BEFAV*

Bio-Inspired Environmentally Friendly Aerial Vehicle

Mission & Requirements:

BEFAV is a fully autonomous electric aircraft that can operate between rural and metropolitan areas to deliver goods. BEFAV aims to blend with nature while not disrupting the wellbeing of communities and local species.

- **300 km operating range with divert range of 10 km**
- **100-200 kts cruise airspeed capability at 1,500 m ASL**
- **3,000 kg MTOW**
- **-40°C to 50°C operating temperature range**
- **VTOL capability**
- **Land autonomously in low visibility**

Aerodynamics:

The aerodynamics team aims to maximize the lift and thrust performance and minimize the drag and noise of the wings, fuselage, landing gear, and propulsion system.

Systems:

The systems team aims to develop a robust and accurate flight dynamics model, ensuring the reliability and functionality of BEFAV in all operational scenarios.

Structures:

The structures team aims to minimize the weight of the main wing, fuselage, canard, landing gear, cabin layout, and engine integration while maintaining structural integrity.

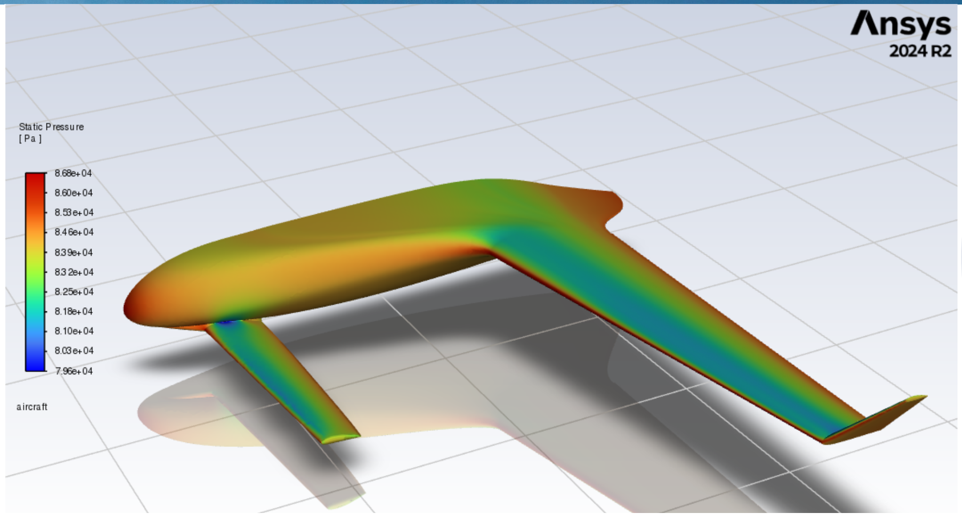
*<u>NOTE</u>: BEFAV project is designed for Aerospace Engineering students, preferably streams A and B.

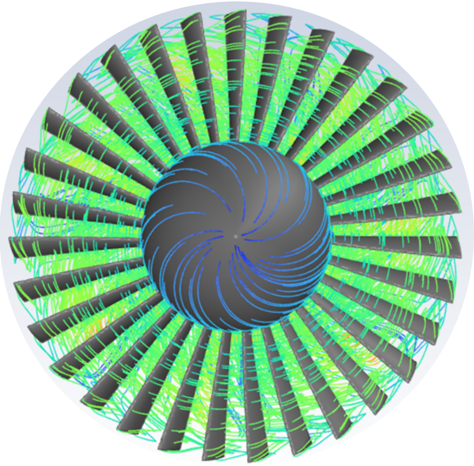
AERODYNAMICS

Bio-Inspiration:

The aerodynamics team implemented several bio-inspired concepts to reduce BEFAV's noise emissions.

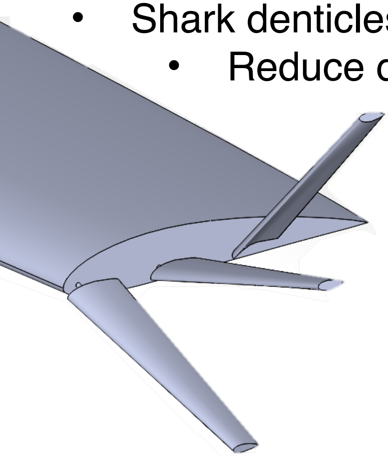
- Owl wing topology
  - Leading-edge serrations on the main wing winglet and stator vanes
  - Trailing-edge serrations to the main wing
- Harris' Hawk wingtips
  - Non-planar wingtip devices increase lift in low Reynolds number flight
- Shark denticles
  - Reduce drag on the landing gear





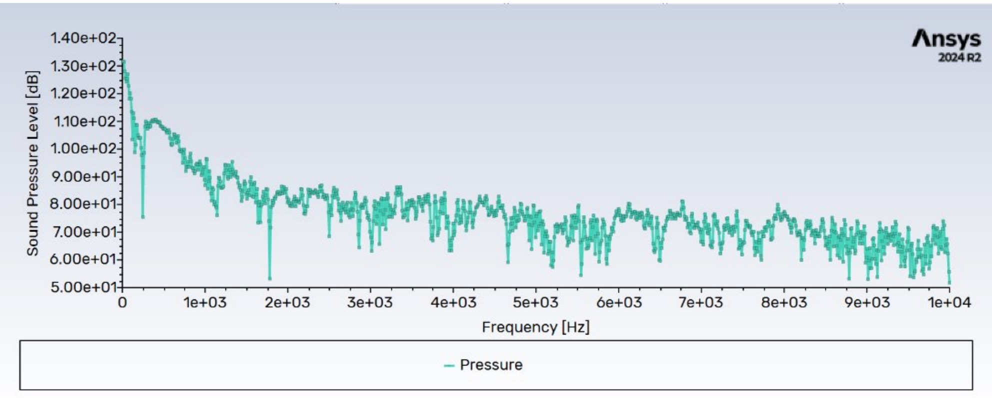
Computational Fluid Dynamics:

The aerodynamics team frequently used CFD techniques to analyze and optimize the aerodynamic behaviour of BEFAV.

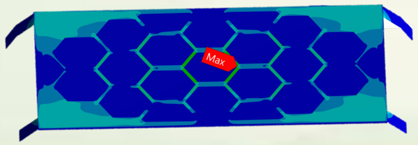


Computational Acoustic Analysis:

CAA techniques were used to verify the effectiveness of noise mitigation techniques on components of BEFAV.

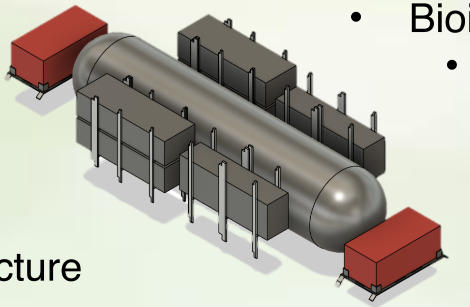


STRUCTURES



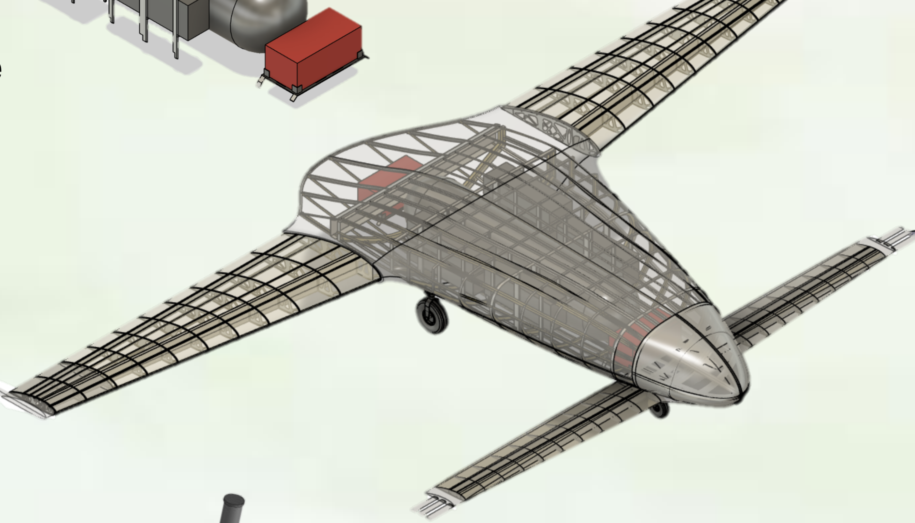
Full Cabin Layout

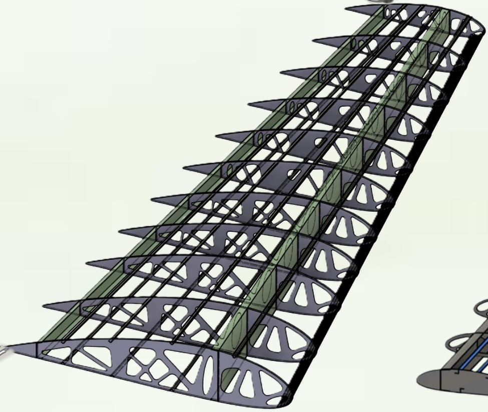
- Choose layout to optimize CoG
- Design internal supports for components
- Bioinspiration: honeycomb structure

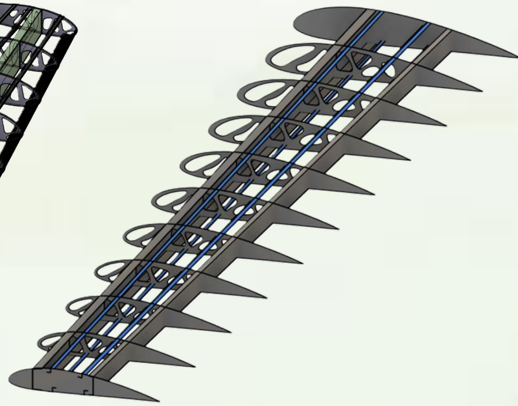


Engine/Propulsion Integration

- Aft-rib (riblet) hinge Develop attachments for engine mount
- Bioinspiration: bird bone
  - T-joints

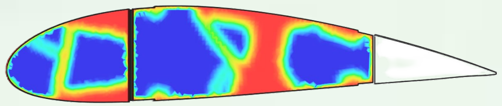


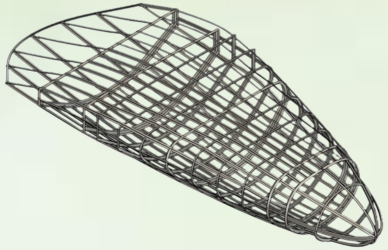


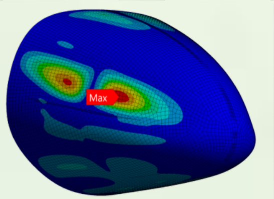


Main Wing and Canard Structures

- Reduce weight, maintain high strength/stiffness
- Limit skin deformation
- Bioinspiration: bird bone structure
  - Topology optimization







Fuselage Structures

- New fuselage structures to match blended wing body configuration
- Midsection semi-monocoque style
- Forward and aft supported by stiffeners
- Bioinspiration: bamboo skin

Full Landing Gear Structures

- Support load of aircraft
- Oleo-pneumatic shock absorbers
- Steerable nose gear
- Bioinspiration: peacock tail

CONTROL SYSTEMS, STABILITY, AND AVIONICS

Flight Dynamics

$$A_{long}=\begin{bmatrix}-0.0730 & 0.0028 & 0.2328 & -9.8100\\ -0.0213 & -0.1973 & 67.00 & 0\\ -0.0001 & -0.0342 & -0.0162 & 0\\ 0 & 0 & 1.0000 & 0\end{bmatrix}$$

$$A_{lat}=\begin{bmatrix}-0.7634 & 0.0090 & -62.1143 & 9.8100\\ -0.0192 & 16.7080 & 0 & 0\\ -0.0551 & 1.3618 & -0.5731 & 0\\ 0 & 1.0000 & 0 & 0\end{bmatrix}$$

$$B_{long}=\begin{bmatrix}\frac{\partial\dot{u}}{\partial Fx_{C1}} & \cdots & \frac{\partial\dot{u}}{\partial Fx_{M4}} & \frac{\partial\dot{u}}{\partial Fz_{C1}} & \cdots & \frac{\partial\dot{u}}{\partial Fz_{M4}}\\ \frac{\partial\dot{w}}{\partial Fx_{C1}} & \cdots & \frac{\partial\dot{w}}{\partial Fx_{M4}} & \frac{\partial\dot{w}}{\partial Fz_{C1}} & \cdots & \frac{\partial\dot{w}}{\partial Fz_{M4}}\\ \frac{\partial\dot{q}}{\partial Fx_{C1}} & \cdots & \frac{\partial\dot{q}}{\partial Fx_{M4}} & \frac{\partial\dot{q}}{\partial Fz_{C1}} & \cdots & \frac{\partial\dot{q}}{\partial Fz_{M4}}\\ \frac{\partial\dot{\theta}}{\partial Fx_{C1}} & \cdots & \frac{\partial\dot{\theta}}{\partial Fx_{M4}} & \frac{\partial\dot{\theta}}{\partial Fz_{C1}} & \cdots & \frac{\partial\dot{\theta}}{\partial Fz_{M4}}\end{bmatrix}$$

$$B_{lat}=\begin{bmatrix}\frac{\partial\dot{v}}{\partial Fx_{C1}} & \cdots & \frac{\partial\dot{v}}{\partial Fx_{M4}} & \frac{\partial\dot{v}}{\partial Fz_{C1}} & \cdots & \frac{\partial\dot{v}}{\partial Fz_{M4}}\\ \frac{\partial\dot{p}}{\partial Fx_{C1}} & \cdots & \frac{\partial\dot{p}}{\partial Fx_{M4}} & \frac{\partial\dot{p}}{\partial Fz_{C1}} & \cdots & \frac{\partial\dot{p}}{\partial Fz_{M4}}\\ \frac{\partial\dot{r}}{\partial Fx_{C1}} & \cdots & \frac{\partial\dot{r}}{\partial Fx_{M4}} & \frac{\partial\dot{r}}{\partial Fz_{C1}} & \cdots & \frac{\partial\dot{r}}{\partial Fz_{M4}}\\ \frac{\partial\dot{\phi}}{\partial Fx_{C1}} & \cdots & \frac{\partial\dot{\phi}}{\partial Fx_{M4}} & \frac{\partial\dot{\phi}}{\partial Fz_{C1}} & \cdots & \frac{\partial\dot{\phi}}{\partial Fz_{M4}}\end{bmatrix}$$

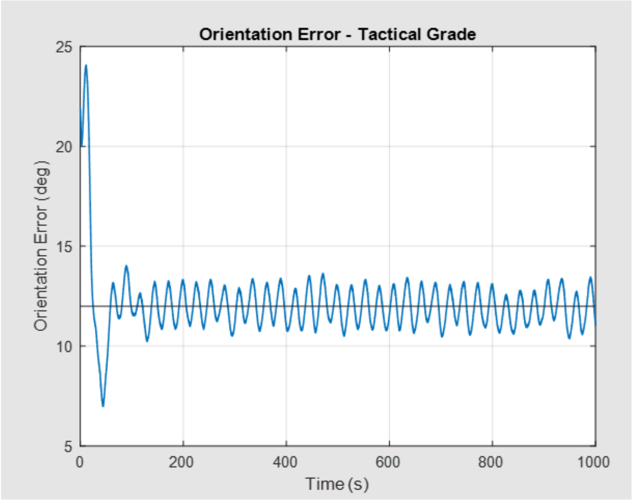
$C = I_{12x12}$ $\quad D_{All} = 0_{12x12}$

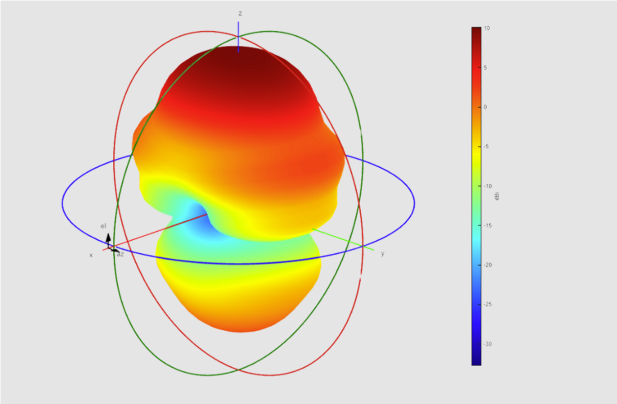
Tactical-Grade Orientation Error

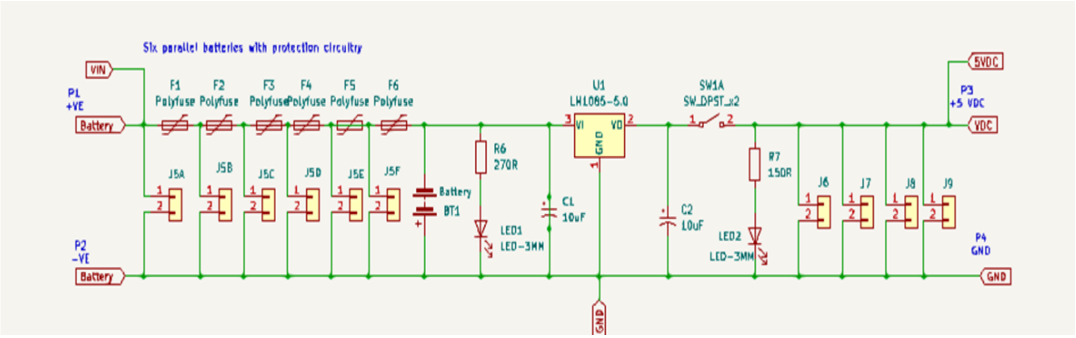
- Mean Orientation Error (12.09°)
- Orientation Error std σ (1.69°)
- Max Gyroscope Bias (0.11°/s)

Radiation Pattern of Yagi-Uda Antenna

- Better signal range and reliability
- Lower power consumption
- Easier integration & testing

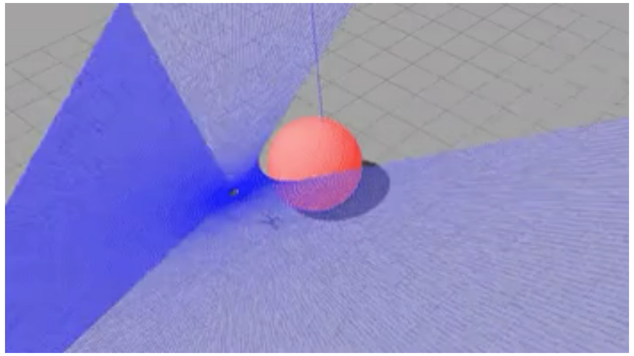






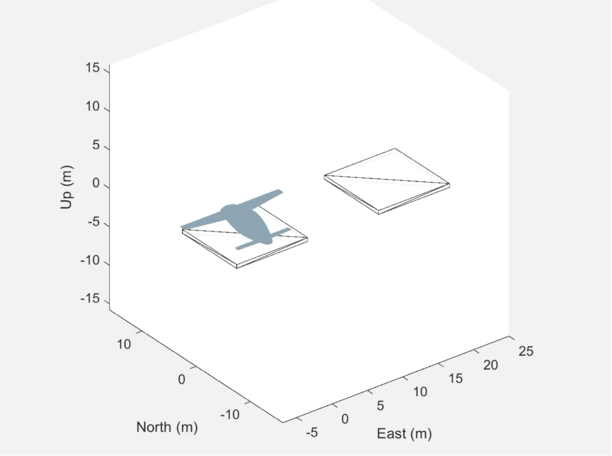
Voltage Regulation and Battery Safety Circuit

- Attitude control for takeoff, cruise, and landing



APF in ROS for PX4-Iris with LiDAR

- Obstacle Avoidance Algorithm for Path Planning



Take-off & Landing Simulation

- Attitude control for takeoff, cruise, and landing