Wind Tunnel Testing Plan

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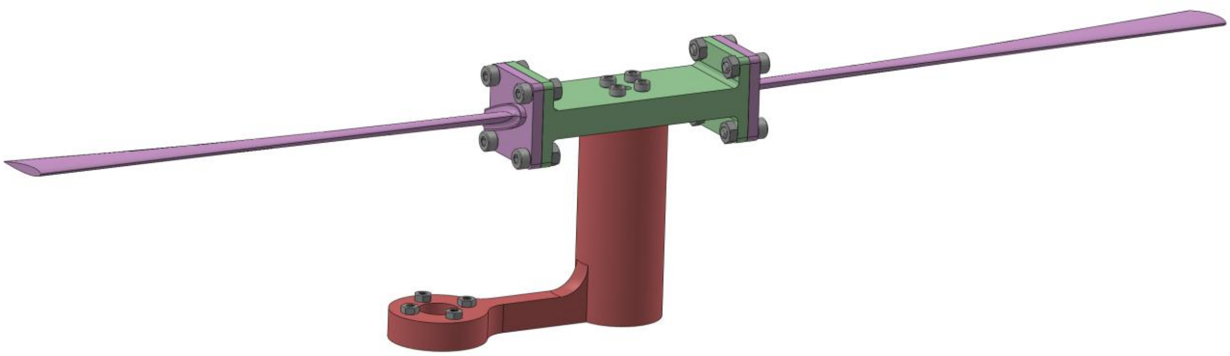
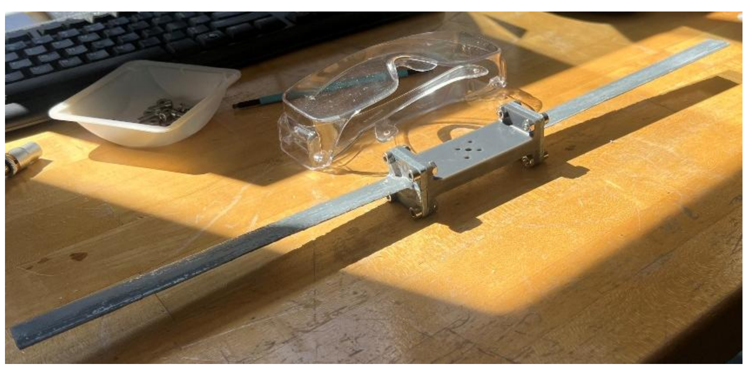
1. What are we testing:
    a. 25 pairs of wings
        i. LHS within design space
            1. AR: [18.75,31.25]
            2. λ : [0.5,1.0]
            3. α_0: $[10,20]\ deg$
            4. α_t: $[3,8]\ deg$
        ii. Total wingspan (b): 460mm





    b. Measuring lift, drag, and airspeed using our own load cells and airspeed sensor & pitot tube
    c. Training surrogate model on L/D using geometry parameters as features
        i. A model for VTOL has already been trained using the thrust stand with a brushless motor with good results
        ii. We want to get this cruise performance model trained so optimization of a stop-rotor lifting surface operating in VTOL & cruise can be done

2. Engineering Diagrams of the mounting structure

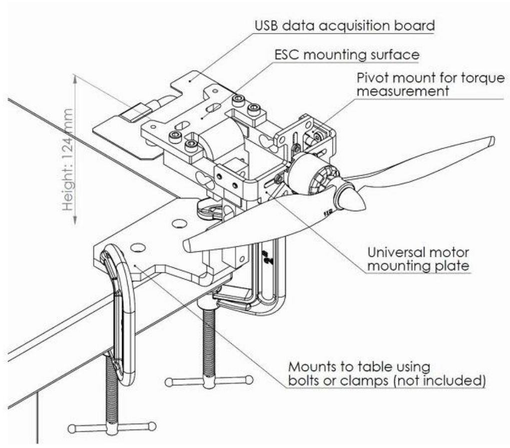


Fig. 1: Hardware overview

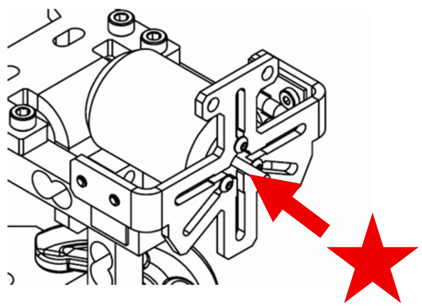


Fig. 2: Mounting shown with 36 mm∅ and 53 mm length inrunner motor.

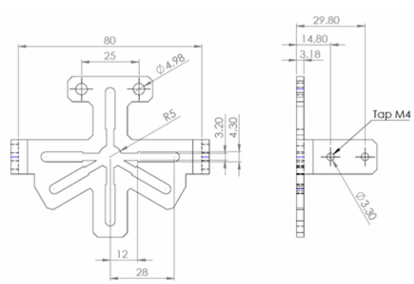


Fig. 3: Motor mounting part dimensions

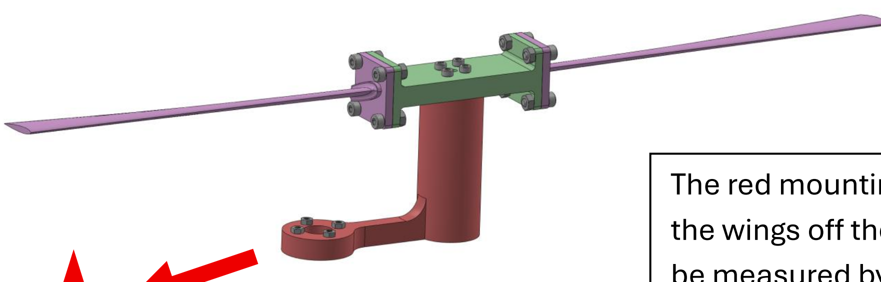


Fig. 4: Off-axis mounting

The red mounting piece will reposition the wings off the motor z-axis so lift will be measured by the 5kg thrust load cell. Drag will be measured by the 2kg torque load cells as a torque with r = 70mm so $Torque = r \times D$

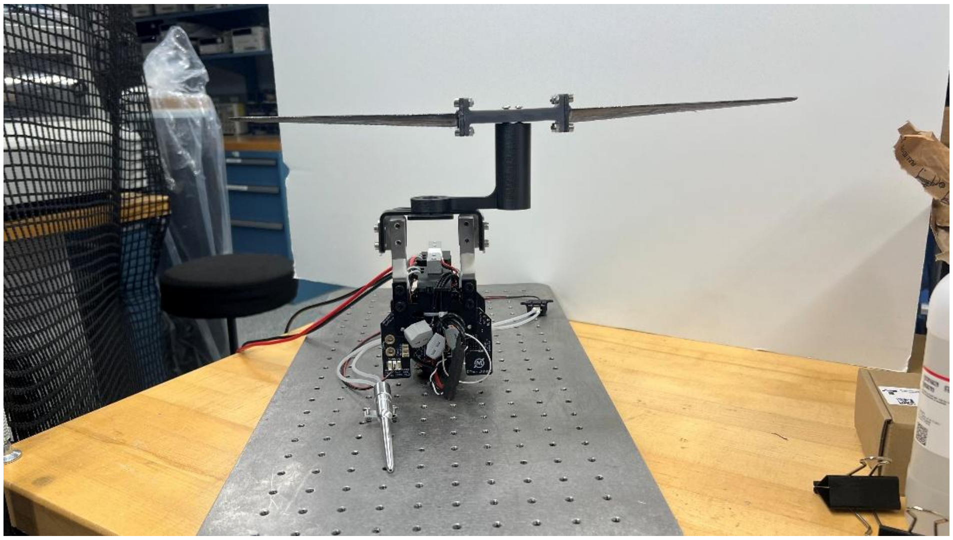


Fig. 5: Front View of Mounted Setup, ignore the ESC electronics & motor on the bottom board, they will be removed for tunnel testing, some preliminary testing showed that pushing the wing in the lift and drag directions resulted in decoupled forces from the load cell data (thrust load cell responded to lift only, drag torque load cells responded to drag only)

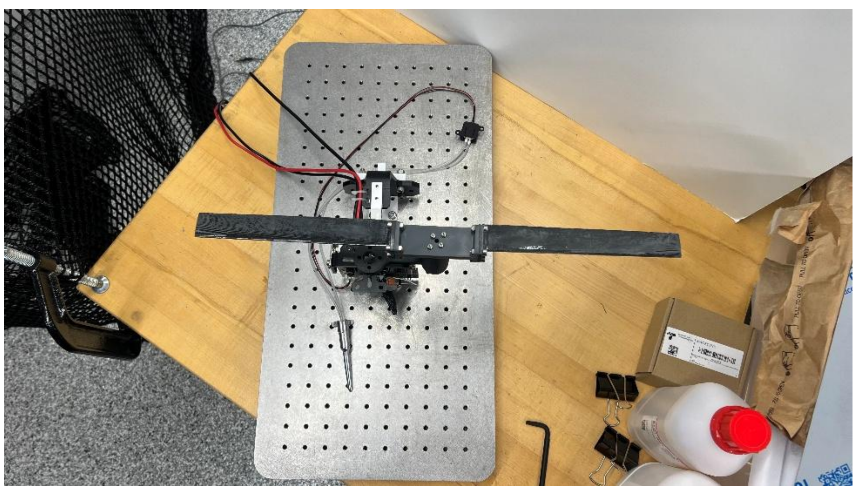


Fig. 6: Top View of Setup

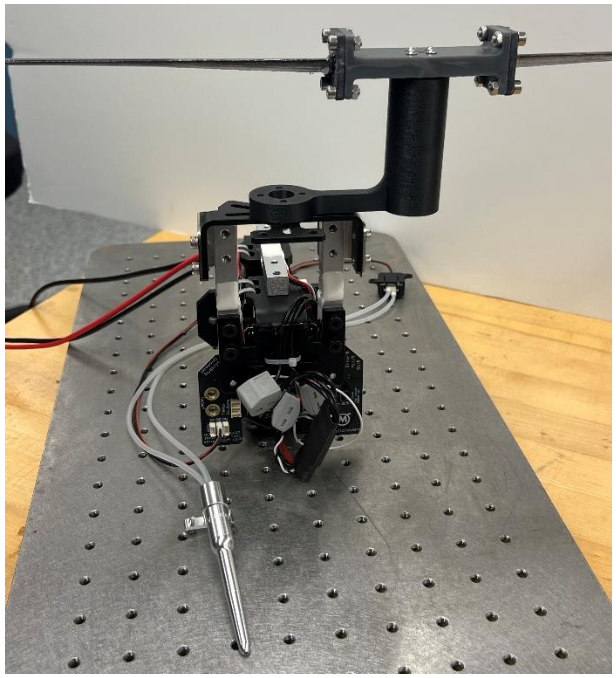


Fig. 7: Mounted setup with wings attached, pitot tube and airspeed sensor will have their own mounts to the optical breadboard for staying in place during testing

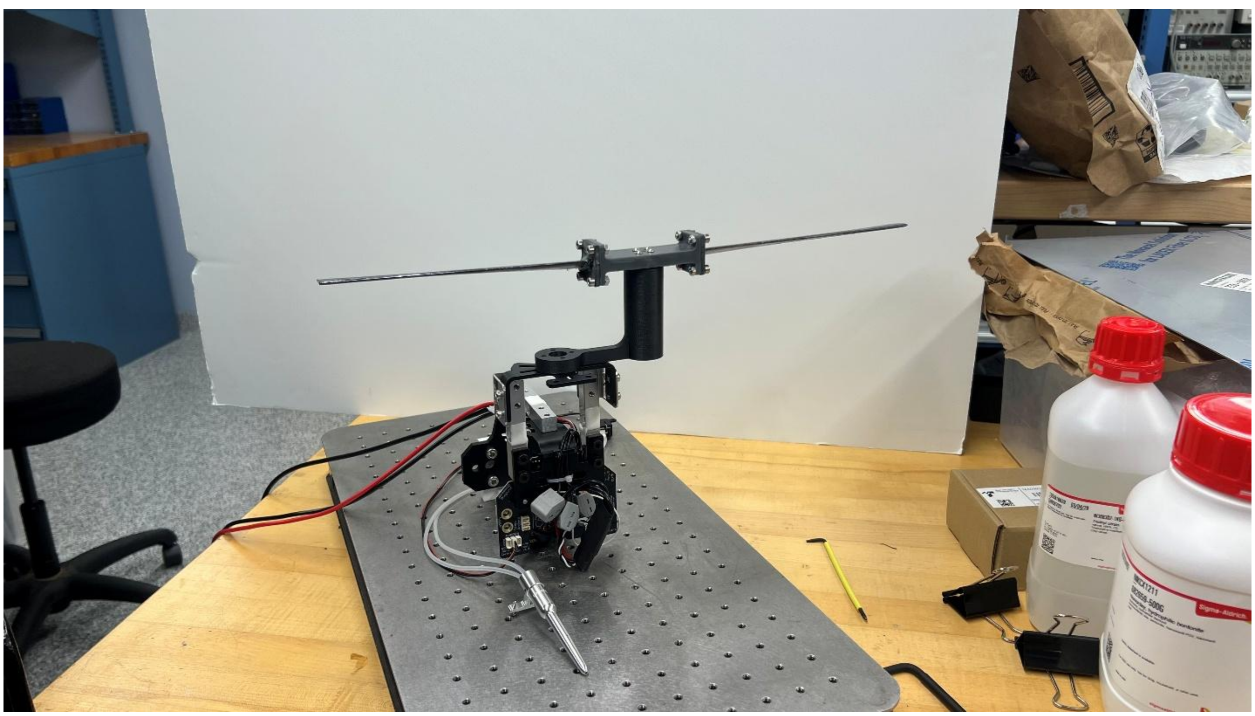


Fig. 8: Mounted setup on optical breadboard (30x60x30cm WxLxH), 25x25mm M6 hole spacing, we will bring C-clamps to clamp the board to the table in front of the 2x3, we have some foam mats as well to isolate more vibration, the setup can be rotated on the breadboard

3. Maximum load estimates and safety factors (if critical)
    a. In rotation, speeds of around 2000 RPM would hit a natural frequency and vibrations would become noticeable which with a $R_{tip} = 0.23m$ gives a wingtip speed of 48.2 m/s which is much higher than the wind tunnel goes to, so 25 m/s in cruise would be well below that limit.
    b. Max thrust during rotation was less than 10N and torque due to drag was less than 0.1 N*m so this setup for cruise should be even less lift and drag, maximum magnitude of load should be around 7N
    c. The thrust stand can handle 50N of lift and 20N of drag, leaving a safety factor of more than 5 for the load cells.
    d. The wings in a worse 3D printing orientation survived until 3500 RPM (wingtip speed of 84.3 m/s) and now with layer lines aligned properly should have no issue, safety factor of >3.4 on airspeed, the lift distribution will be different during cruise but should still have enough leeway here

4. Hazards
    a. PLA wings breaking off, they were under higher stress in rotation testing and did not deform until 3500 RPM+ and 3g+ vibration