ASCENT Project 084

Noise Modeling of Advanced Air Mobility Flight Vehicles

University of California Irvine

Massachusetts Institute of Technology

PI: Jacqueline Huynh, John Hansman

PM: Susumu Shirayama

Cost Share Partner(s): Electra.aero

Objective:

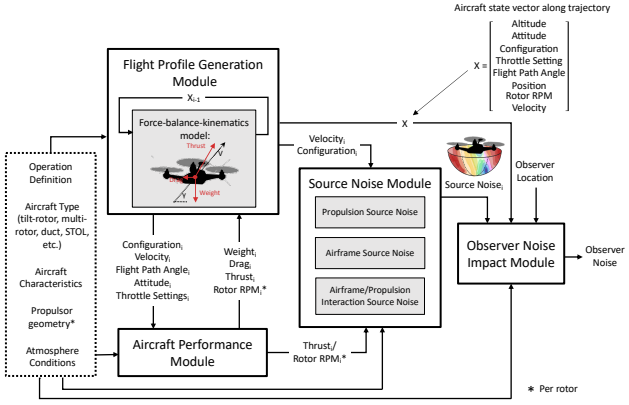
To develop first principles noise models of AAM vehicle configuration(s) to make community noise predictions of these aircraft flying at various operating states. Estimated noise levels from these models will be used to develop methods needed for a AAM-compatible AEDT to make preliminary noise estimates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

Future Work / Schedule:

- Further define flight procedure components of AAM aircraft (Dec 2022)
- Further refine framework for additional AAM aircraft and noise components (March 2023)
- Develop source noise models for representative AAM aircraft components (June 2023)
- Demonstrate noise modeling of representative AAM aircraft for varied operating procedures (Sept 2023)

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Motivation

- Various AAM configurations proposed in industry
- Noise assumed to be a critical aspect of these new AAM configurations
- Community noise impact will be a function of configuration and how vehicles are operated
- Desirable to update AEDT to enable analysis of AAM vehicles and operations

Source: SMG Consulting

Objectives and Methodology

Objectives:

- Develop detailed component-based noise models for AAM vehicles
- Develop simplified noise models that can be compatible with AEDT based on detailed models
- Evaluate potential AAM arrival and departure procedures

Methodology:

- Develop a system analysis framework for AAM to quantify the noise impacts of advanced flight procedures
  - Adapt framework developed in ASCENT 23 (analytical approach for quantifying noise of advanced operational flight procedures)
  - Utilize analysis tools such as ANOPP2, ABEAT to model the key noise sources

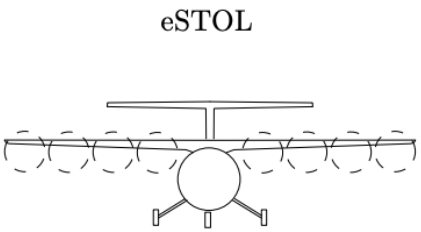
Preliminary Identification of AAM Vehicle Configurations for Analysis

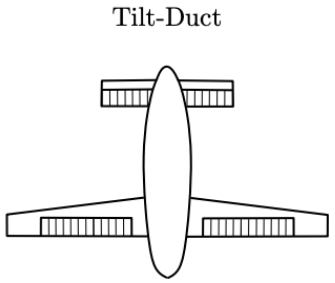
- Various AAM configurations are under consideration in industry, Ex:
  - VTOL
  - VTOL+cruise
  - Short Takeoff and Landing vehicles (STOL)
  - Tilt-duct VTOL
  - Tilt-rotor VTOL
- Work will be expanded to generalized AAM operations for a variety of configurations
  - Will support future developments to model AAM noise in AEDT
  - Representative vehicles from industry used for initial study
  - Will be developed for *generic configurations (i.e. modifiable size)* or representative configurations

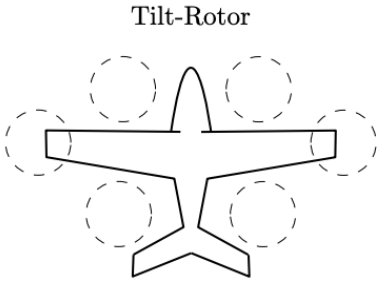
Quadrotor

Lift rotors plus cruise

NASA RVLT reference vehicle configurations
(Figure from Ref. 1)



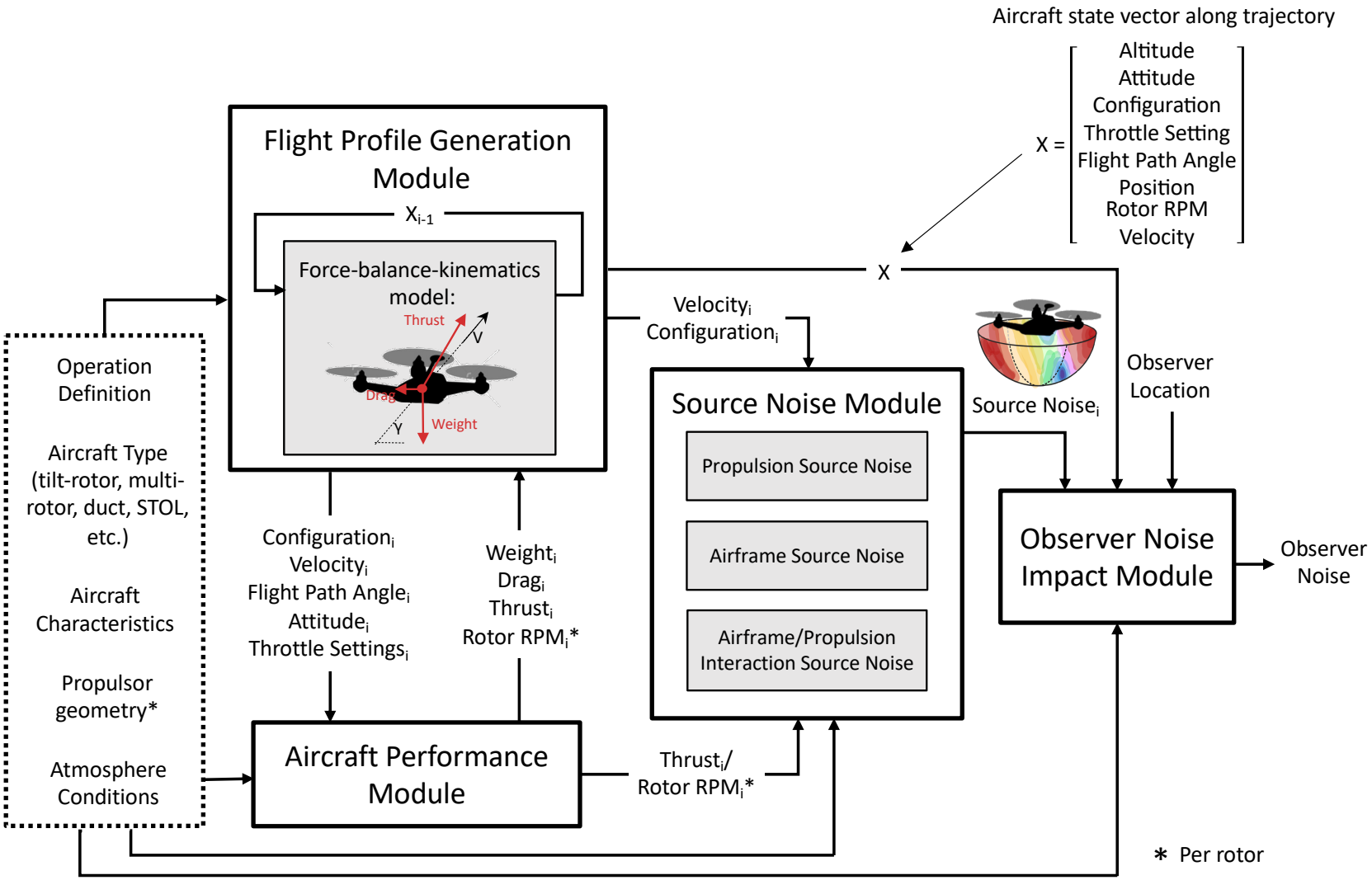




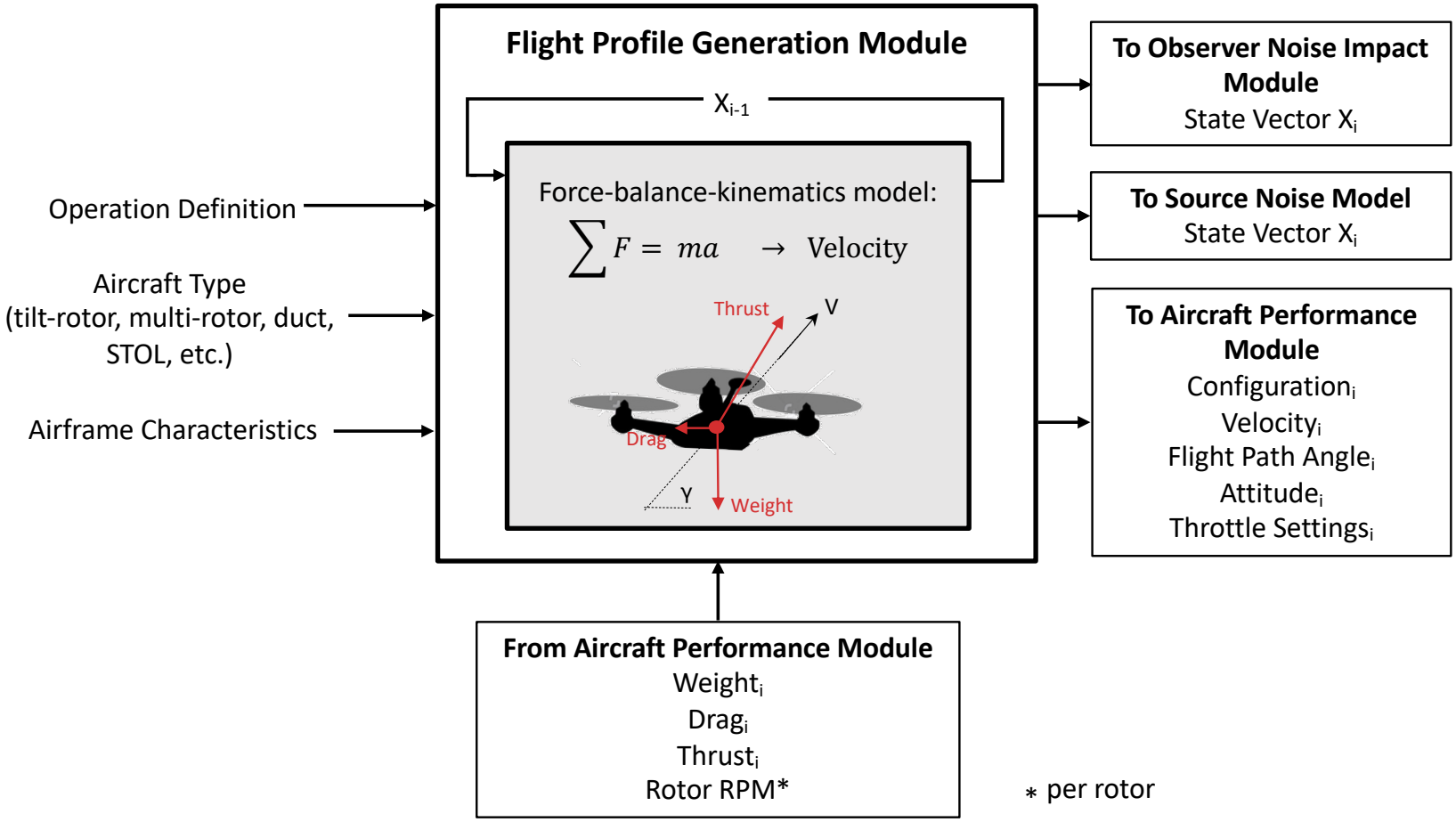
Example Additional AAM Vehicle Configurations,
(figures from ref. 2)

[1] Rizzi, S., Rafaelof, M. "Community noise assessment of urban air mobility vehicle operations using the FAA Aviation Environmental Design Tool", Internoise 2021, Virtual Event.
[2] Courtin, C., Mahseredjian, A., Dewald, A., Drela, M, Hansman, J. "A Performance Comparison of eSTOL and eVTOL Aircraft", AIAA Aviation 2021, Virtual Event.

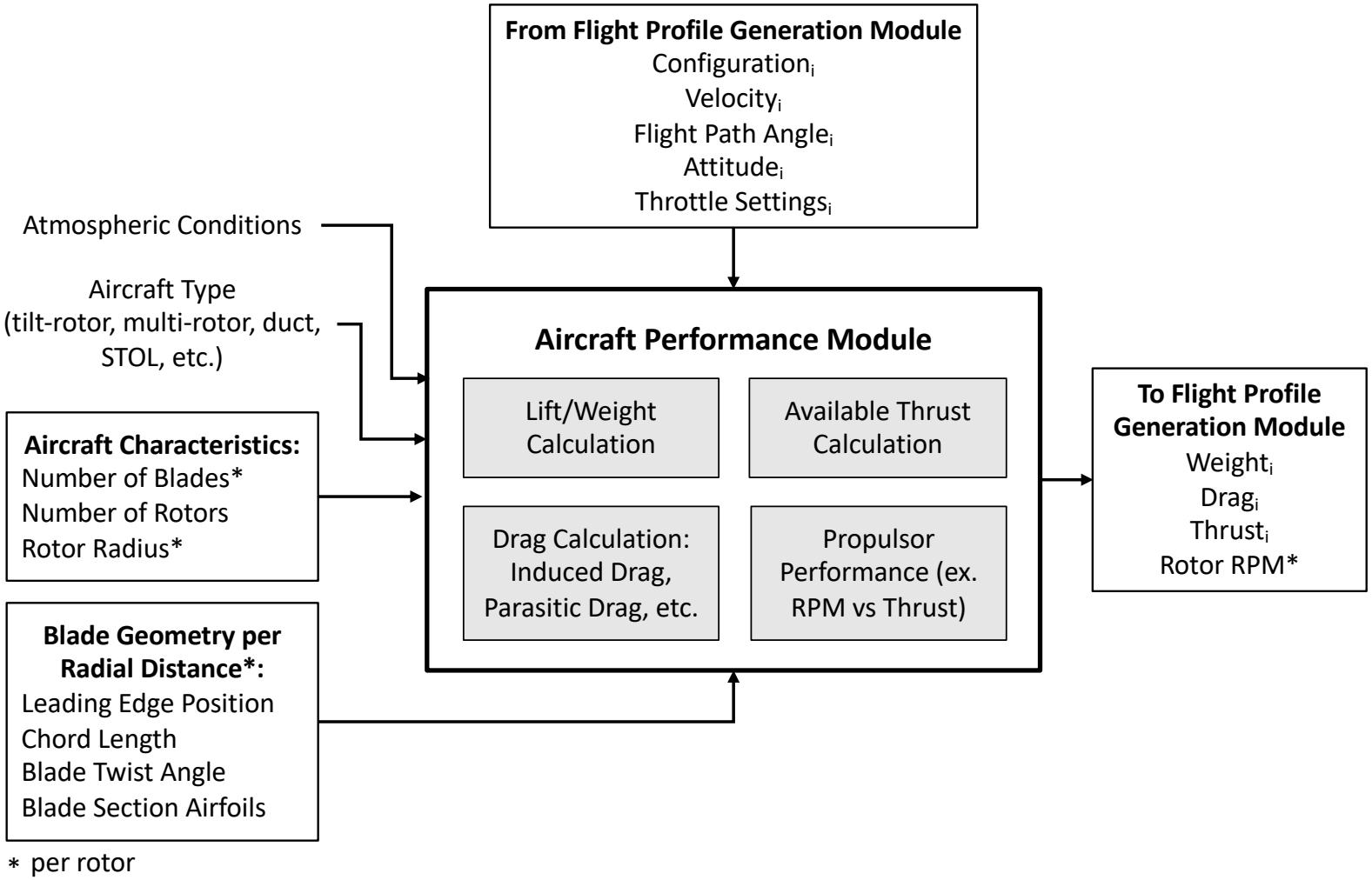
Preliminary AAM Noise Model Framework



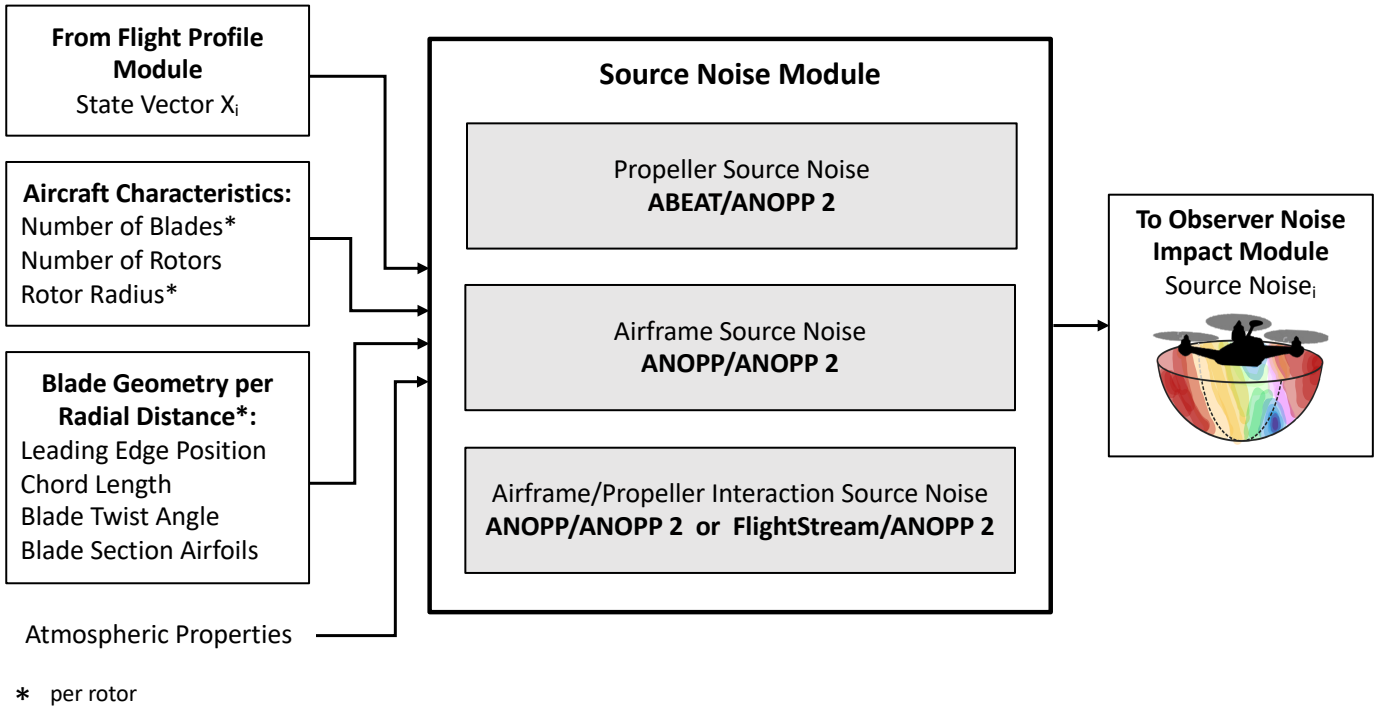
Preliminary AAM Flight Profile Generation Module



Preliminary AAM Aircraft Performance Module



Preliminary AAM Source Noise Module



Source noise module to include:

- Propeller source noise:
  - Loading tonal noise
  - Thickness tonal noise
  - Broadband Blade self noise (each rotor separately, boundary layer effect)
- Airframe source noise:
  - Gear noise, high lift configuration noise, trailing edge noise
- Interaction source noise:
  - Rotor-Airframe/Aerodynamic surface Interaction (RAI)
  - Fuselage-Wake Interaction (FWI)
  - Tonal interrotor constructive destructive interference (CDI)
  - Blade-wake interaction (BWI) from multiple rotors in proximity to one another (from interrotor and intrarotor interactions)
  - Blade-Vortex Interaction (BVI) noise

Current Focus: Noise Model of AAM Vehicles for AEDT Development

- Noise model will be used to model noise at a variety of velocities, flight path angles, and other operating modes for making AAM noise estimates in AEDT
  - AAM configurations can feature unique operating modes (i.e. blown lift for STOL), may need different operating modes for different configurations
  - For AAM version of AEDT, can examine if NPDs and other corrections should use more than one operating condition to interpolate from NPDs
    - i.e. NPD = f(velocity, flight path angle) as opposed to power or a single operating mode

AEDT inputs for noise modeling for different flight segments

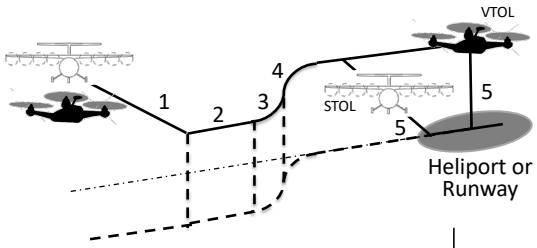
Fixed Wing Aircraft	Helicopters
Altitude and position	
Velocity along the flight path for duration correction	
Engine power & Operating mode (approach, departure, level flight)	Operating mode (16 modes)

Current Focus: Defining Reference Trajectories for AAM vehicles

Flight Procedure Definition:

Ground Track + Segment-by-segment:

- Configuration
  (i.e. Blown Flaps, lift vs. cruise, etc)
- 1 of 3 options:
  - Flight Angle + Velocity
  - Velocity + Power
  - Flight Angle + Power

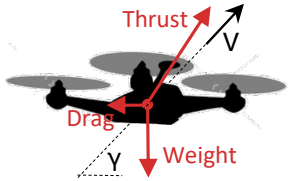


AAM Flight Profile Generator

Flight Performance

Weight, Drag

Force-balance-kinematics model:



Flight Angle + Velocity → Power

Velocity + Power → Flight Angle

Flight Angle + Power → Velocity

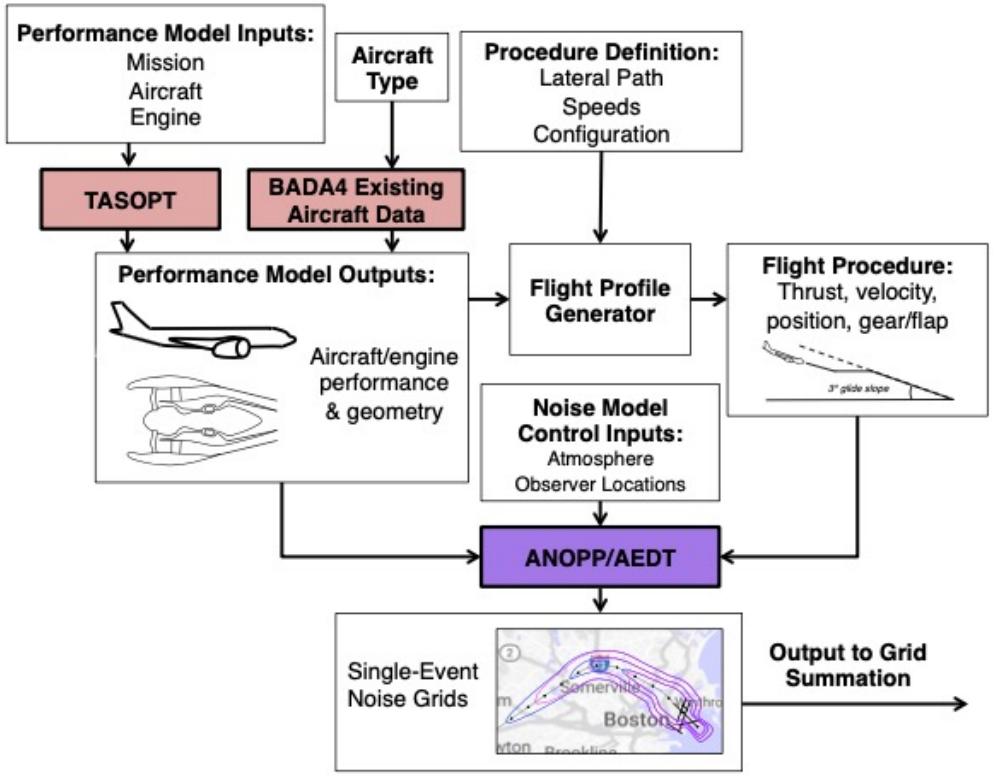
Flight Profile:

Altitude (time)
Position (time)
Configuration (time)
Velocity (time)
Power (time)

APPENDIX

ASCENT 23: Analytical Approach for Quantifying Noise from Advanced Operational Procedures

- ANOPP/AEDT noise analysis coupled with aircraft performance and flight procedure models for commercial transport jet aircraft
  - Advanced flight procedure design for noise abatement
  - Advanced flight procedure noise modeling validation
- Previous work focused primarily on flight procedure re-design for noise abatement at KBOS and currently examining procedures at SEA



Integrated Aircraft Performance, Flight Procedure, and Noise Analysis Framework for Tube and Wing Aircraft