Measurements to Support Noise Certification for UAS/UAM Vehicles and Identify Noise Reduction Opportunities

Project 77

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October 14, 2025
Alexandria, VA

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 13-C-AJFE-PSU through FAA Award Number 112 under the supervision of Dr. Hua (Bill) He. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT

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The Pennsylvania State University

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Cost Share Partner(s): Beta Technologies (UAM OEM)

Objective:

To develop repeatable noise measurement methods for UAS and UAM vehicles and to use these methods to collect noise data on a variety of UAS and UAM configurations across different operating modes, speeds, and altitudes.

Project Benefits:

- Inform noise certification standards
- Research database of UAS and UAM noise
- Reduce negative acoustic impacts of UAS and UAM through design changes and operation

Research Approach:

- Simulate UAS and UAM noise measurements
- Develop noise source separation for distributed propulsion vehicles
- Investigate instrumentation requirements for acoustics, weather, and vehicle state
- Collect noise data on UAS and UAM components and vehicles
- Explore acoustical effects of design changes, operating procedures, and flight control laws

Major Accomplishments (to date):

- UAS noise predictions to inform measurements and validate models
- Measurements of repeatability and variability of multirotor UAS noise
- Development of highly reconfigurable multirotor research UAS vehicles
- Validated multirotor source separation
- Flyover and ground test acoustic measurements of Beta Technologies ALIA-250 UAM aircraft
- Development of a UAS synchrophasing system

Future Work / Schedule:

- Understand causes of variability in UAS and UAM noise
- Expand measurements of UAS/UAM configurations
- Demonstrate in-flight synchrophasing noise control
- Explore effects of flight control system on noise

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Introduction

- **Objectives**
- **Outcomes and Practical Applications**
- **Approach**
- **Recent Accomplishments**
- **Summary**

Objectives

Near term:

- Develop source separation process for "nearly-coherent" noise
- Use simulated environment to design acoustic measurement procedures
- Investigate instrumentation requirements (vehicle, acoustic, weather)
- Collect noise data on a variety of UAS and UAM platforms, including parametric variations of a reconfigurable UAS

Long term:

- Identify the minimum set of instrumentation required to accurately and reliably characterize UAS and UAM noise
- Develop low noise flight procedures for over-actuated vehicles
- Explore low noise design changes
- Develop "acoustically aware" flight control laws

Outcomes and Practical Applications

Outcomes:

- Develop noise measurement and data analysis methods for the accurate and repeatable characterization of highly variable UAS and UAM external noise radiation
- Database of noise measurements across a wide range of UAS and UAM configurations across different operating modes, flight speeds, and altitudes
- Acoustic data processing techniques to separate the contributions of individual rotors or propellers

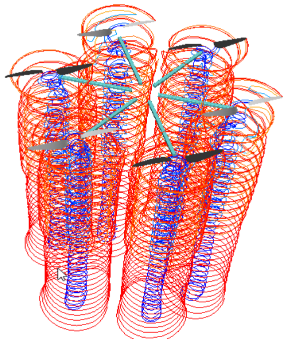
Practical Applications:

- Inform the development of noise certification standards
- Provide FAA and the research community with a better understanding of UAS and UAM external noise
- Provide industry with new experimental approaches to tailoring vehicle designs for low noise
- Reduce negative acoustic impacts of operations through noise abatement guidance and low noise flight control

Research Approach

- Leverage noise prediction tools (e.g., Project 49) to conduct simulated acoustic experiments
- Develop flight procedures and processing methods to characterize and reduce variability and uncertainty
- Collect acoustic data on a variety of UAS and UAM aircraft configurations
- Explore the effects of design changes, operating procedures, and flight control laws on noise

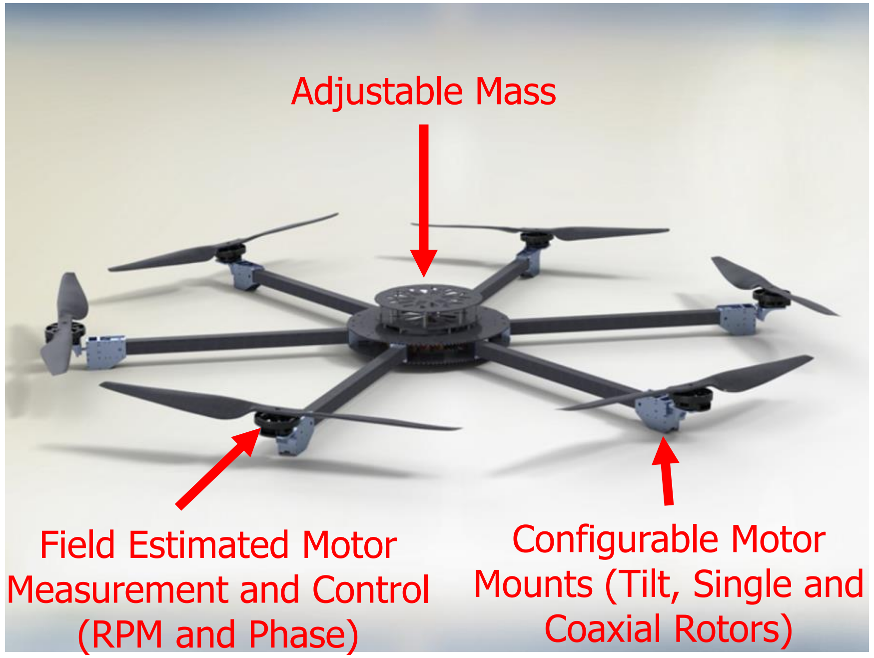
Large reconfigurable UAS in flight with mast mounted air data system

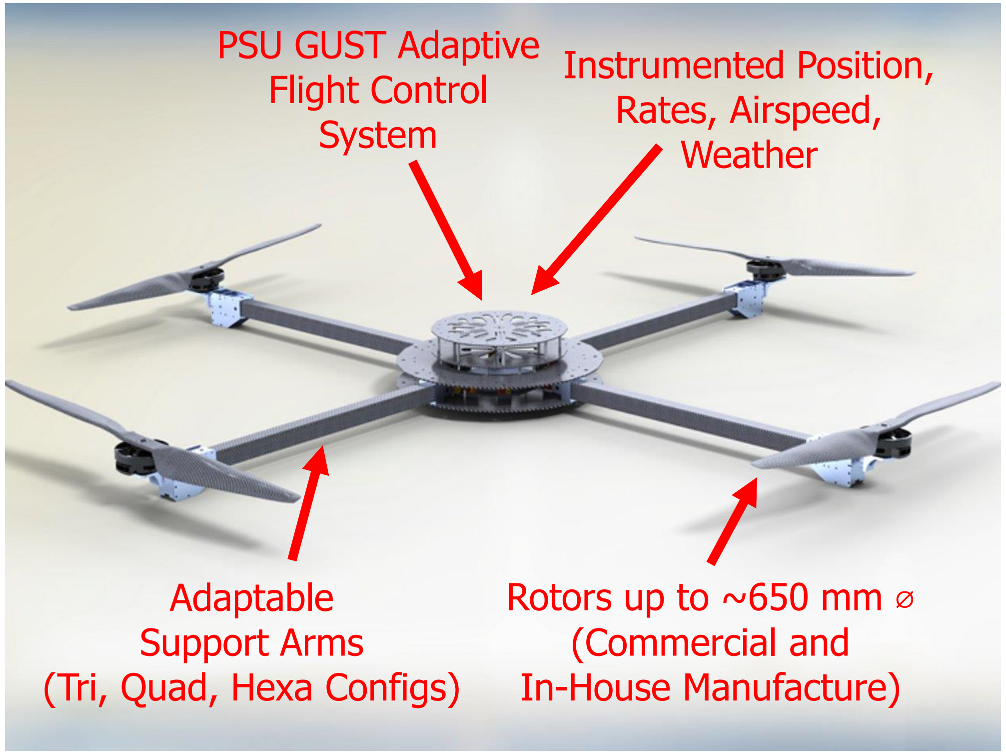


Aerodynamic prediction using CDI's CHARM free vortex wake

Reconfigurable UAS Aircraft

- Large reconfigurable UAS (1.6 m tip-to-tip without rotors)
- Space, weight, and power for research instrumentation sensors
  - Ultrasonic airspeed measurement
  - Onboard recording of RPM and phase
  - Real-Time Kinematic Differential (RTK) GPS

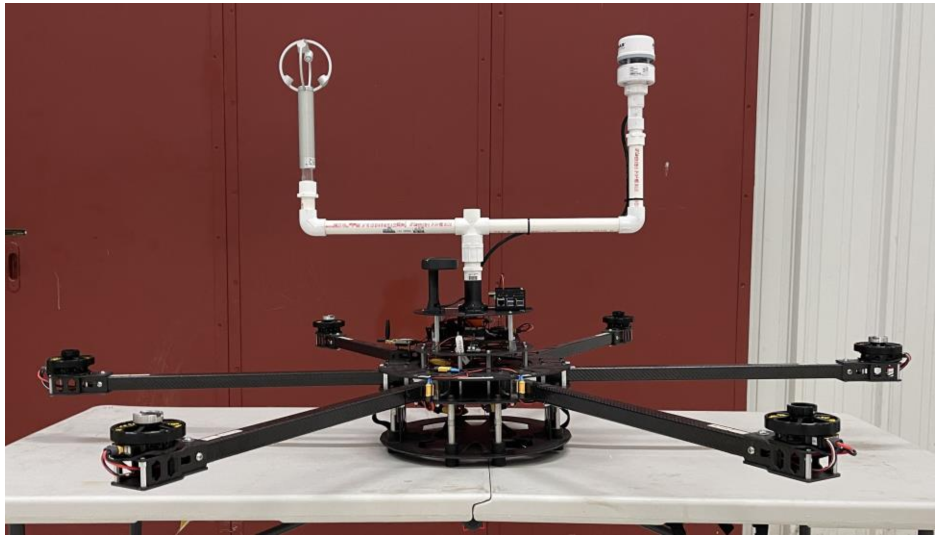




Reconfigurable UAS Modifications

- Weight optimization to increase endurance
- Installed 3D ultrasonic anemometer with faster sampling (~100 Hz) than previous air data system

	RC + GPS	RC + GPS Weather Station
Hexa	31.7 lbs	36.4 lbs
X8	33.2 lbs	37.9 lbs

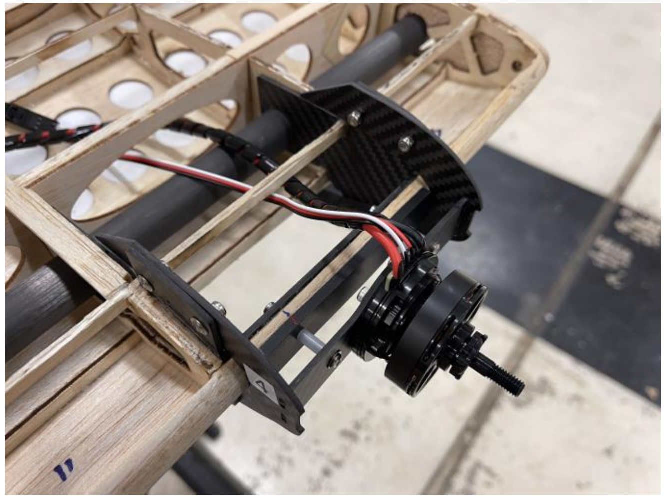


New UAS - Synchrophasing

- Off-the-shelf fixed-wing to reduce complexity
  - Control surfaces and flaps
  - Throttle maps to RPM setpoint
- Wing adapted to support multiple motors, with adjustable mounting locations
- Electronic phase control system for noise reduction

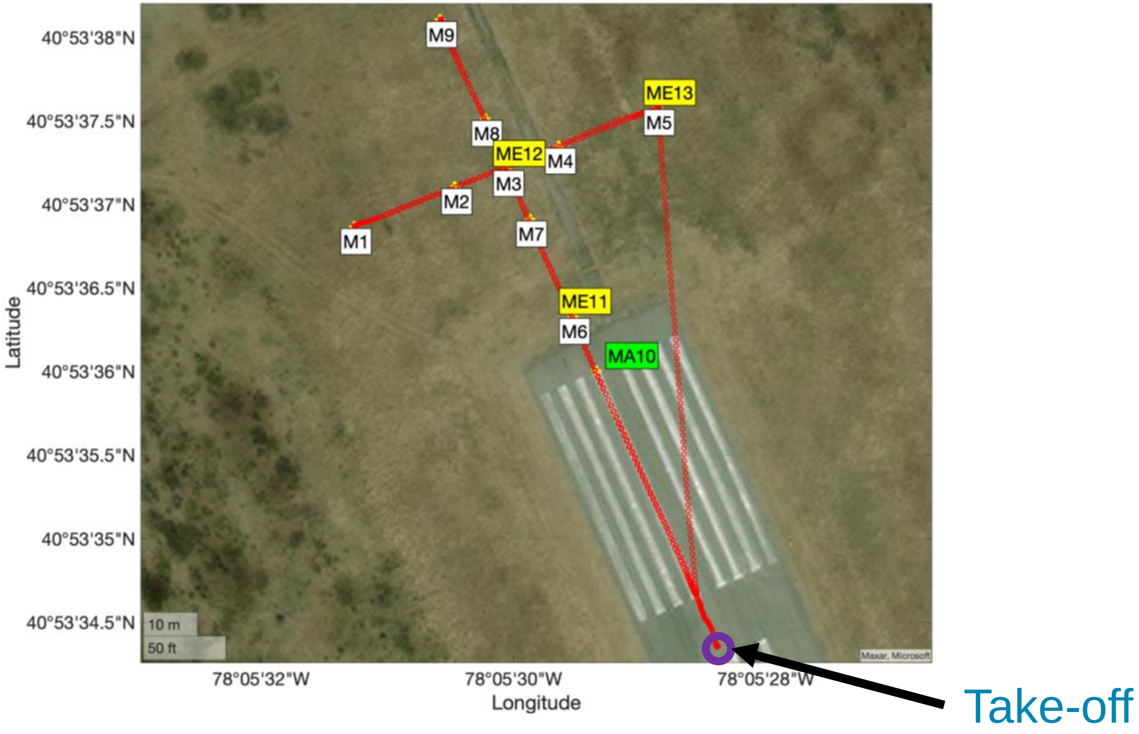
Pilatus PC-6

Wingspan	2720mm / 107.0in
Length	2000mm / 78.7in



Recent UAS Noise Measurements

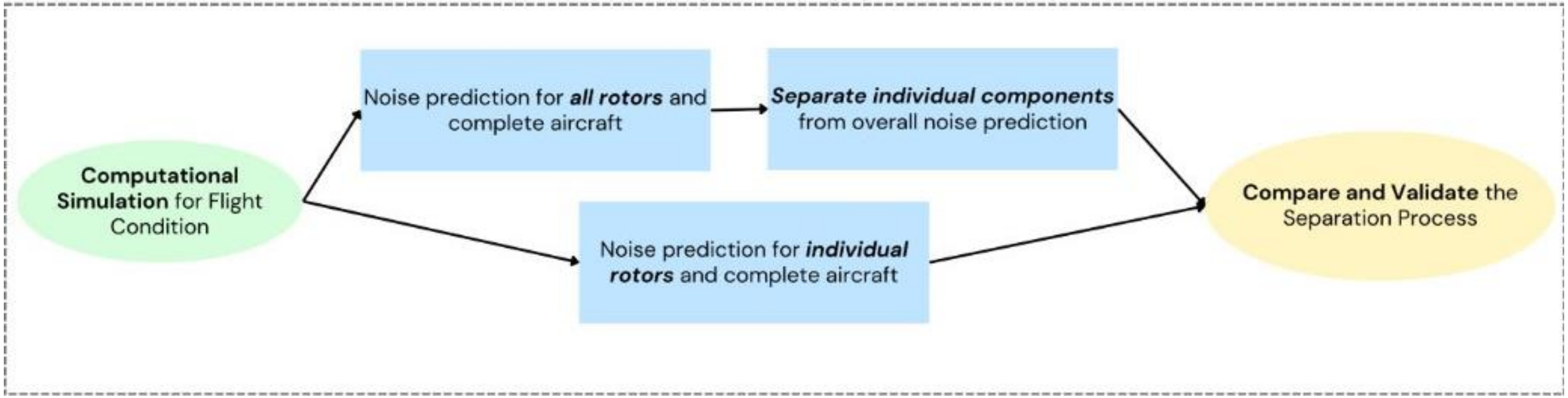
- Collected data with both sonic anemometers
- Included hover and cross flyover



Co-located ground-plane and elevated mics

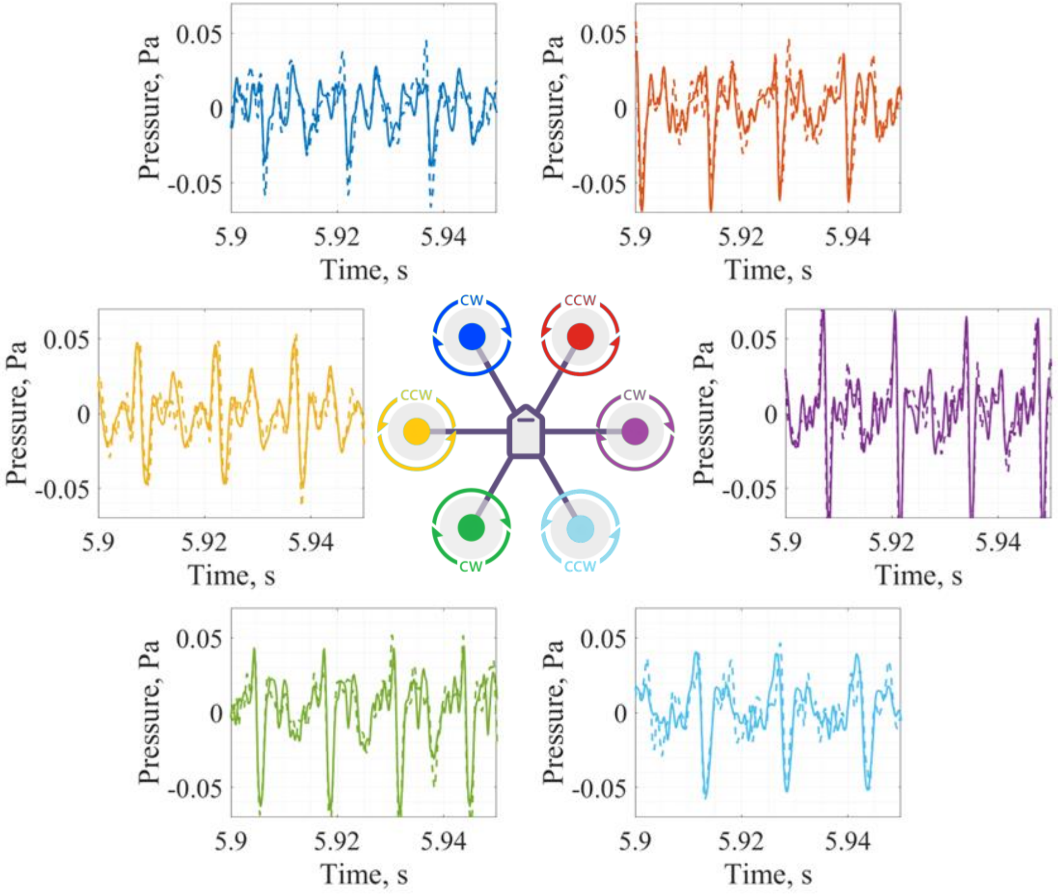
Flight Test Data Analysis

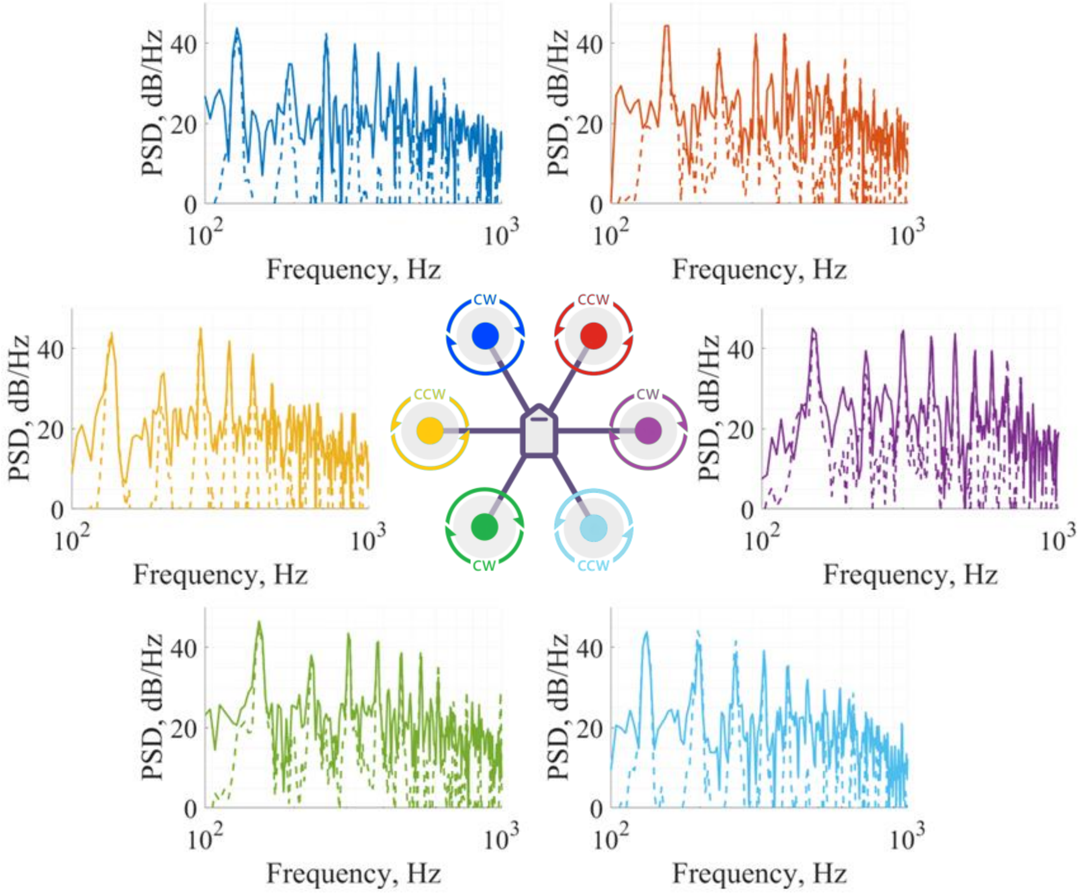
- Noise source separation process developed at Penn State
- Applied to measured noise and state data for helicopters and UAS
- Similar methodology used by NASA on the Joby S4 and BRRC on Archer Midnight
- Current goal is to validate the approach using simulations



SSP in Hover

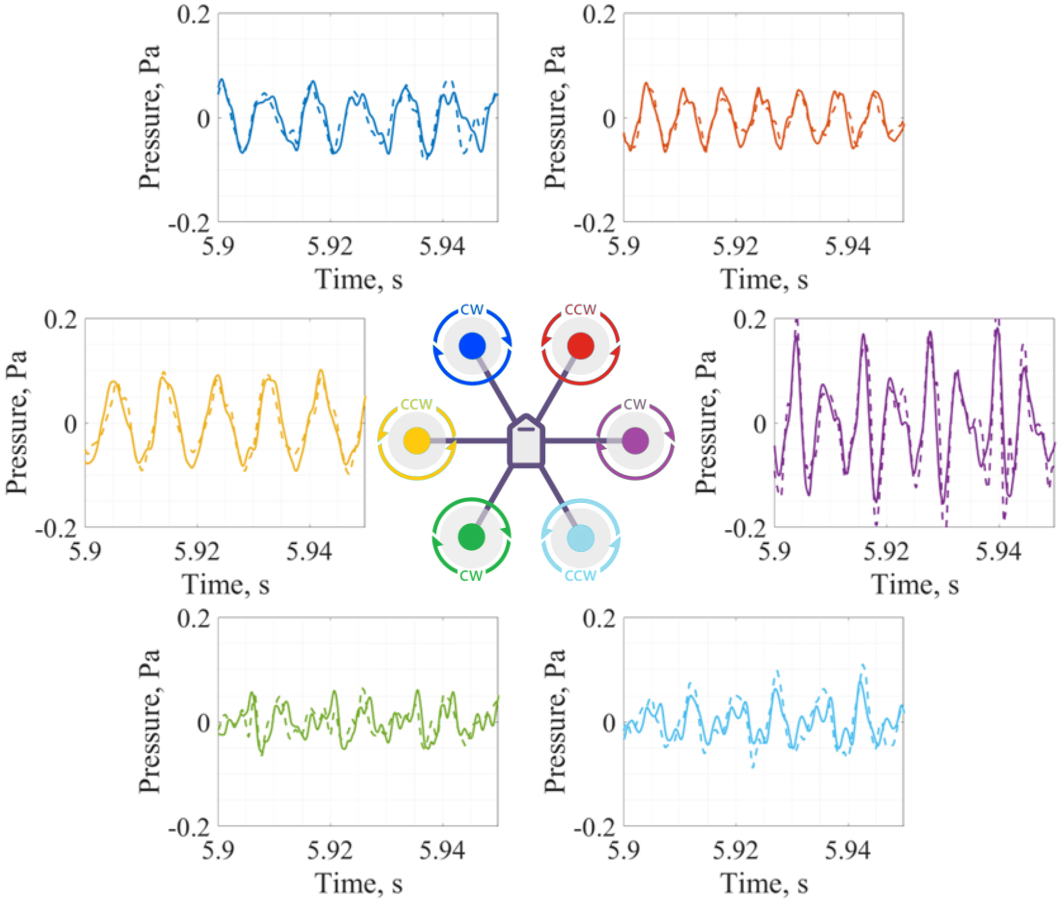
Works in both time- and frequency- domains [predicted-dotted & separated-solid]

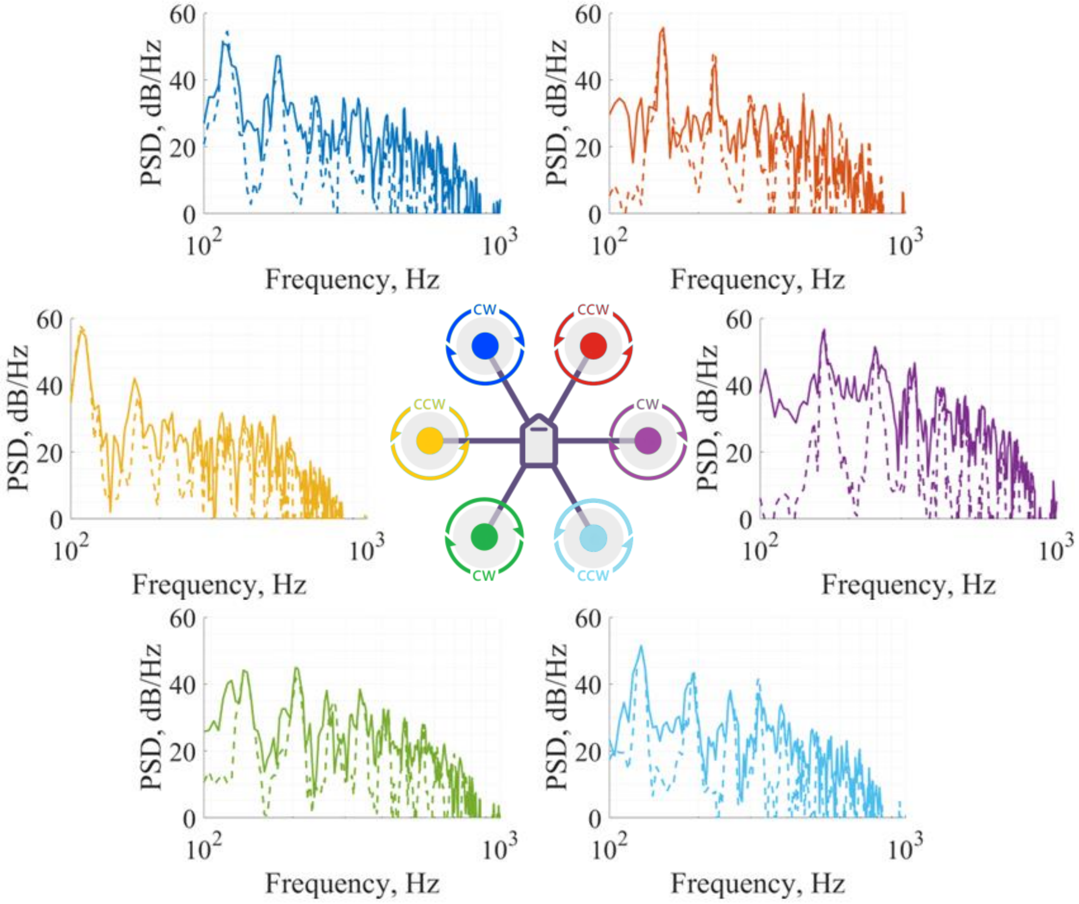




SSP in Level Flight

Works in both time- and frequency- domains [predicted-dotted & separated-solid]

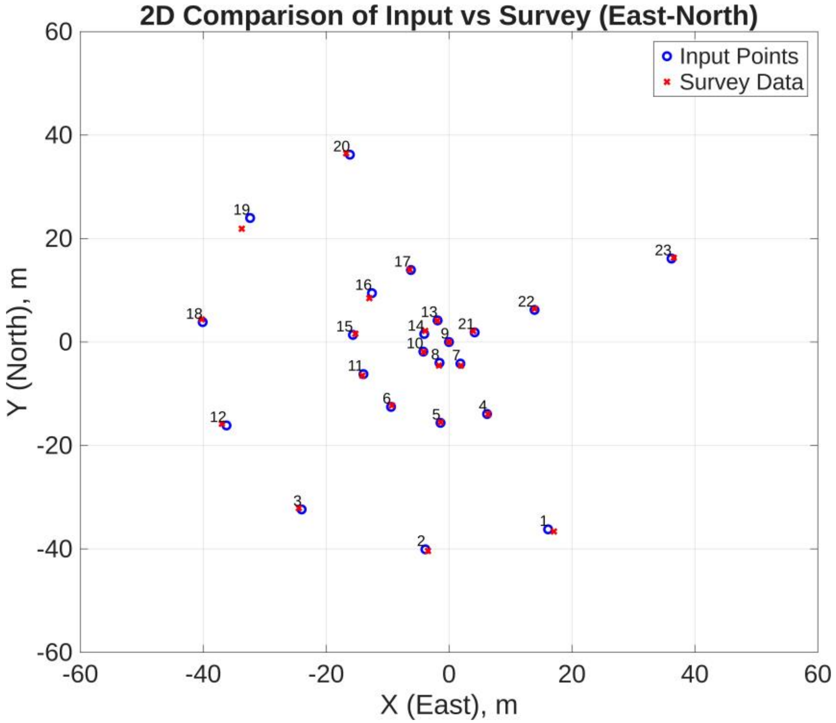




Transient Maneuver Noise Measurements

- Developed test procedures to measure noise during transient maneuvers
- “Snapshot” array technique to capture directivity over a short time interval

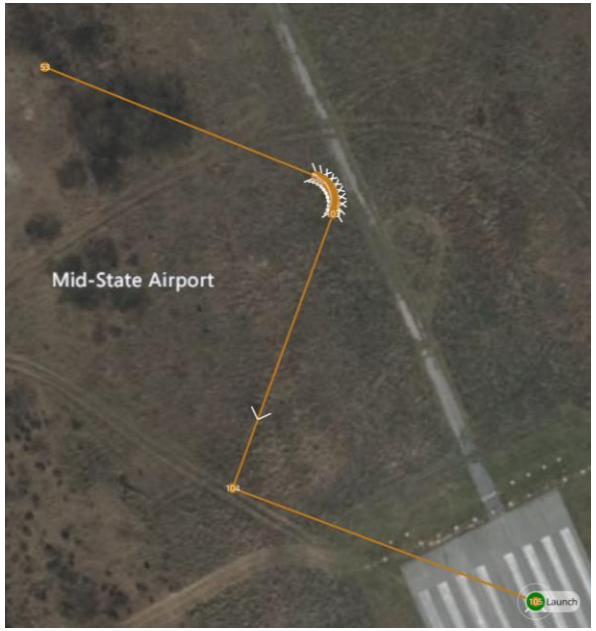
Survey Array Locations



Example Turn Maneuvers

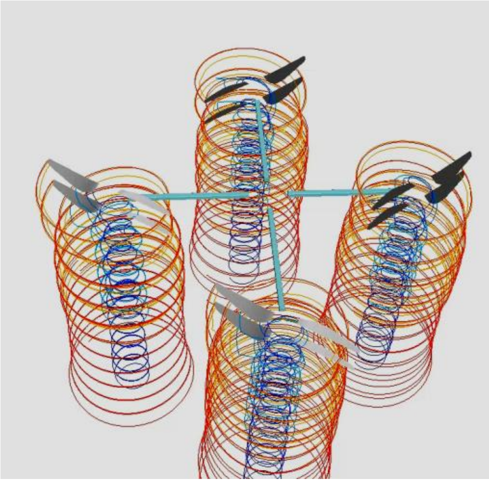
East - 20m radius

West – 5m radius

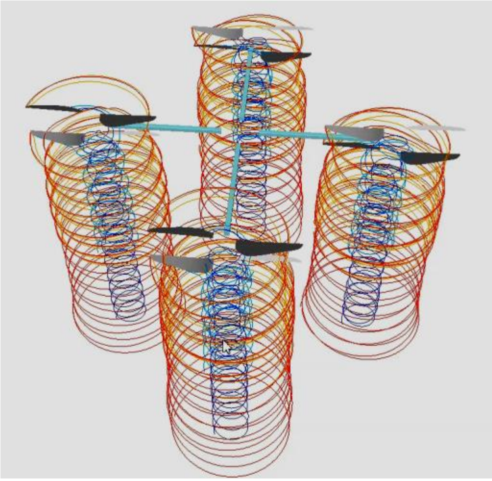


Noise Predictions

- Penn State Noise Prediction System (PSU-NPS)
  - DEPSim (flight simulation)
  - CHARM (aeromechanics)
  - PSU-WOPWOP (acoustics)
- Predictions for co- and counter-rotating X8 configurations



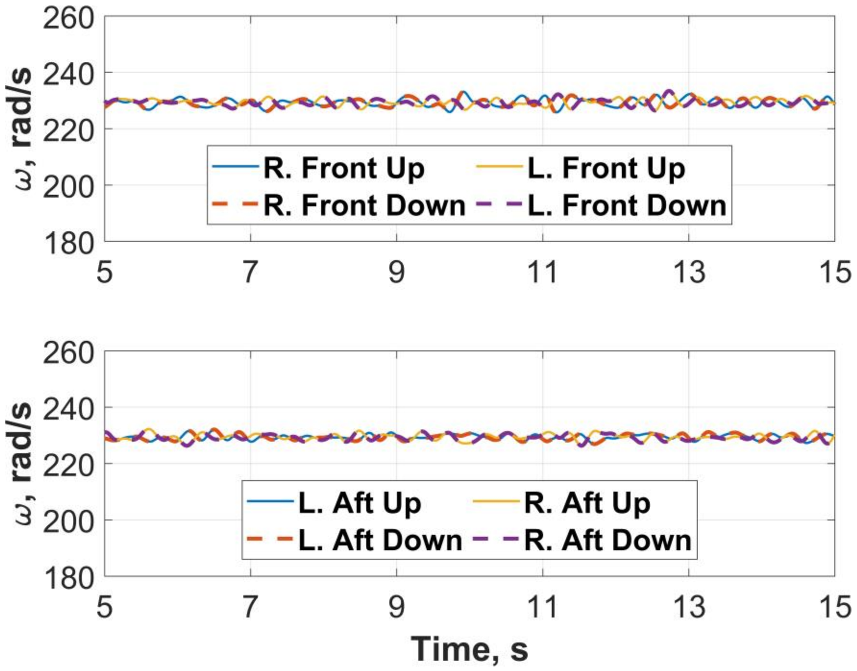
X8 Co-rotating



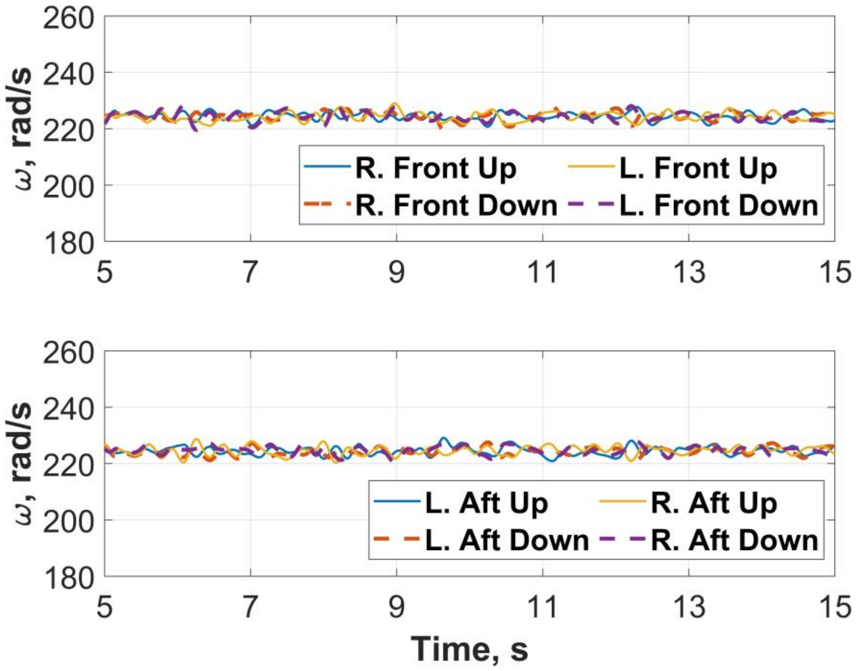
X8 Counter-rotating

X8 Hover Trim

- RPM trimmed to 35 lbf weight
- Co-rotating rotors have slightly higher RPM than counter-rotating
- All eight rotors have similar RPM in either configuration



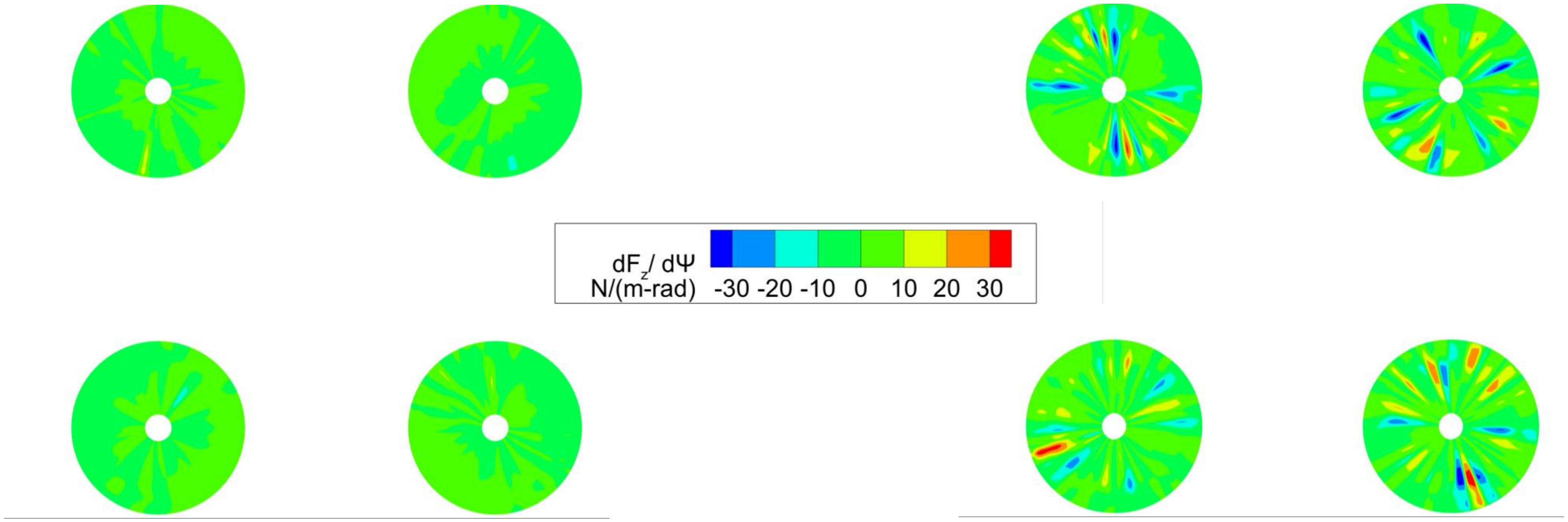
X8 Co-rotating



X8 Counter-rotating

Azimuthal Thrust Variations

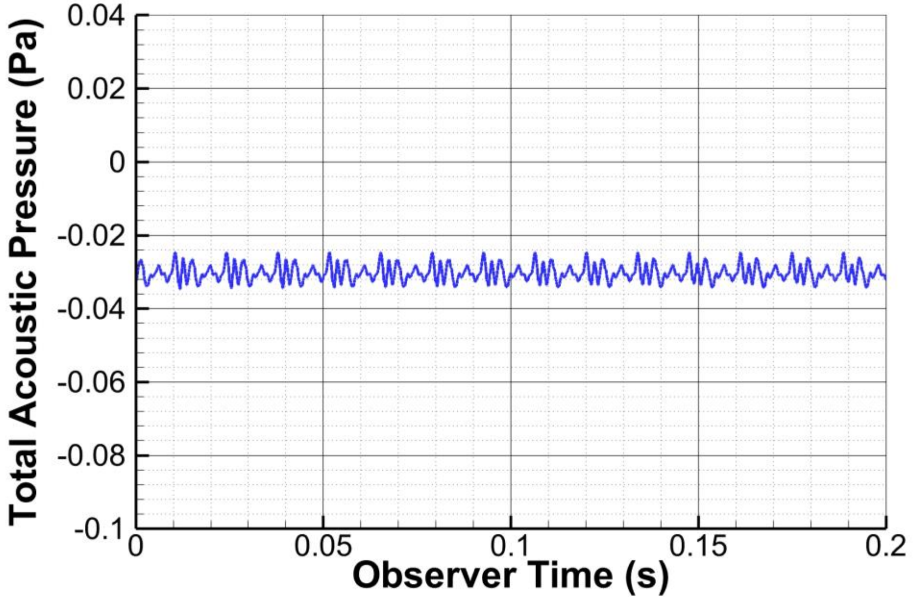
- Time rate of change of lower rotor blade loads
- Stronger interactions for counter-rotating rotors than for co-rotating



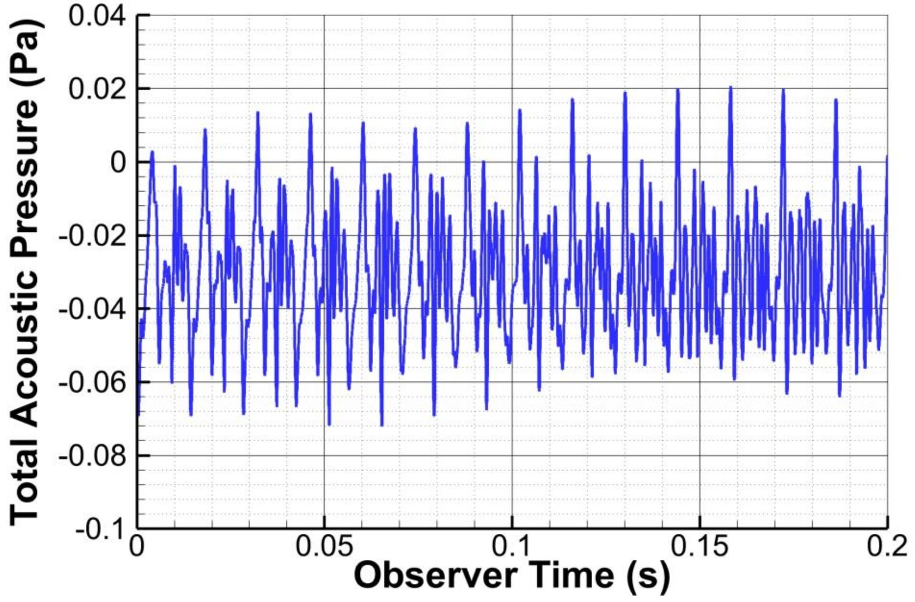
X8 Co-rotating X8 Counter-rotating

Acoustic Pressure Time History

- Acoustic observer at 20 rotor radii, 80° below rotor plane
- Counter-rotating configuration significantly noisier than co-rotating
- Counter-rotating interaction noise is impulsive, consistent with prior laboratory studies



X8 Co-rotating

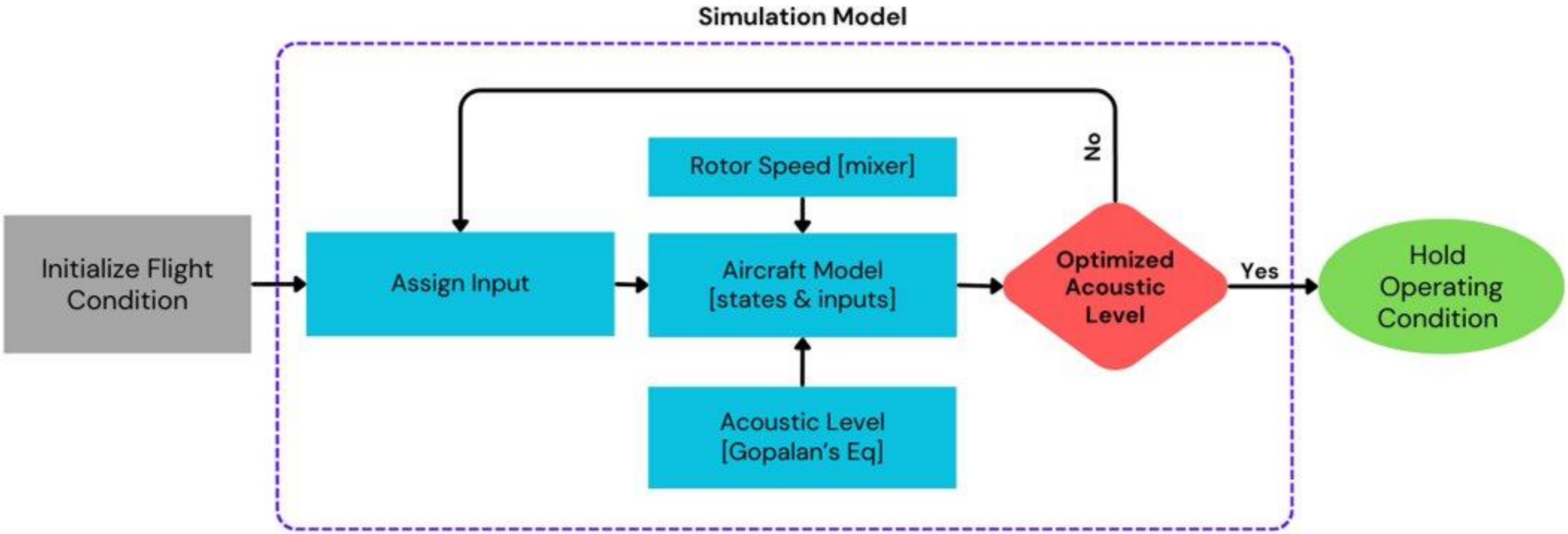


X8 Counter-rotating

Aeroacousic Controller Design

Outline of Proposed Approach:

- Aircraft flight dynamics status: implemented
- Acoustics status: implemented
- Aeroacoustic controller status: in progress



Summary

- Developed new UAS configurations and predicted noise
- Preparing for in-flight sychrophasing demonstration
- Verification of source separation process
- Developing new aeroacoustic flight controller

Next Steps

- Noise measurements of new UAS configurations
- Evaluation of snapshot array configuration
- Noise measurements of Beta Technologies' ALIA A250 VTOL and ALIA CX300 CTOL aircraft for research purposes

Plans for FY2026

- Predictions of noise during transitions between vertical and forward flight modes
- Experimental validation of transition noise predictions
- Investigation of effects of wind and turbulence on noise generation and variability
- Implementation and demonstration of a low noise flight control system
- Assessment of weather and instrumentation requirements for UAS noise measurements

Acknowledgements

- PI: Eric Greenwood, Penn State University (PSU)
- PM: Hua (Bill) He (FAA)
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- Senior Personnel: Vítor Tumelero Valente (PSU)
- GRAs: Joel Sundar Rachaprolu, Rupak Chaudhary, EzzEldin ElSharkaway (PSU)
- Industrial Partners: Beta Technologies
- Advisory Panel: Christopher M. Hobbs (FAA), Rudramuni K. Majjigi (FAA), David A. Senzig (FAA), Philip McCarthy (NRC), D. Caleb Sargent (Sikorsky), Royce Snider (Bell), Parthiv Shah (ATA), Juliet A. Page (BRRC), Shane Lympany (BRRC), Jeremy Bain (Joby), Austin Thai (Joby)

Thank You!