Noise Modeling of Advanced Air Mobility Flight Vehicles
ASCENT Project 84

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Project manager: Susumu Shirayama, FAA
Cost Share Partners: Electra.aero, Wisk, CDI

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ASCENT

Project 084

Noise Modeling of Advanced Air Mobility Flight Vehicles

University of California, Irvine
Massachusetts Institute of Technology
PI: Jacqueline Huynh, R. John Hansman
PM: Susumu Shirayama
Cost Share Partner(s): Electra.aero, Wisk, CDI

Objective:

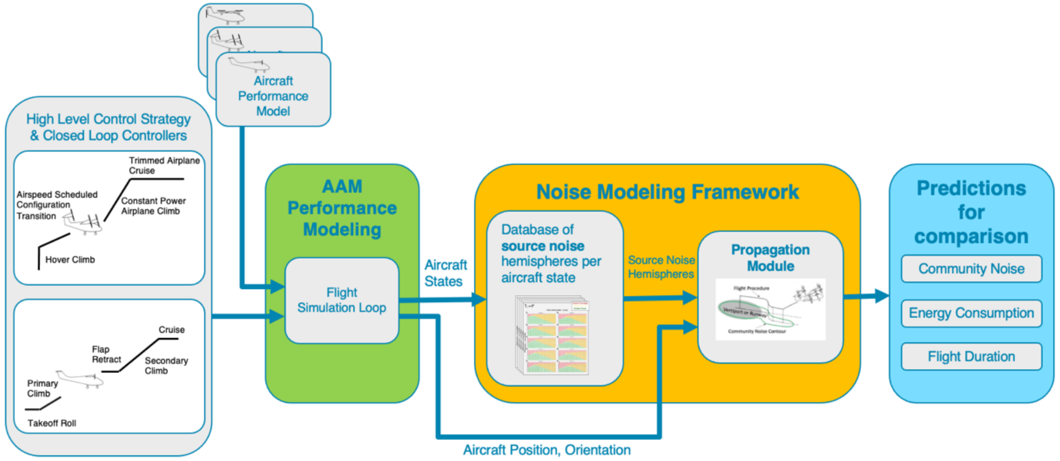
To develop first principles noise models of AAM vehicle configuration(s) to make community noise predictions of these aircraft flying at various operating states. Estimated noise levels from these models will be used to develop methods needed for an AAM-compatible AEDT to make preliminary noise estimates of these vehicles.

Project Benefits:

This project will develop noise modeling methodologies for a variety of AAM vehicles where existing noise data is currently very limited. The noise analysis models will also be applicable to study potential noise abatement methodologies through source noise modifications, procedure modifications, or both. Future developments to model AAM noise in AEDT will be directly supported by this effort.

Research Approach:

A UAM/AAM compatible noise model will be developed and used to model noise at a variety of velocities, flight path angles, and operating modes using a flight profile generator for making AAM noise estimates



Major Accomplishments (to date):

- Developed and refined performance and noise modeling framework
- Carried out case studies on representative AAM vehicles
- Demonstrated approach on sample AAM trajectories at AIAA Aviation and Journal of Aircraft [1][2][3].
- Identified applicable operational envelopes from performance and noise framework
- Evaluated noise modeling approaches in sophisticated flight regimes
- Preliminary comparisons between manufacturer noise data, and noise modeling tools

Future Work / Schedule:

- Validate the impact of inflow modeling on noise
- Determine preliminary implications for AAM operations in AEDT
- Collect and use noise data from manufacturers to further validate noise models

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Motivation

- Various AAM configurations proposed in industry
- Noise assumed to be critical design aspect
- Community noise impact will be function of configuration and operational mode
- It is unclear how or if AEDT can be used to accommodate these new vehicles

Source: electra.aero

Source: wisk.aero

Source: jobyaviation.com

Objectives

- Develop detailed component-based noise models for AAM vehicles
- Evaluate noise levels of relevant AAM arrival and departure procedures
- Use detailed models to inform and develop simplified noise analysis methods compatible with AEDT

Approach

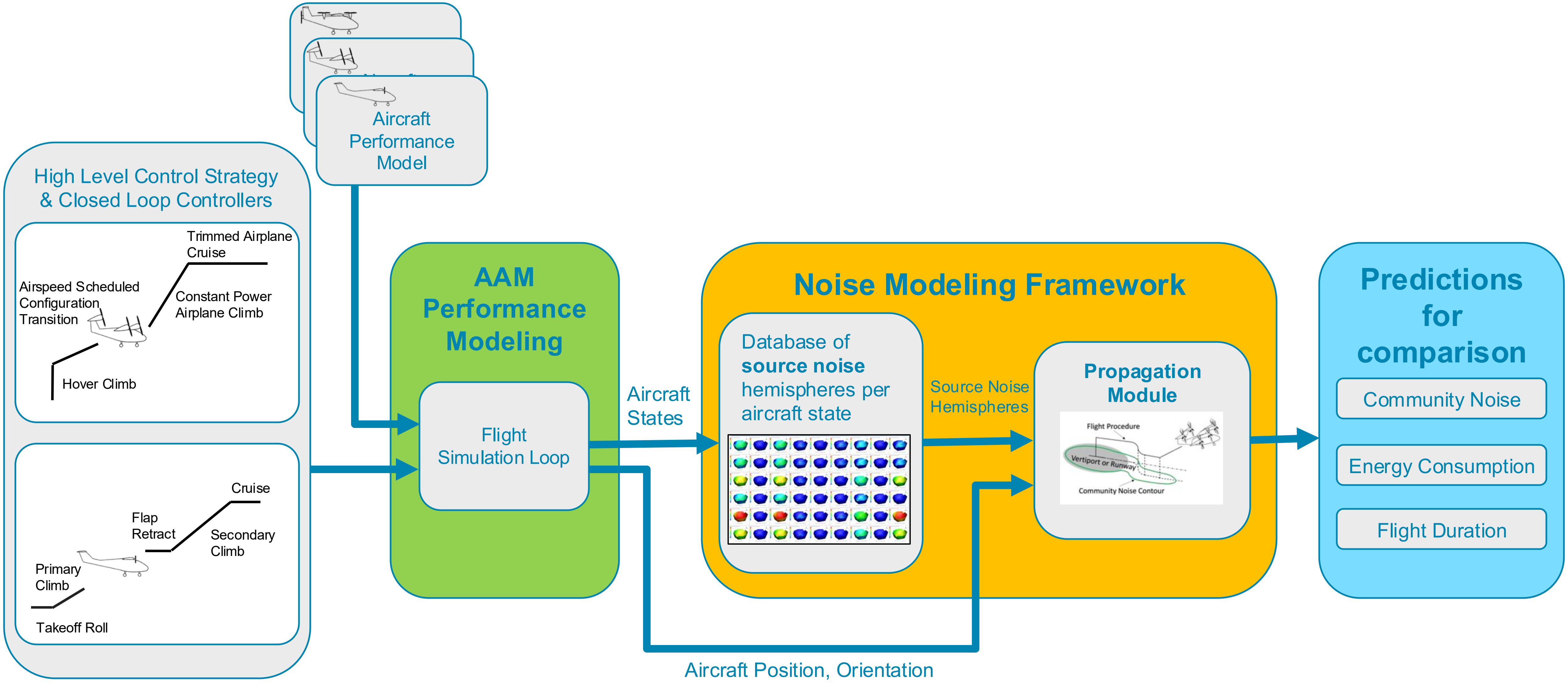
Develop performance framework for representative AAM vehicles to identify range of realistic operating conditions [1]

Develop noise modeling framework for representative AAM vehicles to assess noise impact of operations [2][3]

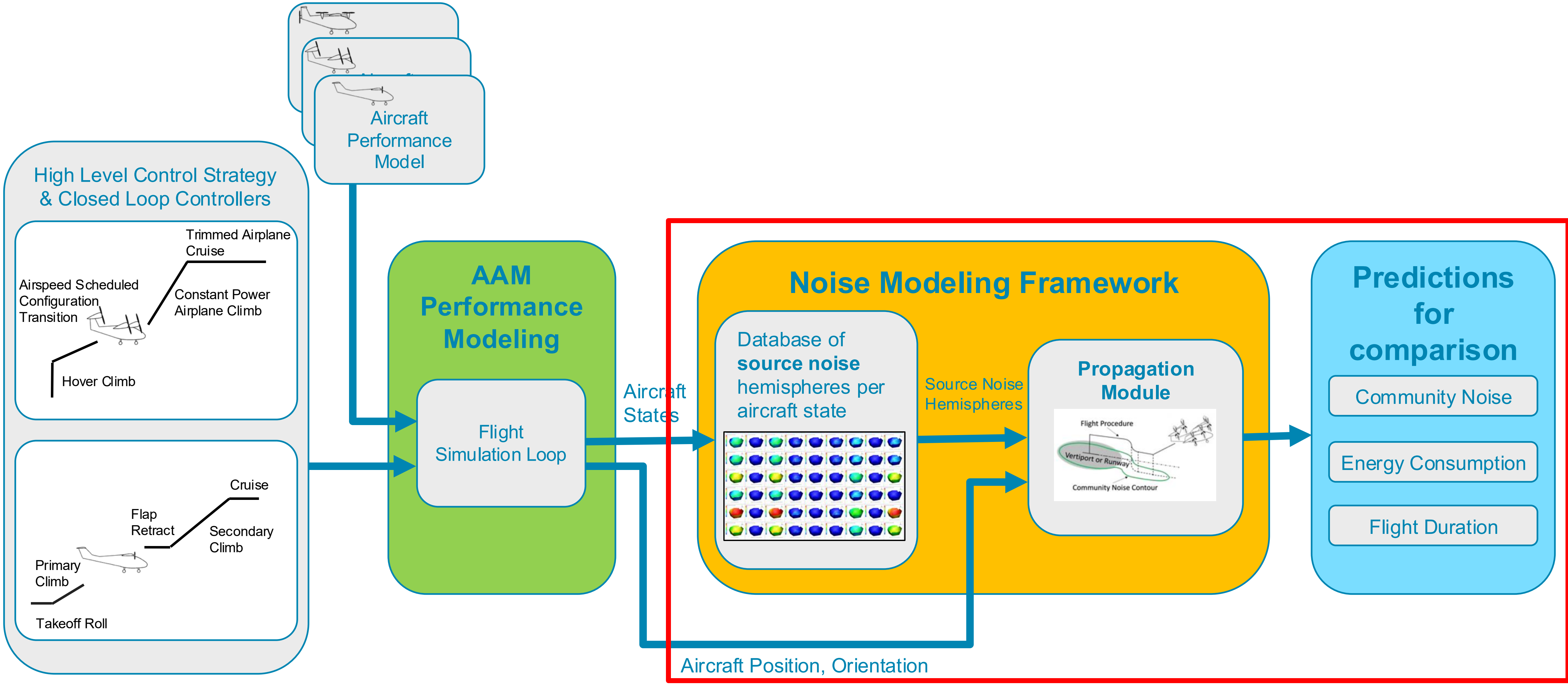
Validate predictions against published and collaboration-available data to best inform AEDT requirements

[1] : Yeung et al., 2023 [2] : Gonzalez et al. 2025 [3] Pellerito 2025 (PhD Thesis)

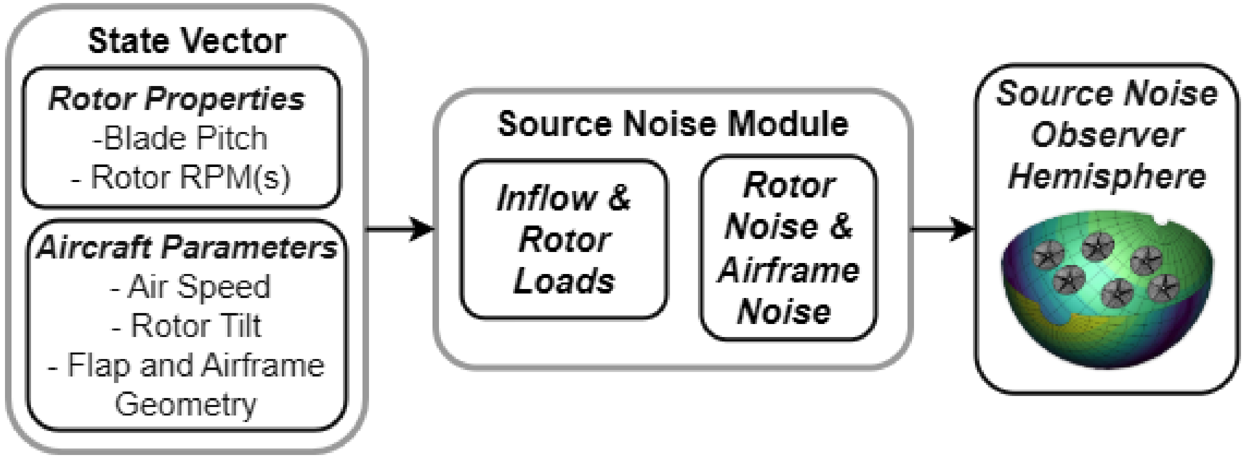
Research Approach



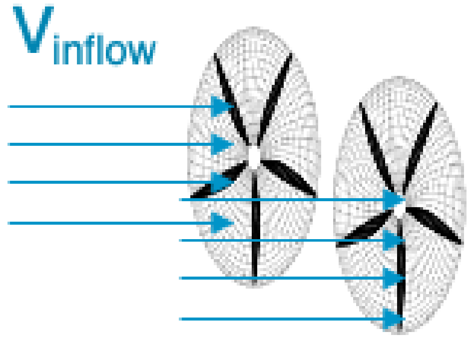
Research Approach



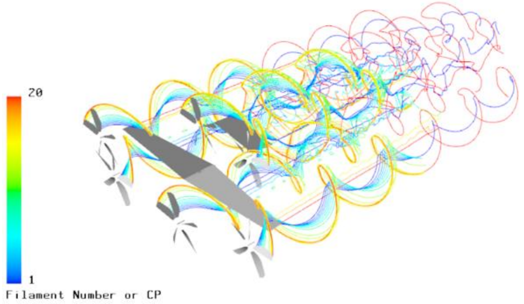
Community Noise Modeling



Yeung et al., 2023



ABEAT

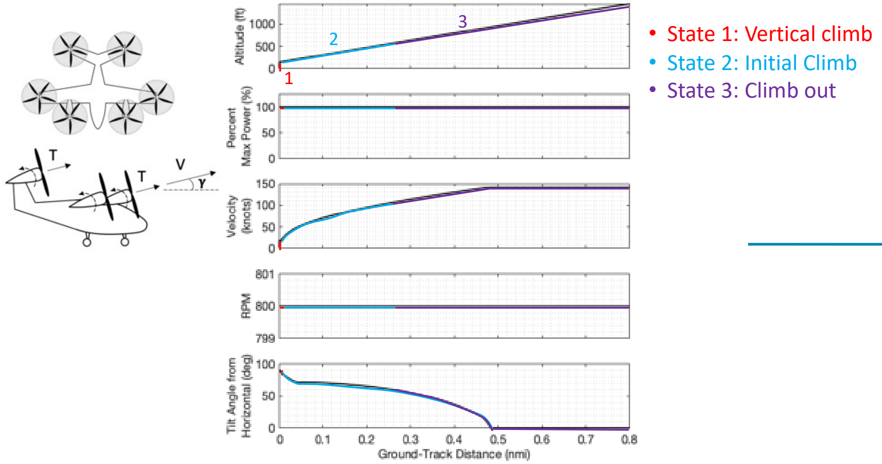


CHARM

- The Source Noise Module: determines Rotor and Airframe noise
  - **Rotor tonal noise** solved using Farrassat methods, **rotor broadband noise** solved using BPM empirical methods, implemented in ANOPP or PSUWOPWOP
  - Airframe trailing edge and flap noise modeled using Fink and Gao methods in ANOPP
- Options considered to generate rotor loads and inflow models needed to model rotor noise :
  - **ABEAT** uses blade element momentum theory to calculate rotor loading from a simplified uniform inflow model without considering complex flow around a vehicle
  - **CHARM** uses fast panel and fast vortex methods to calculate aerodynamic loads including complex flow around a vehicle such as non-uniform inflow and wake interference to be modeled

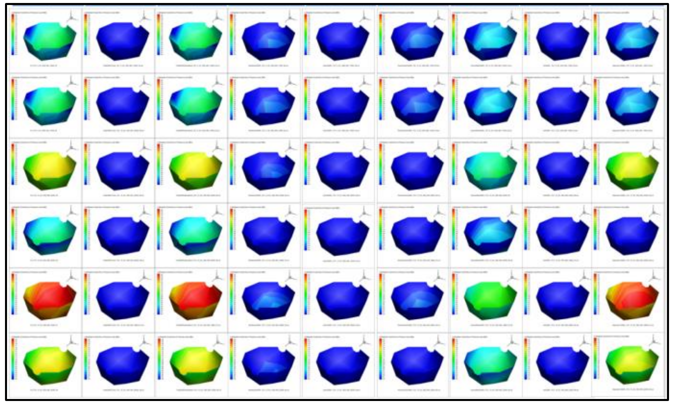
Community Noise Modeling

Vehicle flight trajectory modeled and noise model inputs determined



*Only 3 states shown for clarity

Noise hemispheres are determined from a pre-computed database at each timestep along the trajectory

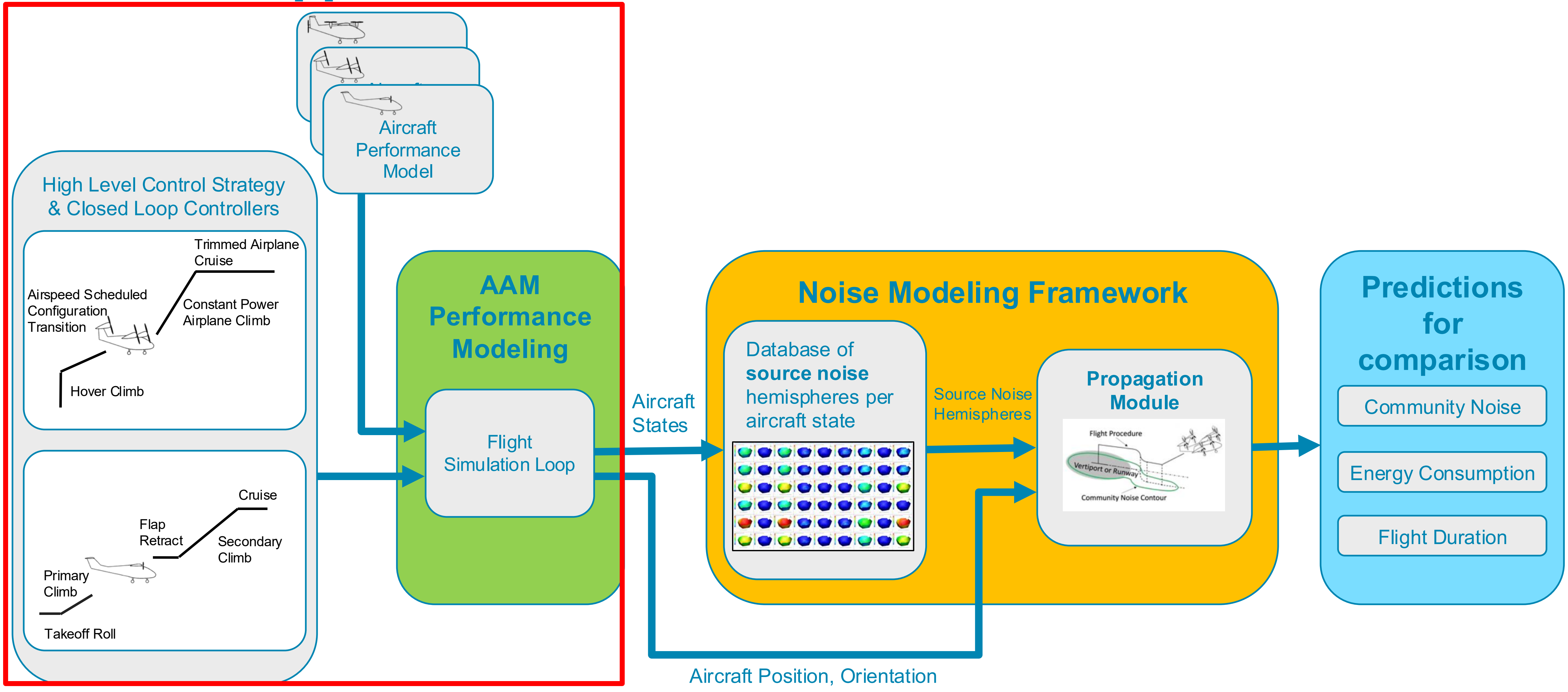


Resulting noise contour modeled from propagated hemispheres along full flight procedure

Time and energy also determined for completeness

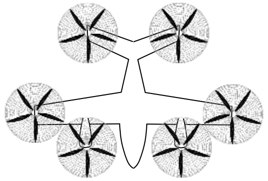
[3] Gonzalez 2025 (PhD Thesis)

Research Approach

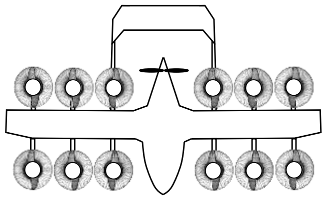


Reference Flight Operations

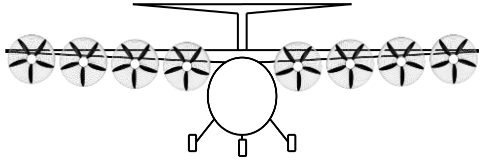
- AAM Aircraft Architectures



Tilt Rotor



Lift + Cruise



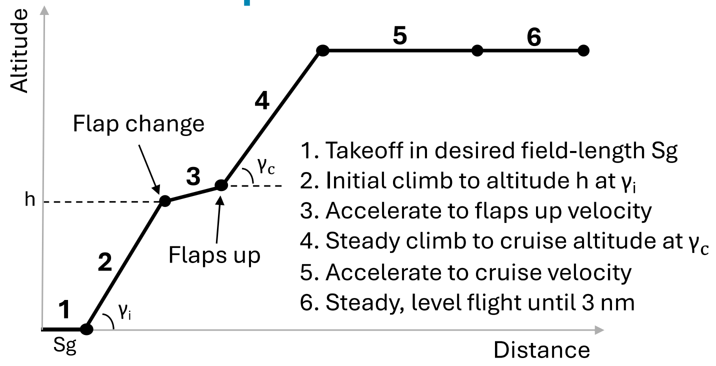
STOL

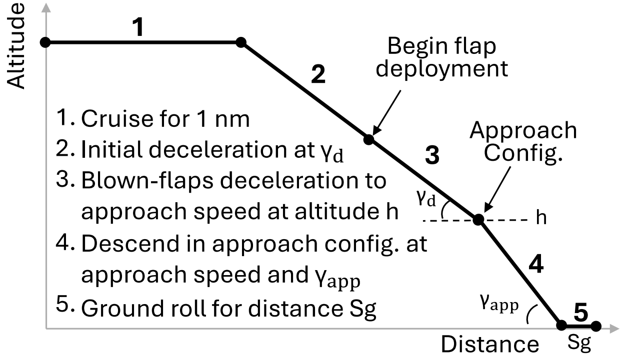
- Generic Flight Operation Segments

Departure

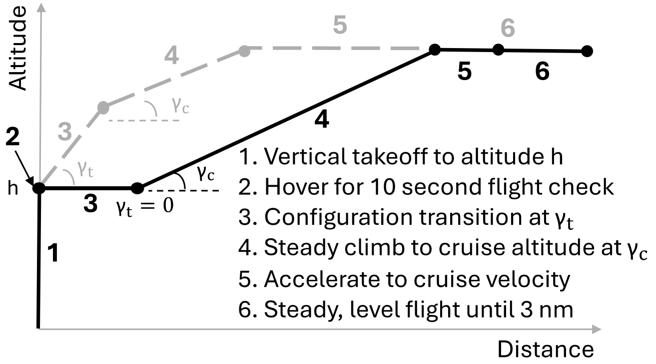
Arrival

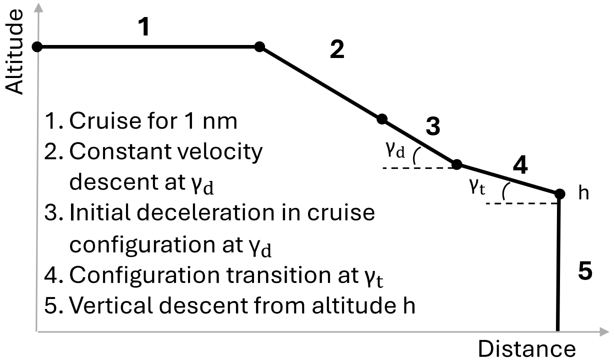
STOL:





VTOL:





Detailed in Pellerito et al, Impact of Flight Trajectory Design on Performance and Noise for AAM Aircraft, Journal of Aircraft, 2025

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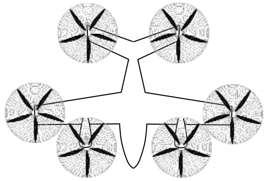

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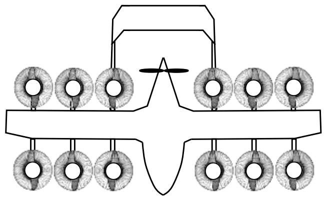

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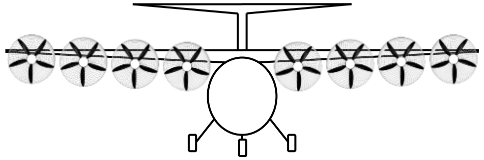
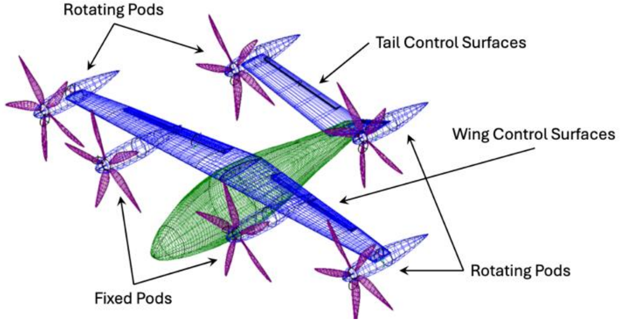
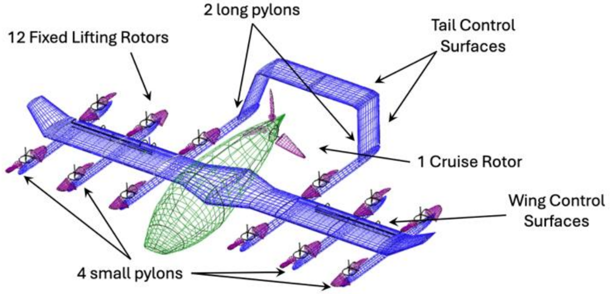


STOL

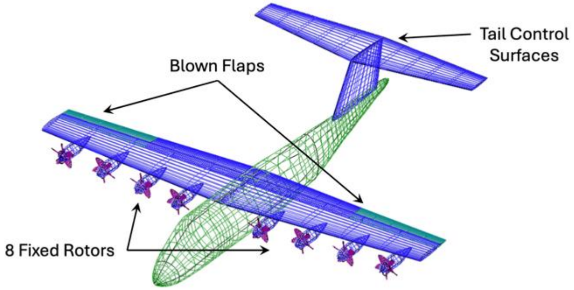
4000 lb, 4 passenger



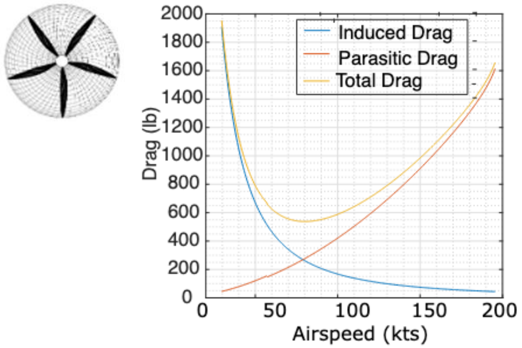
2800 lb, 2 passenger

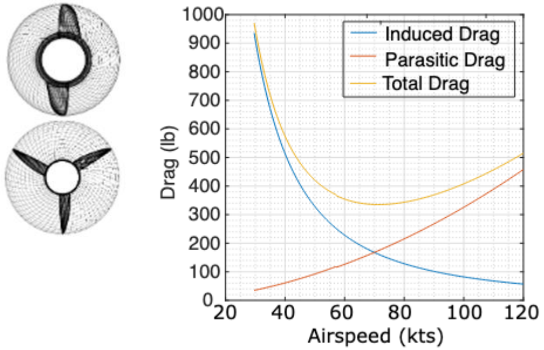


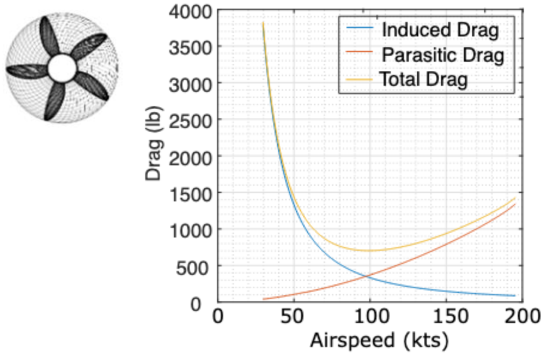
6000 lb, 9 passenger



Drag polars determined from physics based drag build-up, rotors from BEM theory







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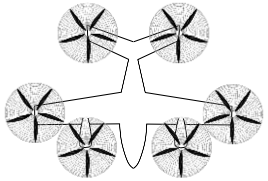
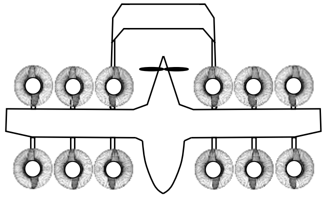


Tilt Rotor



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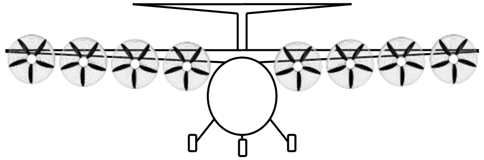
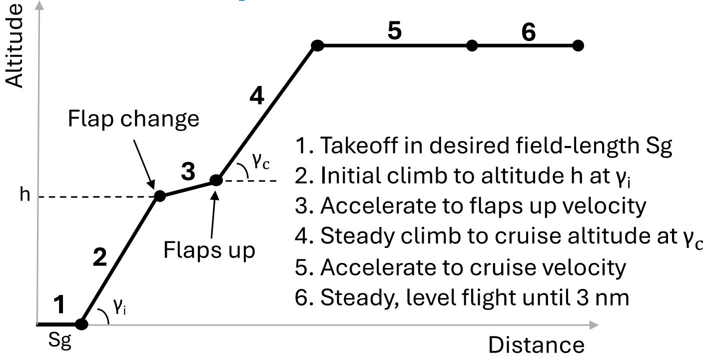
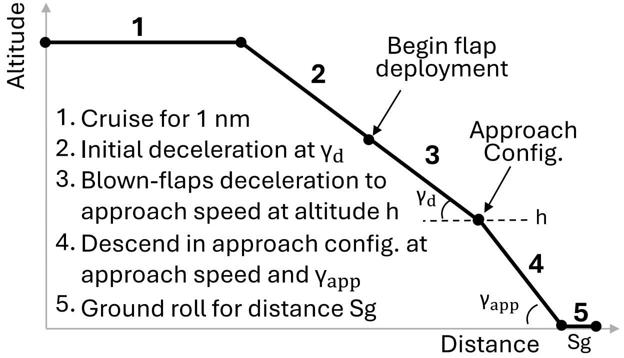


STOL

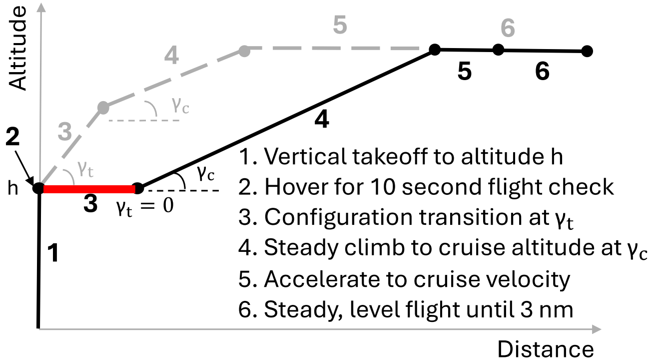
- Generic Flight Operation Segments

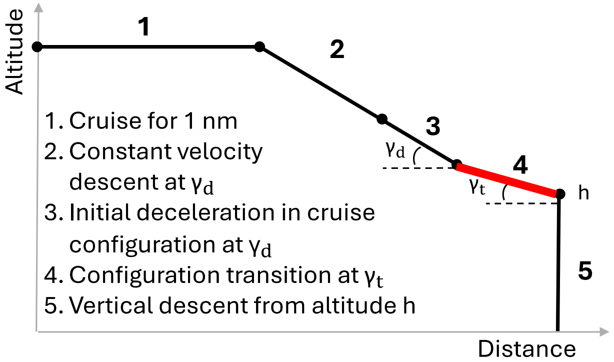
STOL:





VTOL:



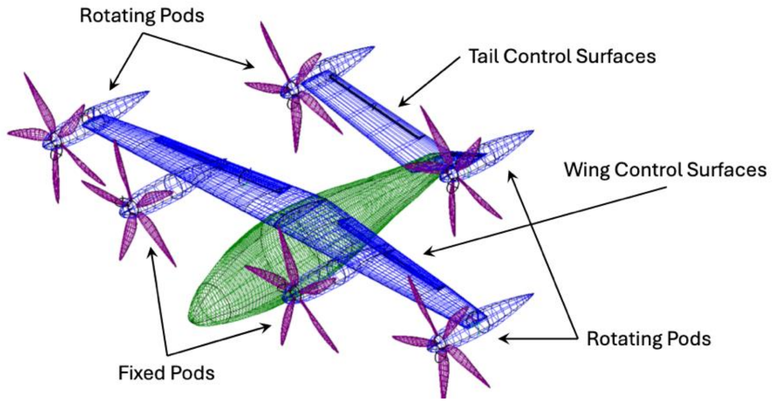


Detailed in Pellerito et al, Impact of Flight Trajectory Design on Performance and Noise for AAM Aircraft, Journal of Aircraft, 2025

Tilt Rotor as Test Case

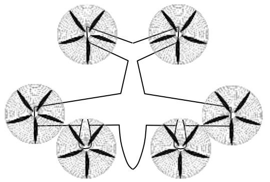
- Vertical takeoff and landing vehicles expected to transition from helicopter-style thrust borne flight to airplane-style wing borne flight at low altitudes
  - Atypical flight conditions – difficult to predict noise-conditions
  - Over-actuated systems – many control philosophies can result in a similar flight
  - Multipurpose – no clear delineation between a thrusting rotor and a lifting rotor

- Other vehicles have their own complexities, but the Tilt Rotor will be discussed as an example

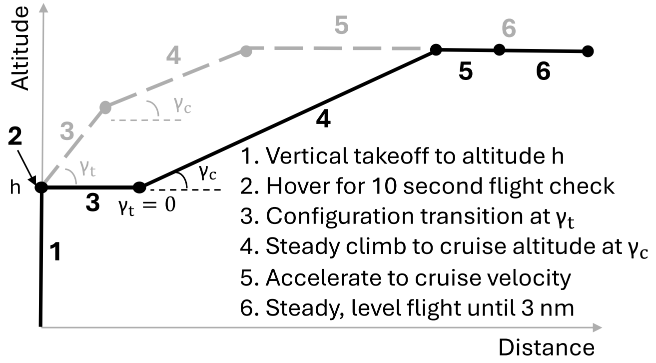


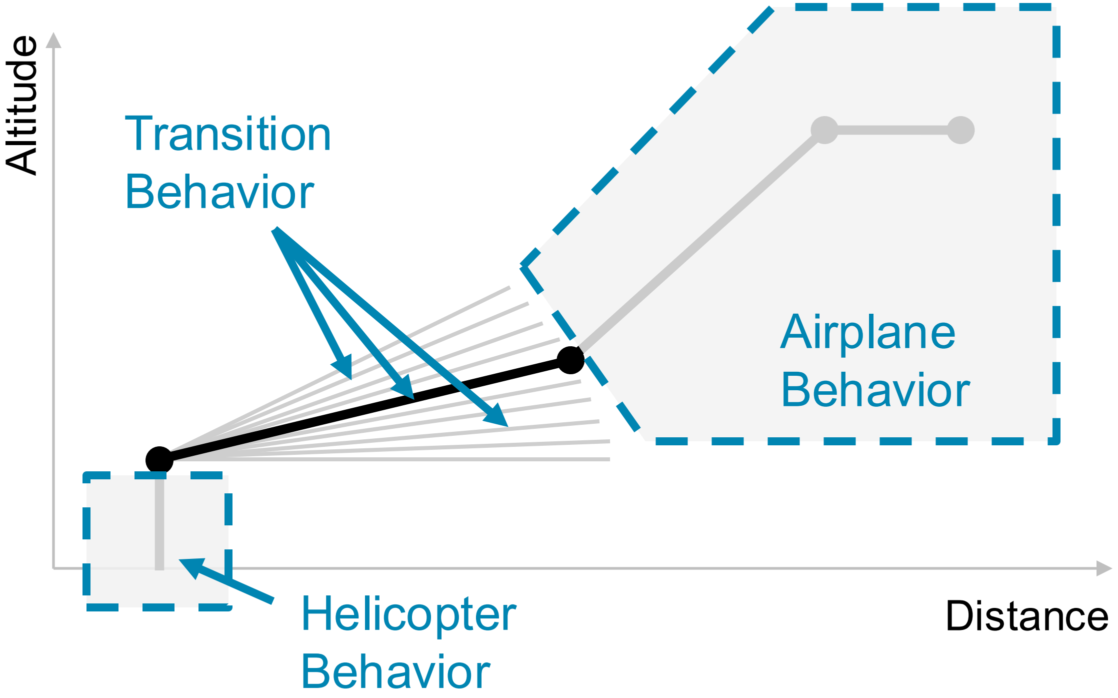
Tilt Rotor Example

- There are many ways to navigate transition with no clear strategy
- One reasonable concept is to tilt rotor nacelles according to airspeed

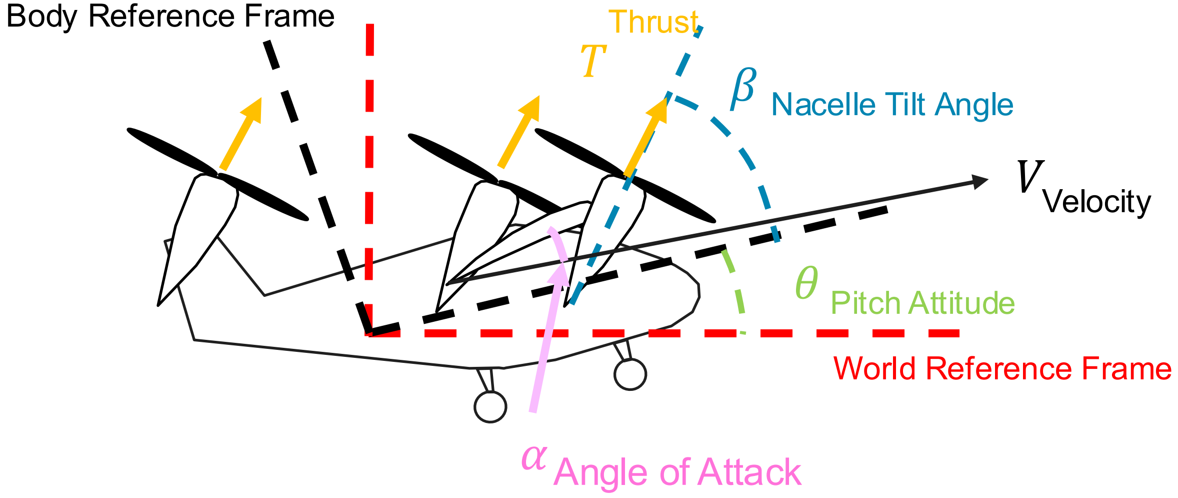


Tilt Rotor

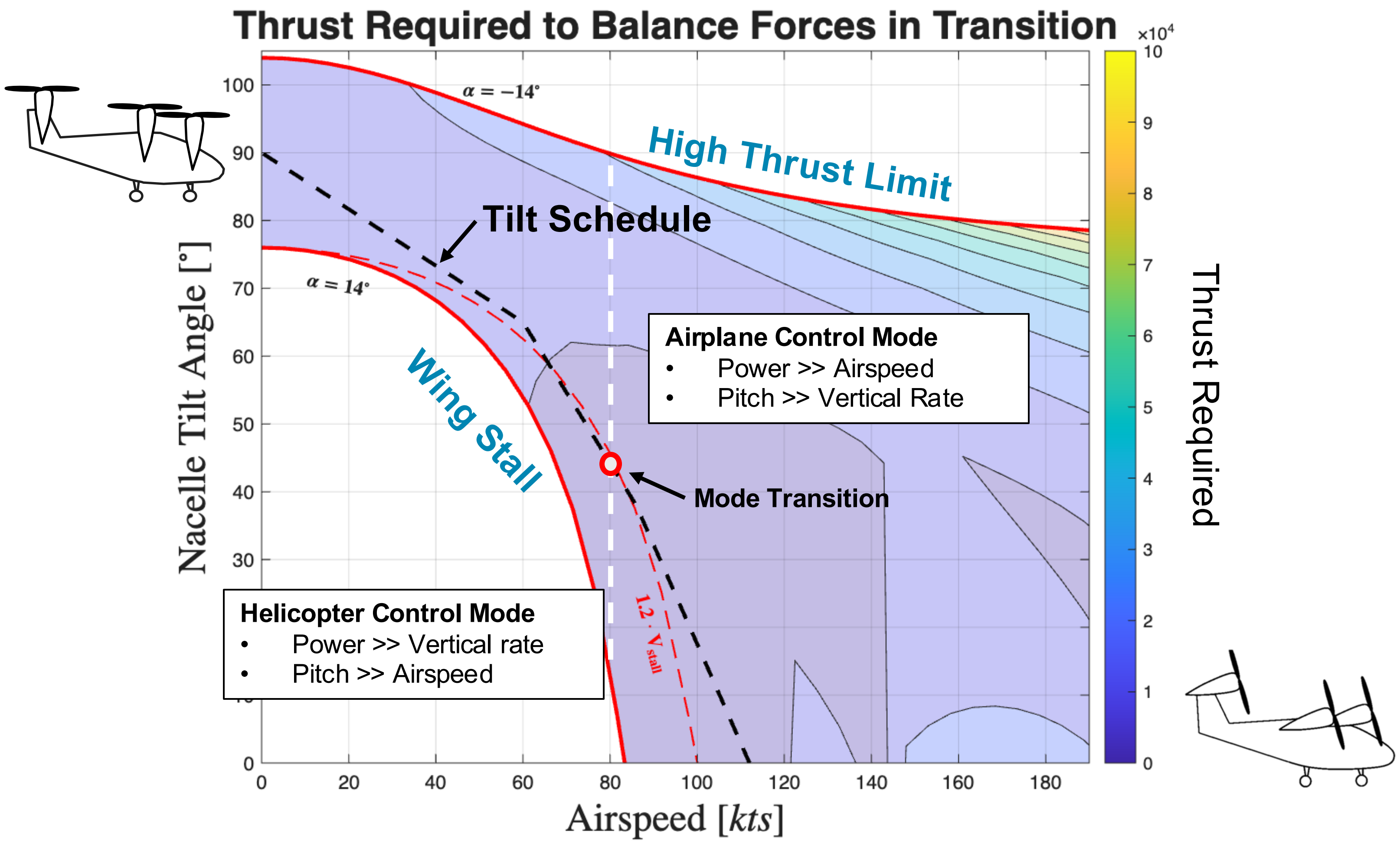




- Complex vehicle means more options for control



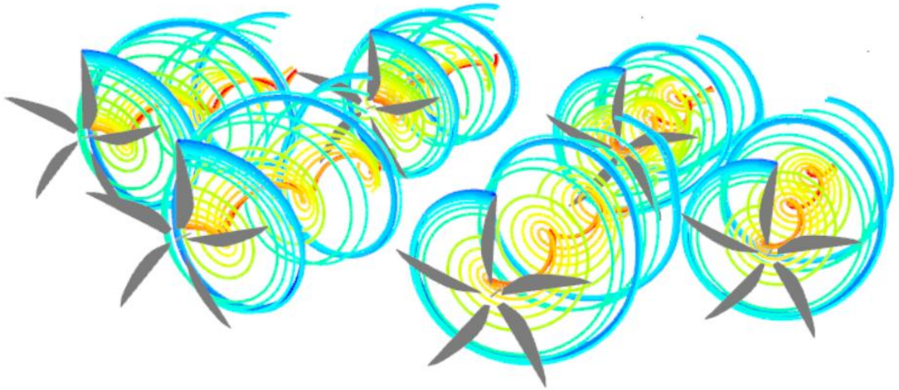
Transition Control Example – Tilt Speed Scheduling

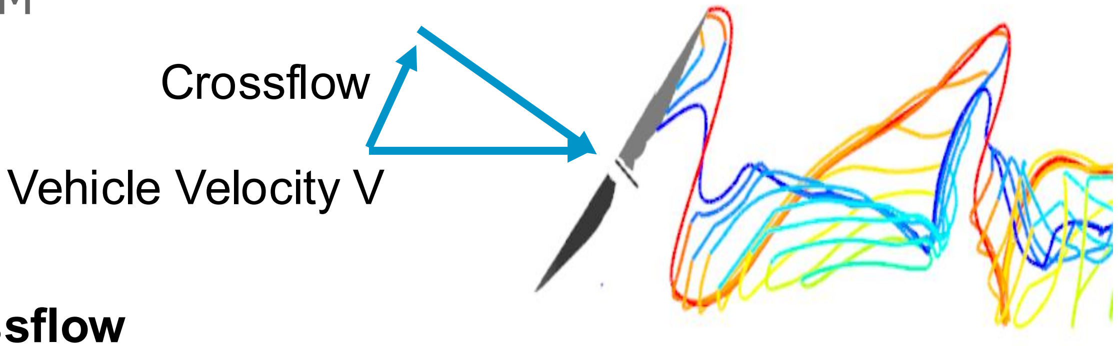


Factors that Influence Noise in Transition

Rotor-Rotor Interaction

- Results in noise from blade interaction with turbulent wake from forward rotors
- Can be modeled in CHARM





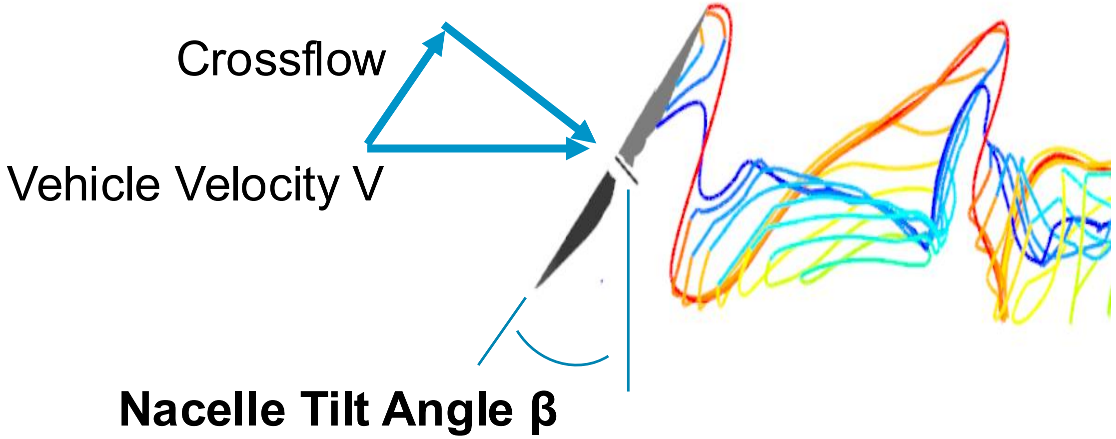
Crossflow

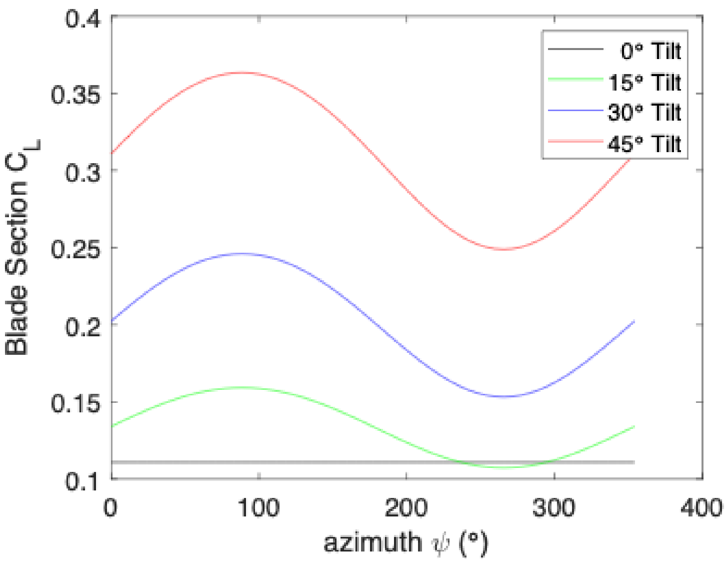
- Results in cyclically varying angles of attack during rotation
- Changes noise though unsteady blade loading
- Can be modeled in CHARM & ABEAT

Rotor-Wing interaction noise

- Prominent mechanisms:
  - Interaction of wing on forward propeller potential field
  - Interaction of propeller viscous wake on rearward wing
- Can be modeled in CHARM

Effect of Crossflow

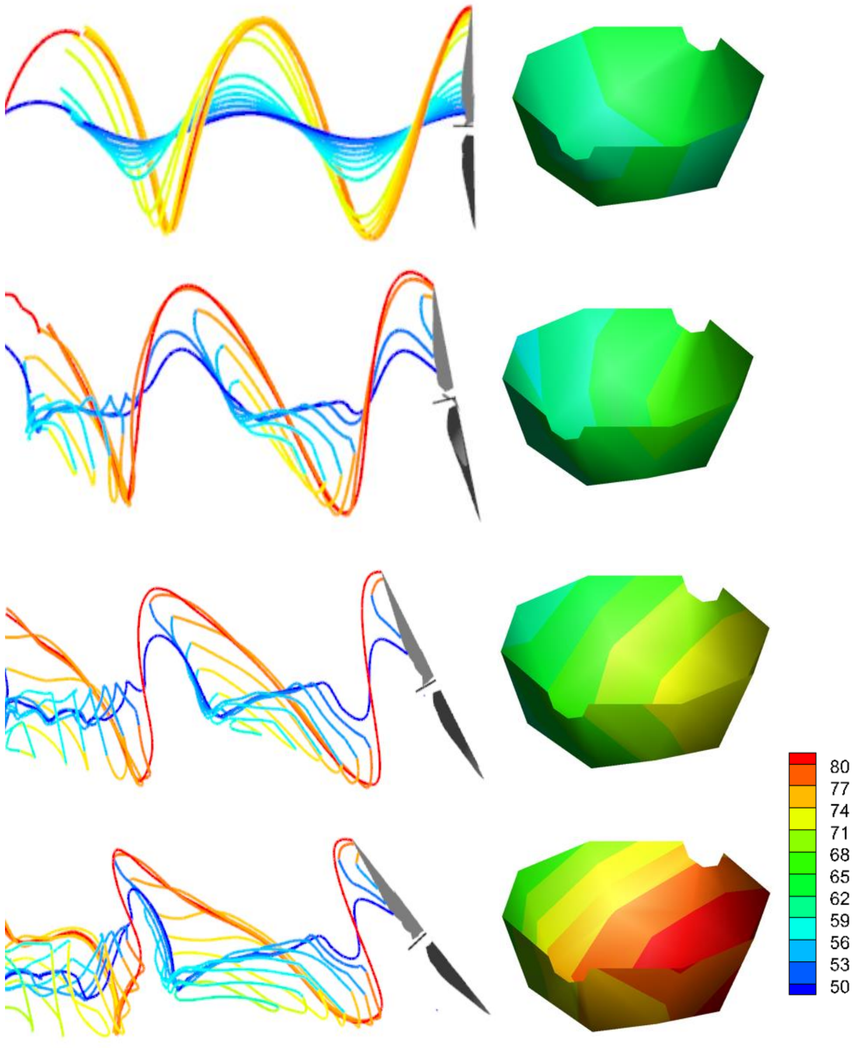




Increased rotor angle increases CT (and required power) for constant blade pitch

- Different control strategy required during transition
- Nacelle Tilt Angle β with respect to vehicle velocity results in cyclic blade loading due to crossflow
- Constant blade pitch through transition results in increased thrust/power through transition
- Constant power transition requires variable blade pitch through transition

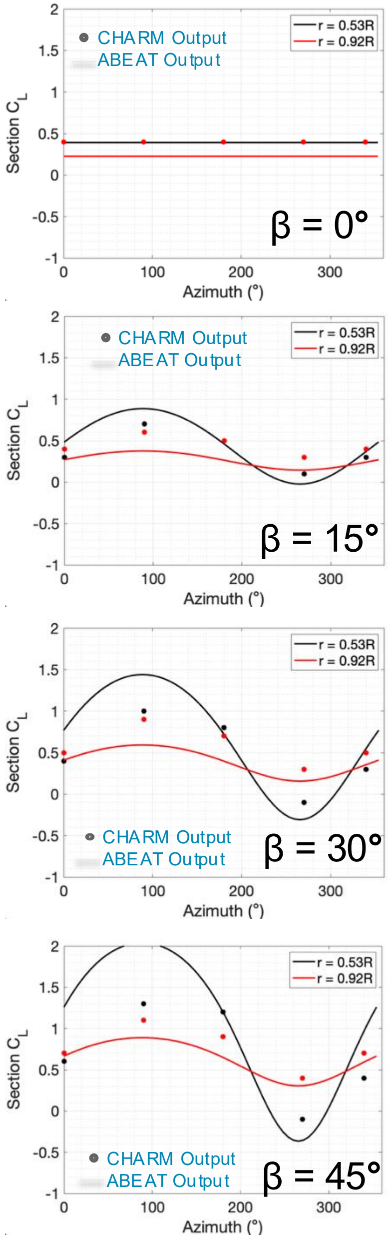
CHARM vs ABEAT Results Modeling Crossflow



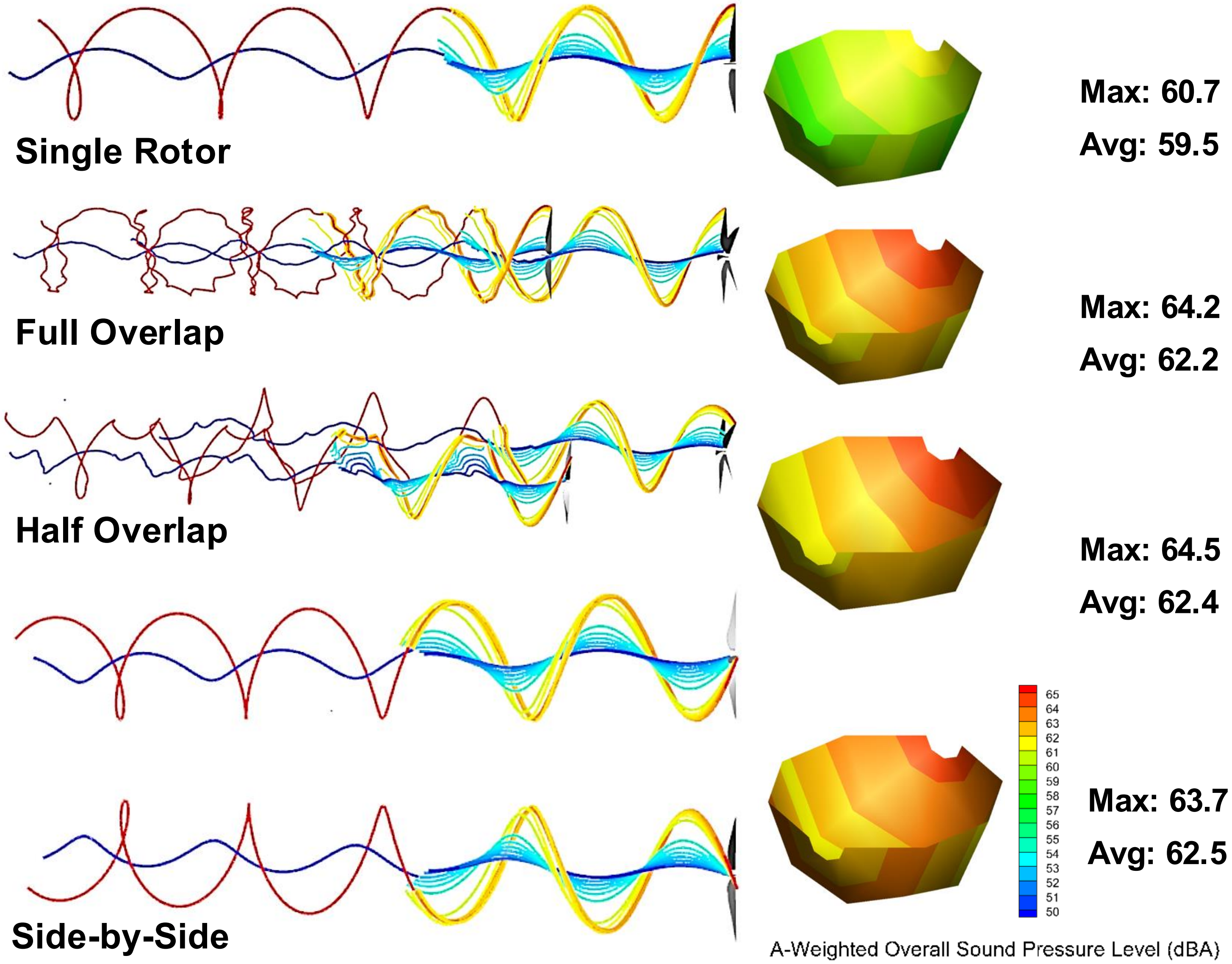
A-Weighted Overall Sound Pressure Level (dBA)

	CHARM	ABEAT
β = 0°		
Max dBA	61.3	60.8
Thrust (N)	1244	1323
β = 15°		
Max dBA	62.9	62.7
Thrust (N)	1480	1447
β = 30°		
Max dBA	67.3	68.0
Thrust (N)	2140	2533
β = 45°		
Max dBA	75.0	74.5
Thrust (N)	2986	4240

- Maximum expected crossflow at β = 45° for VTOL rotor
- Average noise increases by ~15 dB for 90 to 45°
- Both CHARM and ABEAT show consistent thrust and noise increase



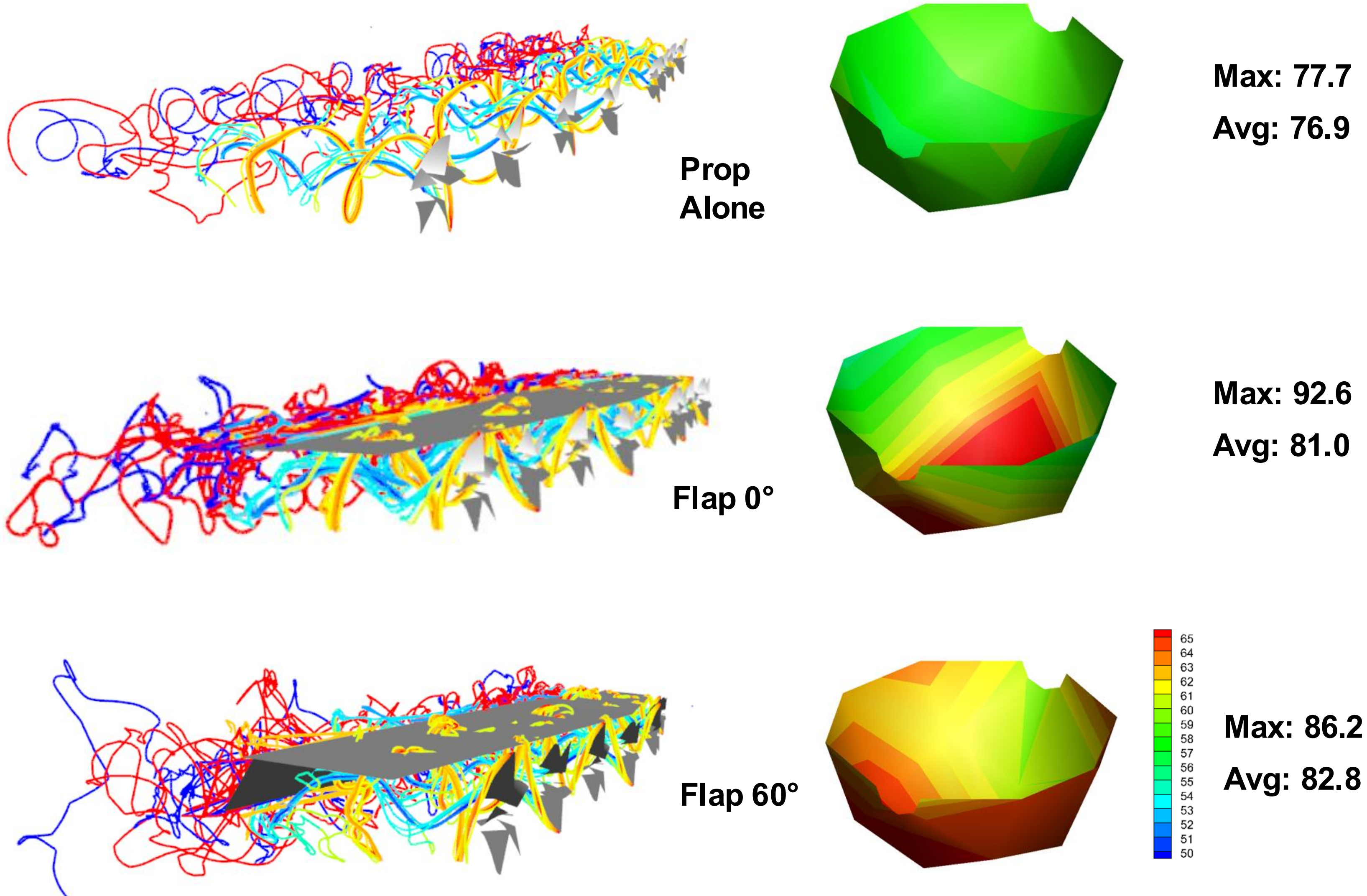
Effect of Rotor-Rotor Interaction



- Preliminary model in CHARM
- VTOL rotor(s) modeled in various configurations of rotor-wake interaction
- Constant blade pitch and RPM 700
- Preliminary Vortex Lattice Model indicates little difference in noise magnitude
- Double rotors in various configurations vary average noise by less than 0.5 dB

*Forward to rear rotor spacing from representative tilt-rotor vehicle

Rotor-Wing Interaction

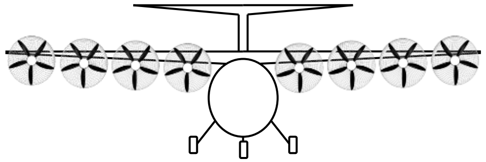


A-Weighted Overall Sound Pressure Level (dBA)

- STOL vehicle modeled with wing in both flap up and deployed
- Preliminary CHARM model indicates an increase in noise due to the addition of wing
  - Interaction of wing on forward propeller potential field
  - Interaction of propeller viscous wake on rearward wing
- Flap 60° configuration modeled at a lower power and vehicle speed (indicative of landing)

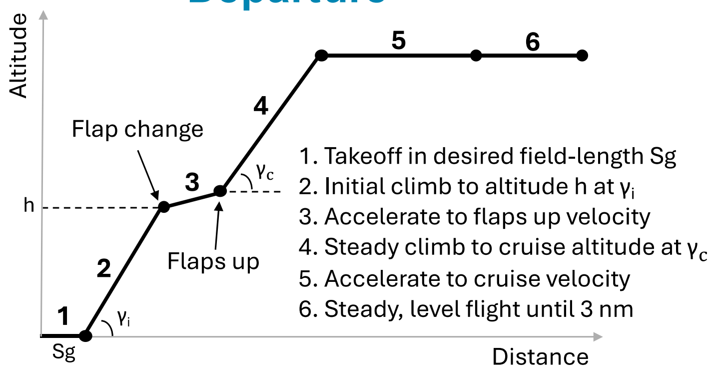
STOL example

*Preliminary results ignore airframe interaction

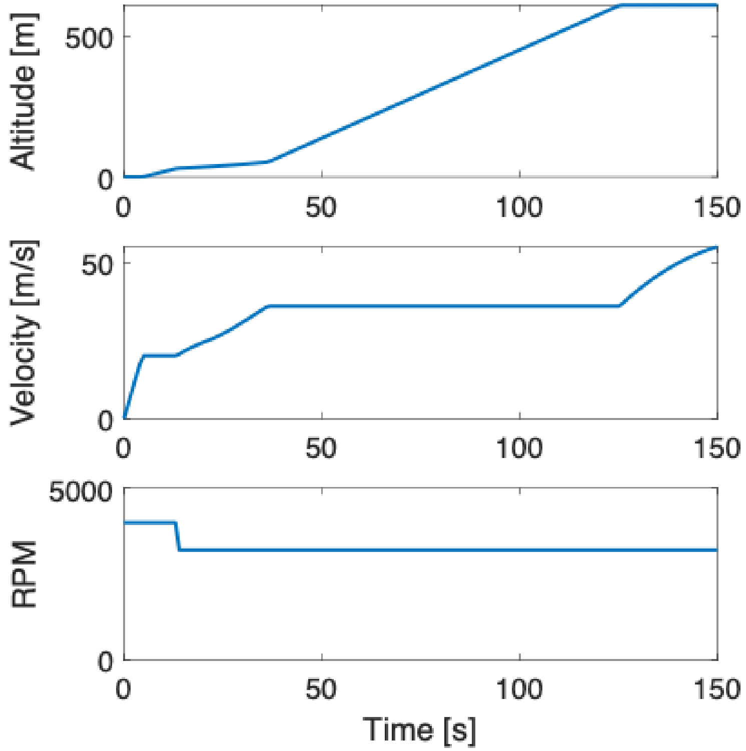


STOL
6000 lb, 9 passenger
M_{tip} 0.5 in this example

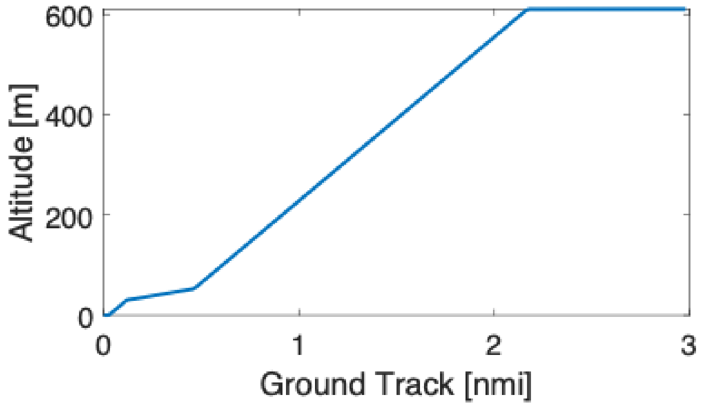
Departure



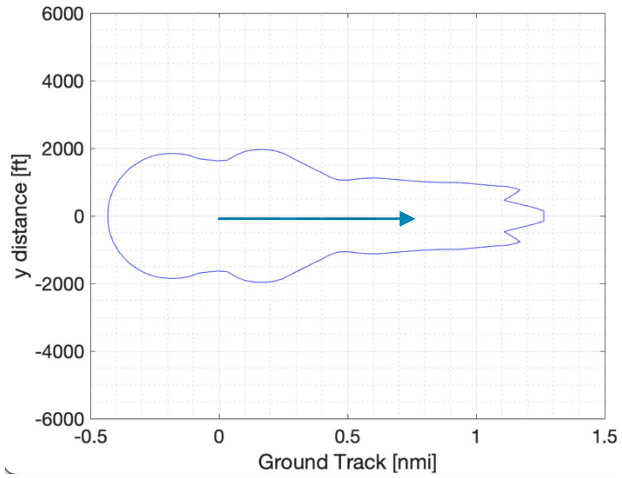
State Values



Altitude Profile



65 $L_{A,max}$ (dBA) Noise Contour

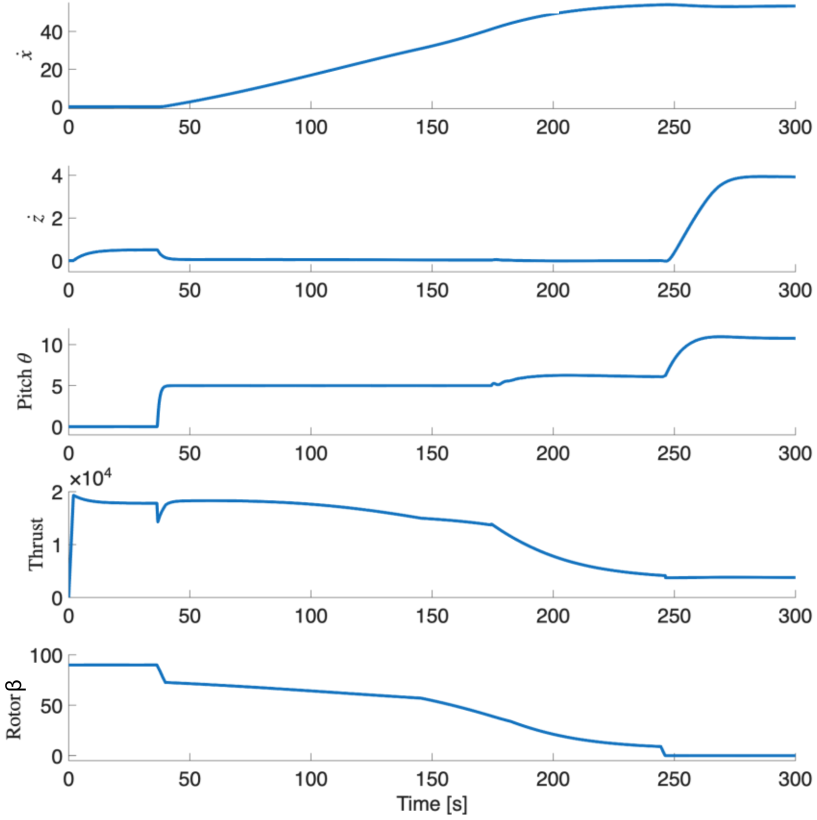


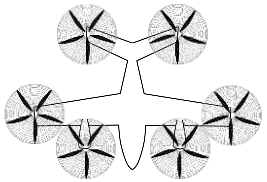
Ground Track [nmi]

Tilt example

*Preliminary results ignore airframe interaction

State Values

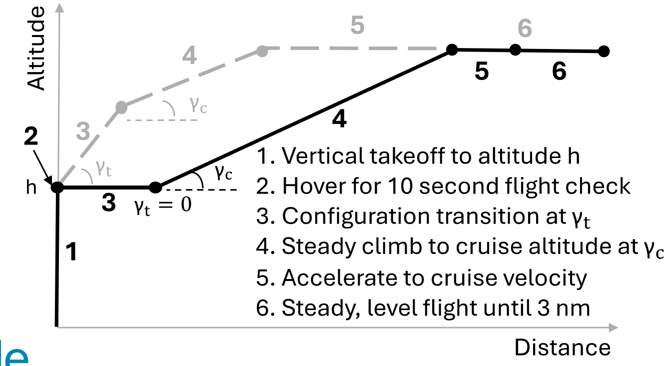




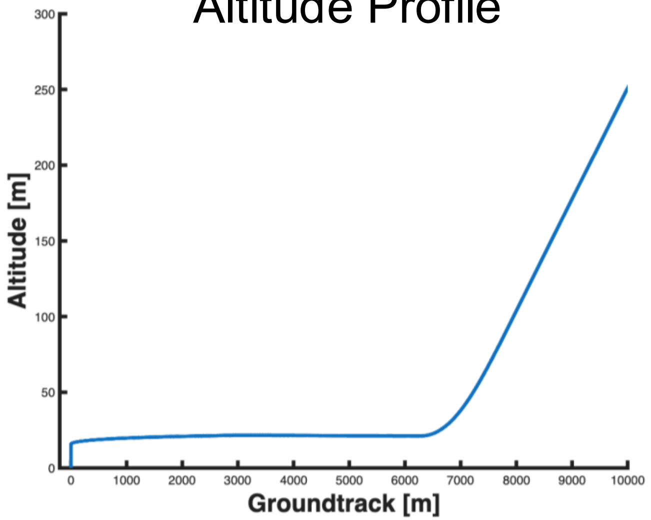
Tilt Rotor

4000 lb, 4 passenger

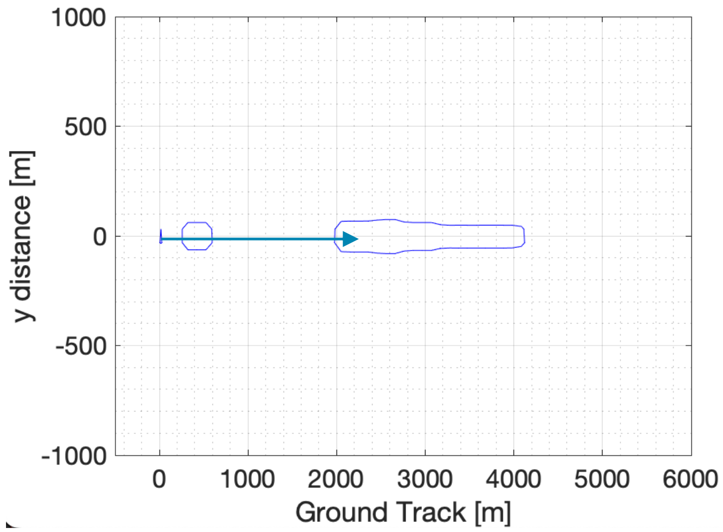
M_{tip} 0.35 in this example



Altitude Profile



65 $L_{A,max}$ (dBA) Noise Contour



Future Work

- Continue evaluating noise impacts due to operational effects to available noise data of Joby, Wisk, and Electra Vehicles
- Deeper exploration of implications for AAM operations in AEDT development
  - Evaluate importance of airframe noise interactions
  - Evaluate need for high resolution noise modeling
  - Consider noise optimized control strategies
  - Do sensitivity analysis of source and propagated community noise for AAM trajectories
  - Evaluate if the current AEDT structure would allow enough conditions (as identified in the sensitivity analysis) to adequately model AAM footprints for representative trajectories or if alternate approaches are required
- Continued validation and model refinement as data becomes available

Recent Accomplishments and Contributions

Publications

- [1] Yeung, et al. "Flight Procedure and Community Noise Modeling of Advanced Air Mobility Flight Vehicles", AIAA Aviation 2023. doi.org/10.2514/6.2023-3361
- [2] Gonzalez, V. et al, (2025) "Impact of Flight Trajectory Design on Performance and Noise for AAM Aircraft", Journal of Aircraft (in production)
- [3] Gonzalez, V. (2025) "A Methodology for Integrating Vehicle Performance into Traffic Flow Management Analysis for AAM Airspace Integration" PhD Thesis, University of California Irvine

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