-commercial-aircraft-fleet/

[3] L.H. Smith Jr., Wake ingestion propulsion benefit, J. Propuls. Power 9 (1)(1993) 74–82.

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