Validation of a Mid-Fidelity Approach for Aircraft Stability and Control Characterization

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Contents

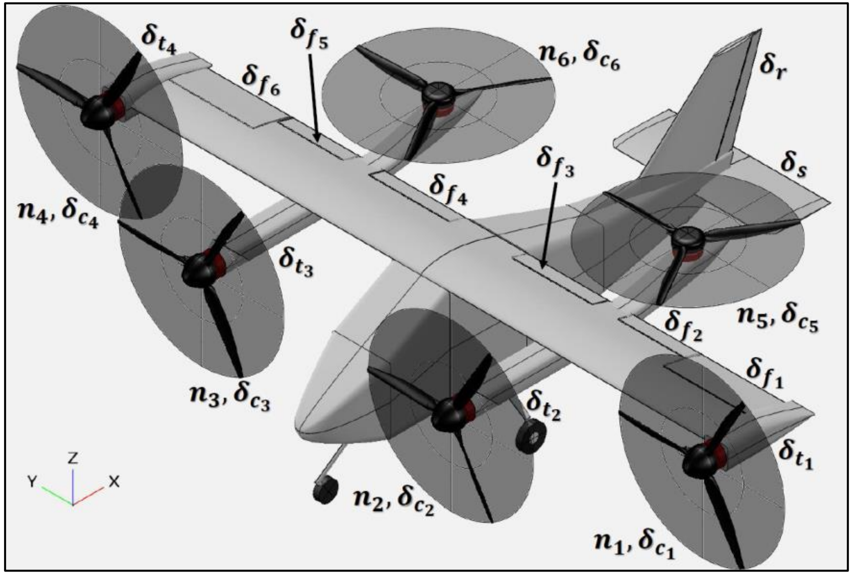
Research Motivation

- Electric vertical takeoff and landing (eVTOL) aircraft configurations
- Future Advanced Air Mobility (AAM) transportation system
- CFD and wind-tunnel testing are resource intensive
- Investigation of mid-fidelity prediction methods
- **Application:** flight dynamics simulation development

RAVEN eVTOL Vehicle

- RAVEN – **R**esearch **A**ircraft for e**V**TOL **E**nabling Tech**N**ologies[1]
- Tilt-rotor eVTOL configuration with six variable-pitch propellers
- Collaboration between NASA and Georgia Tech
- Vehicles at different scales
- 24 independent control effectors
  - Six propeller speeds $(n_1, n_2, \ldots, n_6)$
  - Six collective angles $(\delta_{c_1}, \delta_{c_2}, \ldots, \delta_{c_6})$
  - Four tilt angles $(\delta_{t_1}, \delta_{t_2}, \delta_{t_3}, \delta_{t_4})$
  - Six flaperons $(\delta_{f_1}, \delta_{f_2}, \ldots \delta_{f_6})$
  - Stabilator (δ_s)
  - Rudder (δ_r)
- Built for modeling and controls research

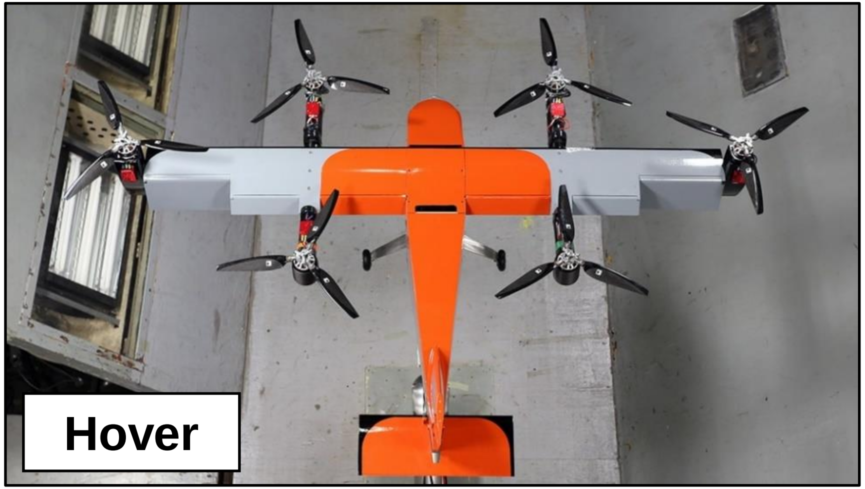
1. German, B. J., Jha, A., Whiteside, S. K. S., and Welstead, J. R., "Overview of the Research Aircraft for eVTOL Enabling techNologies (RAVEN) Activity," *AIAA AVIATION 2023 Forum.*



RAVEN control effector definitions.

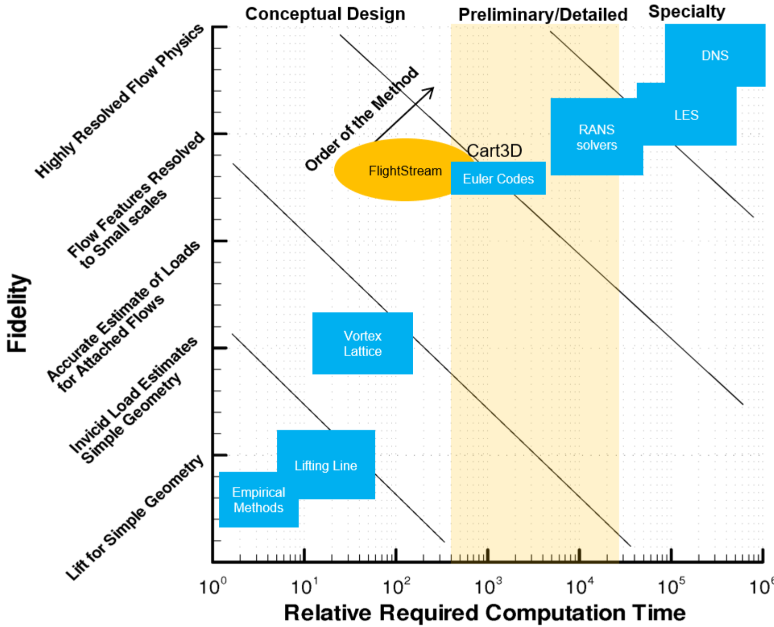
RAVEN SWFT Model

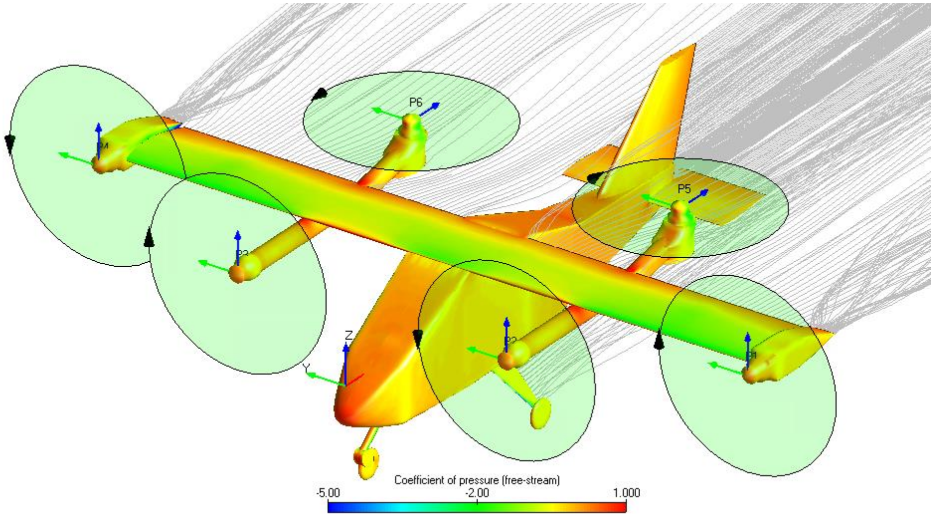
- SWFT: **S**ubscale **W**ind-Tunnel and **F**light **T**est
- Similar in scale and utility to the NASA LA-8
- 28.6% scale version of 1000-lb vehicle
- 37 lbs, 5.7 ft wingspan, 19.5 in diam. propellers
- Static wind-tunnel test in Nov-Dec 2022



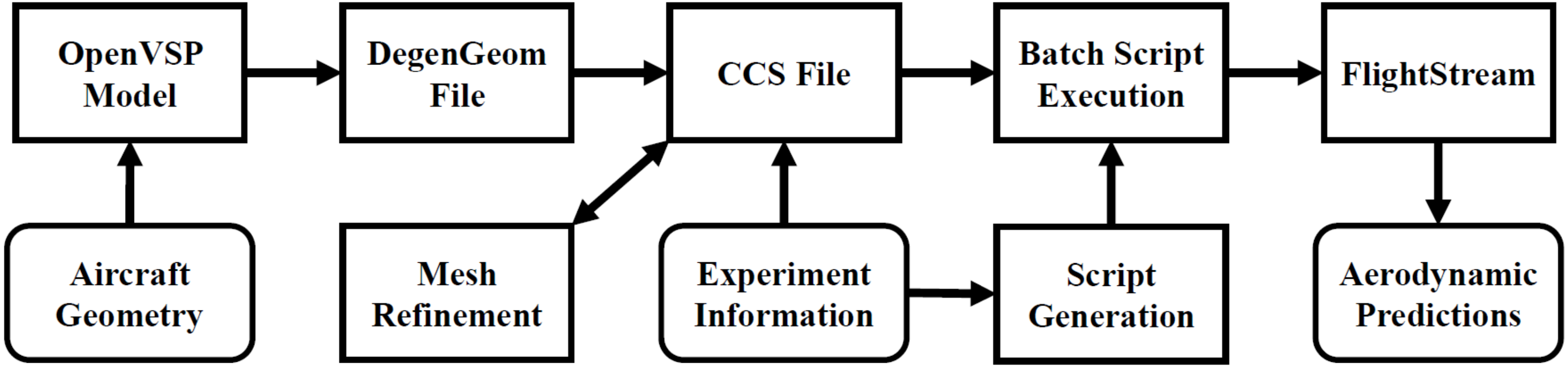
FlightStream®

- Surface-vorticity panel method
- Created by Research in Flight
- Low-to-mid fidelity predictions
- Conceptual/preliminary design
- Propulsion-airframe interactions
- Nonlinear aerodynamics

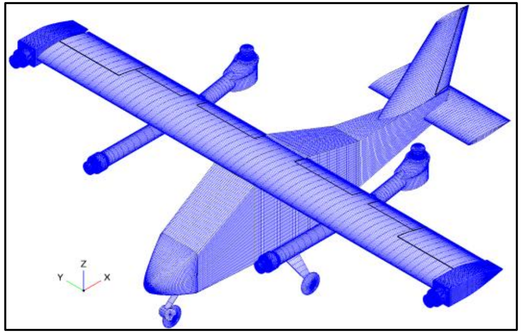




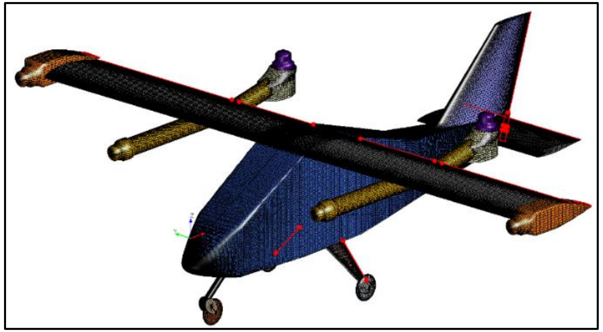
Aerodynamic Modeling Approach



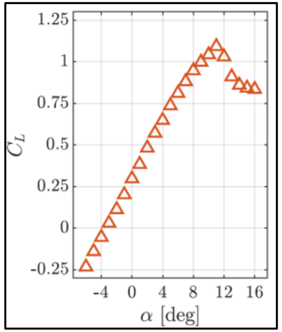
Process to execute FlightStream® simulations.



OpenVSP geometry.



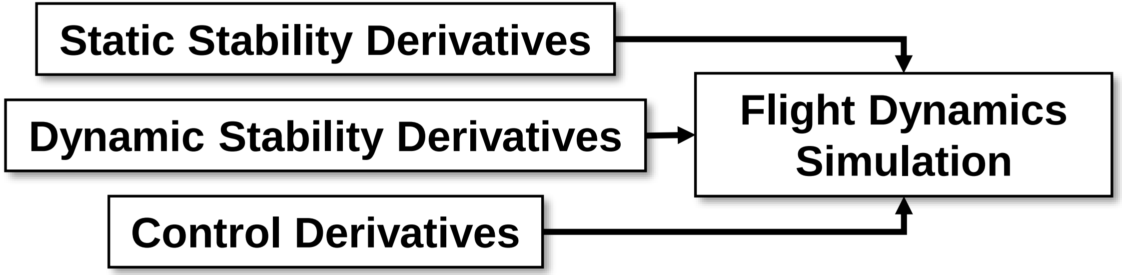
FlightStream® geometry.



Aerodynamic predictions.

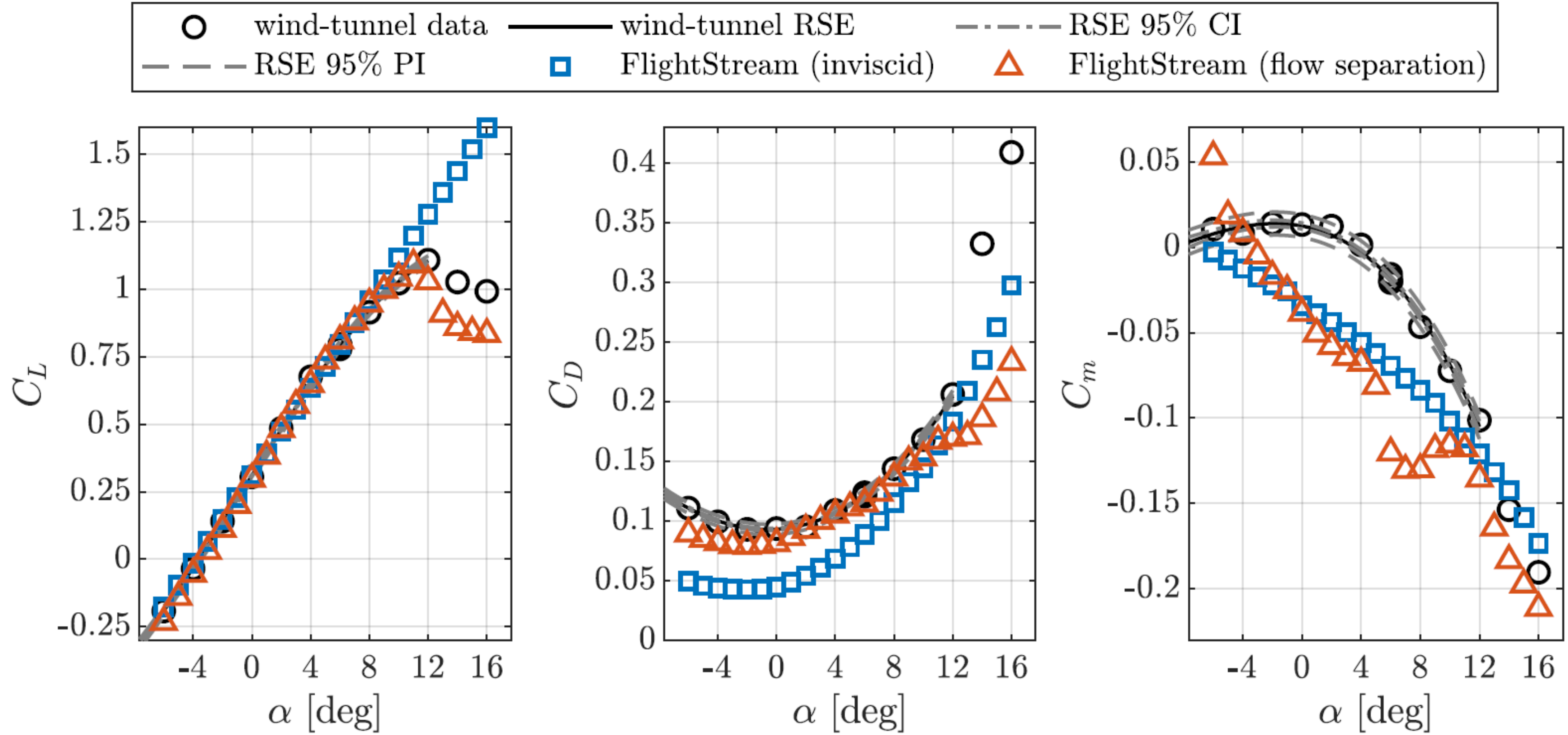
RAVEN SWFT Validation Study

- RAVEN SWFT isolated-airframe configuration
- Analysis of aircraft performance, stability, and control characteristics
  - Angle of attack sweeps
  - Angle of sideslip sweeps
  - Angular velocity sweeps
  - Control surface sweeps



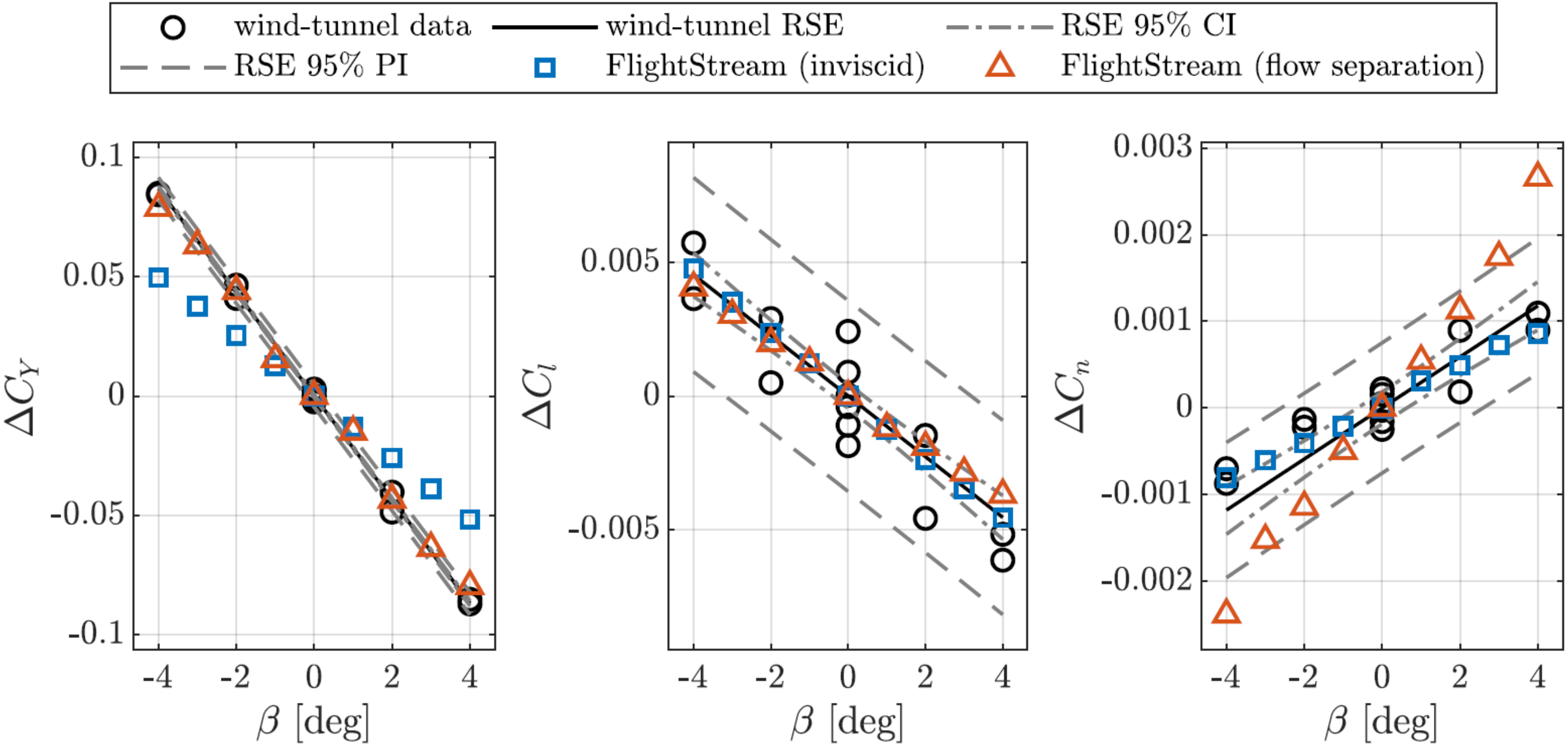
- Comparison to static wind-tunnel data
  - Measured data points
  - Response surface equation (RSE) predictions
  - RSE 95% confidence and prediction intervals
- FlightStream® solutions with and without flow separation modeled

Results: Angle of Attack Sweep



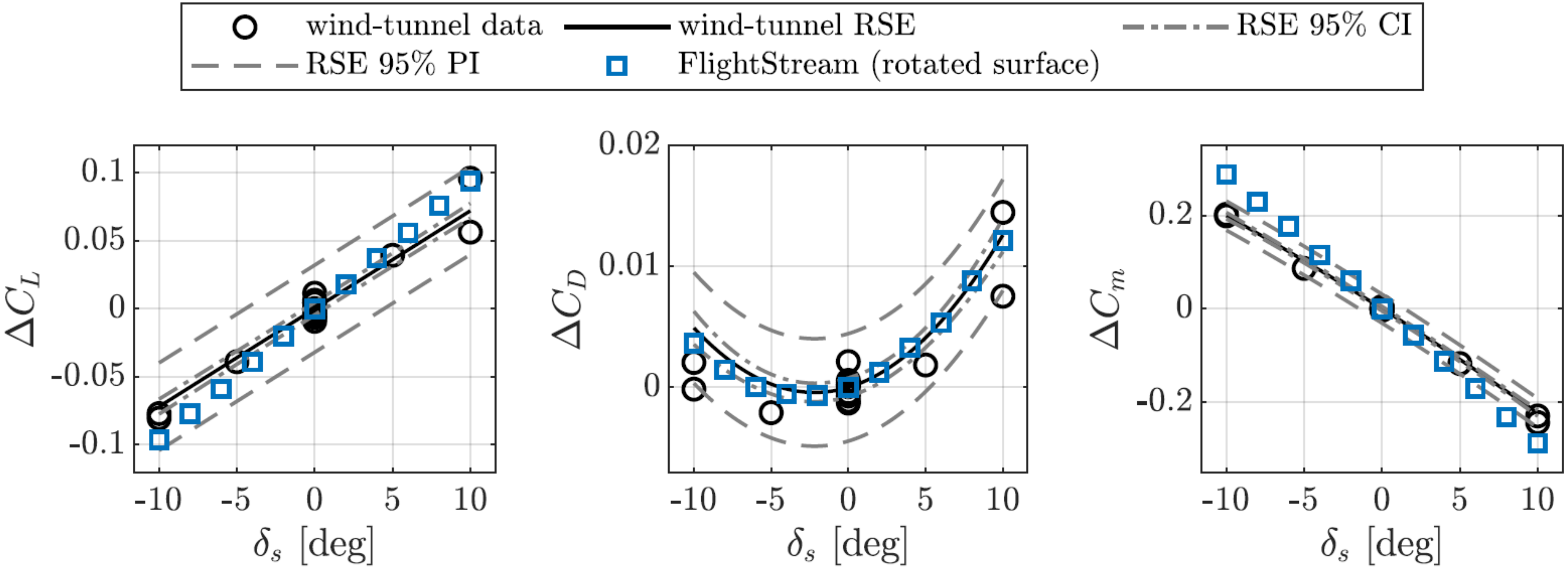
Angle of attack sweep at $\bar{q}$ = 3.5 psf (V = 54.3 ft/s) and β = 0 deg.

Results: Angle of Sideslip Sweep



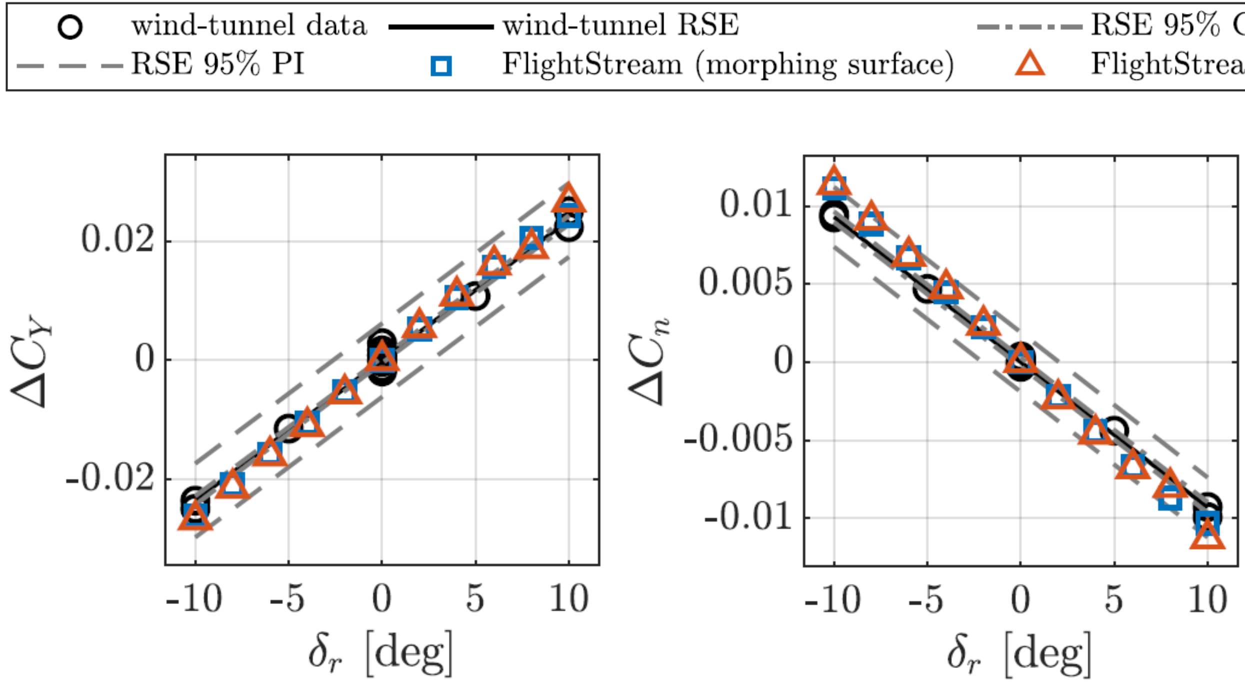
Angle of sideslip sweep at $\bar{q}$ = 3.5 psf (V = 54.3 ft/s) and α = 2 deg.

Results: Stabilator Sweep

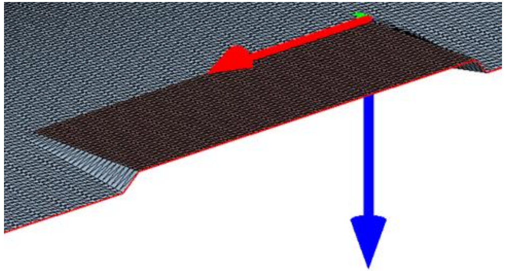


Stabilator sweeps at $\bar{q}$ = 3.5 psf (V = 54.3 ft/s), α = 2 deg, and β = 0 deg.

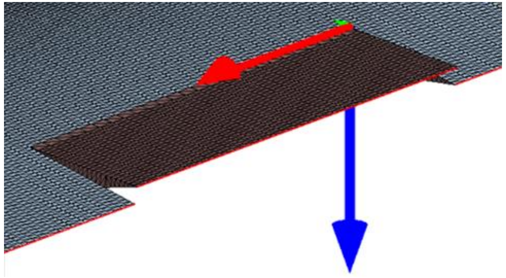
Results: Rudder Sweep



Rudder sweep at $\bar{q}$ = 3.5 psf (V = 54.3 ft/s), α = 2 deg.

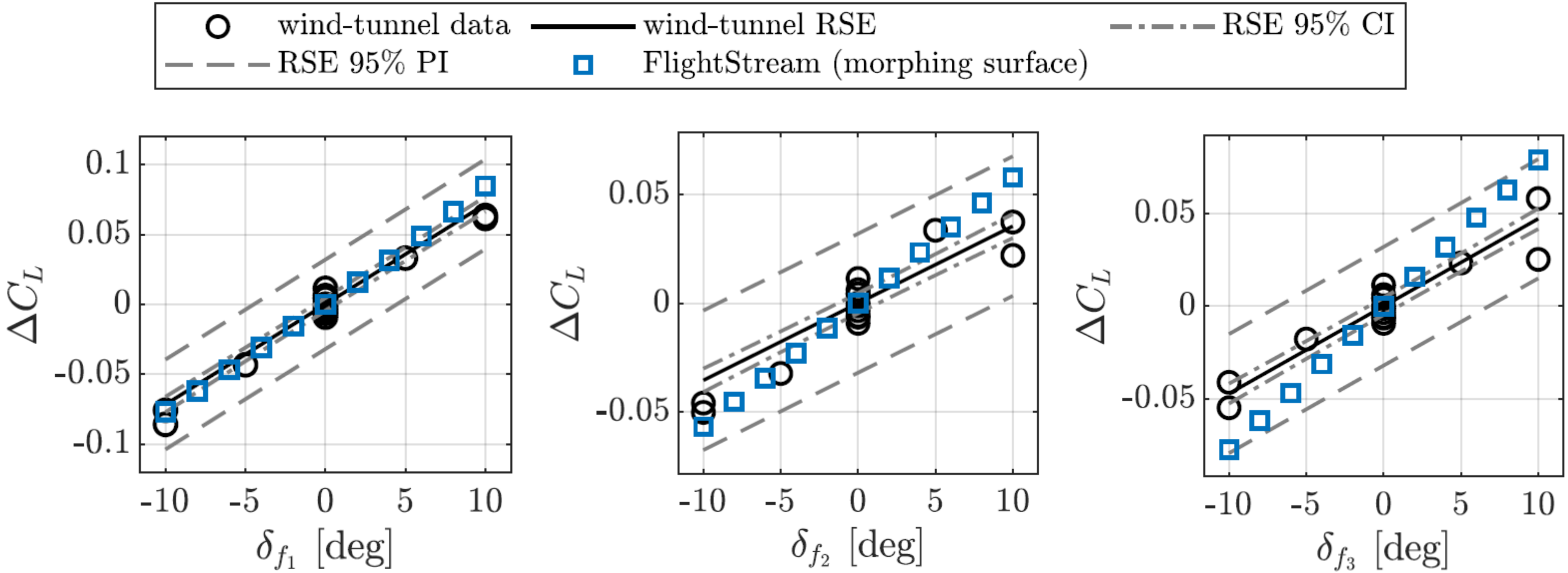


Morphing surface.



Physical surface.

Results: Flaperon Sweep



Outboard flaperon **Midboard flaperon** **Inboard flaperon**

Left flaperon sweeps at $\bar{q}$ = 3.5 psf (V = 54.3 ft/s), α = 2 deg, and β = 0 deg.

Concluding Remarks

- eVTOL aircraft present new aero-propulsive modeling challenges
- Accurate prediction tools are needed throughout the design process
- FlightStream® yields flow solutions accessible early in vehicle design
- Comparison of FlightStream® predictions to static wind-tunnel data
- Future work:
  - Analysis for the RAVEN SWFT powered-airframe and other eVTOL aircraft
  - Validation of dynamic derivative predictions
  - Refinement of FlightStream® flow models and grid generation

Questions

Thank you for your attention.