WEEK 2

Article: Kim *et.al.*, Acrobatics at the insect scale: A durable, precise, and agile micro–aerial robot, *Science Robotics*, 2025.

QUESTIONS 2b

1. How was the double body flip maneuver programmed? Was it manually controlled in real-time, or was the sequence pre-programmed? Additionally, what is the control latency between the controller and the robot, and how does this impact high-speed maneuvers? Tracing the letters "MIT" with the robot demonstrates its trajectory-tracking ability (Figure 1D). How does the control system process sensory information and ensure high accuracy?

2. The most impactful design change in the paper, regarding flight duration and flapping amplitude, is the extension of the polyamide flexure along the wing. Can you explain why it so important for the center of pressure (COP) and the hinge center to be close to each other to ensure low stress in the structure of the wing? Also, why does having the COP closer to the hinge center allows better performance in flapping amplitude? Is it because the lever arm between the hinge center and COP is reduced and therefore the parasitic forces that come from the air have less negative effect on the motion of the wing? Does the large COM-COP distance which is an advantage for large angular accelerations can be a problem for the liftoff of the robot?

3. In Figure 4B, the lateral drift of the robot increases gradually over the course of the 1000-second hovering experiment, and in Figure 4C, altitude variations remain minimal in comparison. This suggests that lateral control precision degrades over time while vertical control remains relatively stable. What might be the primary contributors to this discrepancy? Moreover, how could we implement an adaptive controller to compensate for thermal drift and improve positional accuracy over extended flights?

4. The robot features a nearly symmetrical four-wing configuration. How does the weight distribution influence stability and maneuverability? How does the lift-to-weight ratio impact the MAV's ability to do acrobatic maneuvers? Does a trade-off exist between agility and control? Could moving a small internal weight and thus purposely changing the center of mass improve control during mid-flight acrobatics?

5. In Figure 2F the robot's lift force is plotted as a function of driving voltage and frequency. It can be observed that increasing the voltage increases the lift force. Nevertheless, lift force peaks at 330 Hz. How can these trends be reconciled? Which factors determine the optimal frequency and amplitude of input voltage?

6. The authors increased the wing area by two times to compensate for the reduced stroke amplitude. What are the aerodynamic implications of this design choice? Given that the microrobot operates at relatively low Reynolds number, where viscous forces dominate, how does this increase in wing area affect overall aerodynamic efficiency and flight stability? How might the increased wing area affect the robot's flapping frequency, power requirements, and maneuverability compared to designs with smaller wings and larger stroke amplitudes? Additionally, what are the implications for scaling the robot further, either up or down in size?